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Population Change in Times of War: Biodistance Analysis of Medieval and Early Modern Skeletal Populations from Adriatic Croatia

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POPULATION CHANGE IN TIMES OF WAR: BIODISTANCE ANALYSIS OF MEDIEVAL AND EARLY MODERN SKELETAL POPULATIONS FROM ADRIATIC CROATIA

by

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ABSTRACT

POPULATION CHANGE IN TIMES OF WAR: BIODISTANCE ANALYSIS OF MEDIEVAL AND POST-MEDIEVAL SKELETAL POPULATIONS FROM ADRIATIC CROATIA

by

Lindsey Jo Helms Thorson

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Under the Supervision of Professor Dr. Patricia Richards

Research by doctoral candidate Lindsey Jo Helms Thorson, under the supervision of Dr. Patricia Richards, investigated population during the Ottoman expansion into Croatian territories to determine whether migration contributed significantly to changes in the biological make-up of the population. The study focused on phenotypic trait variation, using cranial and dental metric and nonmetric data, in two skeletal samples from the Medieval (pre-Ottoman) period and two skeletal samples from the Early Modern (Ottoman) period in the central Dalmatian region of Croatia, curated at the Croatian Academy of Sciences and Arts – Anthropology Center. Historical narratives suggest that as the Ottoman Empire expanded into the Croatian territories a large depopulation event occurred as many Croats fled in fear of continued Ottoman raiding followed by the Ottoman *sürgün* policy of forcible repopulation of the region by Orthodox Vlach and Serbian laborers and soldiers. This model was tested against the evidence for changes to phenotypic variation in the central Dalmatian region's population from the Medieval to the Early Modern periods using biological distance analyses of cranial metric, cranial non-metric, dental metric and dental non-metric traits. The data indicate that the Ottoman conflicts were a major disruptive factor and primary cause for the population change in the 16-17th centuries in the Dalmatian region of Croatia. The movement of people combined with the prolonged period of warfare and resettlement led to secondary factors such as environmental degradation, disease

outbreaks and famine that further contributed to the identified changes to the population, as reflected in phenotypic traits. Contrary to expected results biodistance analysis identified consistent changes to the female portion of the population over time, while for the male portion of the population results concerning change over time were inconclusive. Suggesting that the normal migration pattern of an initial male-led flow followed later with a mature migrant stream is not followed in the context of severely disruptive interstate warfare.

To

my ever-patient husband

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CHAPTER I

INTRODUCTION

Focusing on the Medieval and Early Modern (Ottoman) periods of Croatia, this project aims to identify potential effects caused by the Ottoman-period warfare and migration on the Dalmatian population. Warfare and migration are known to have dramatic effects on populations (Knüsel and Smith, 2014b; McLachlan, 2015; O'Rourke, 2012; Tsuda and Baker, 2015). Warfare acts as a significant disruptive factor leading to the out-migration of people, and additionally can also lead to environmental degradation, disease outbreaks, and famine (Curta, 2013; Knüsel and Smith, 2014b). Migration has been recognized as a factor in the transfer of material goods, ideas, institutions, and job skills, as well as reflecting traces of the original surroundings of the people who move (Campbell and Crawford, 2012). These biological traces can include physiological, metabolic and physical stress, demographic differences and evidence for the spread of disease and immunization. In addition, evolutionary mechanisms such as gene flow, genetic drift, and natural selection may also operate when two populations come into contact. Biological distance analysis is one tool used by archaeologists to document and identify population change and migration in the past and is the primary method utilized in this study.

Little to no research on migration has focused upon the rise of state-level societies and warfare. State-level warfare, can be a primary cause of migration. Not only is state-level warfare a disruption in itself, but also it has been documented to cause additional disruptive factors such as deterioration of the environment, and economic systems (Martines, 2013). Standing armies need to be fed, they need fires to keep warm, and so they often decimate local environments

(Martines, 2013). War disrupts economic systems most by disrupting trade routes, subsistence activity and through depopulation and lack of laborers (Martines, 2013). Populations experiencing prolonged periods of low-intensity warfare tend to suffer great losses to their population caused directly by violent deaths, however, far greater losses are incurred by emigration due to fear and unrest, disease due to poor living conditions, deaths due to famine, and loss from enslavement or imprisonment (Knüsel and Smith, 2014a, 2014b). Additionally, newly conquered territories are often repopulated with people less resistant to the new socio-political regime (Goffman, 2002; Tsuda and Baker, 2015). Collectively these effects can greatly alter a population's gene pool within a short period of time.

In Medieval Croatia a historically documented period of prolonged state-level warfare and raiding between the Ottoman Empire, the Habsburg Empire and the Republic of Venice initially caused a dramatic decline in the population due to out-migration, captive taking, violent death, disease and famine. Later a re-population event (both forced and free) of unoccupied and abandoned lands by Vlach and Serbian peoples occurred.

The Vlachs were Orthodox Christians, while the Croats were primarily Roman Catholics. The Croats were mostly sedentary agriculturalists. While, the Vlachs were mobile stock-herding pastoralists of sheep and goat, and sometimes cattle and oxen, utilizing a transhumant subsistence strategy (Bracewell, 1996; Goldstein, 1999b). The social orginization of both Croats and Vlachs was patrilocal.

Few studies have focused on a single locality where both out-migration and in-migration are historically documented. In this study we can examine the consequences of Croats leaving as well as Vlachs arriving at the same locality. Therefore, we can observe migration from a locality viewpoint as well as from a population viewpoint. In contexts of endemic warfare and warfare

related migration, such as that of the Late Medieval period of Croatia (12-15th centuries), human cranial and dental metric and nonmetric phenotypic traits can identify changes to population composition affected by the kinds of effects described above.

This dissertation uses data from the Medieval and Early Modern (Ottoman) periods of Croatia to identify potential effects caused by Ottoman-period warfare and migration on the Dalmatian population. It is expected that if Ottoman activities resulted in a reduction of the Croat population and subsequent replacement by an Orthodox Vlach or Serbian population, then multivariate statistics (i.e., PCA, MCA and MMD) should be able to detect a clear separation between a pre-conflict medieval Croat sample, comprised of individuals from the Šibenik-Sv. Lovre and Koprivno-Križ I sites, and a post-conflict Ottoman period sample, comprised of individuals from the Koprivno-Križ II and Drinovci-Greblje sites.

In Early Modern Croatia male honor was likely "associated with courage, integrity and status," along with the medieval Christian knight dedication to "defending the faith" (Dursteler, 2011:373). Migration studies suggest migration is often a male-led behavior especially "among societies in which male statuses and roles were largely determined by success in war, and in which young males therefore actively sought opportunities for conflict" (Anthony, 1990:898). Given the historically documented migration related to the Ottoman conflict period, one possible expected outcome is that the degree of male and female phenotypic variation exhibited in the Early Modern period will differ from that seen in the Medieval Period. The second objective of this research is to test for differences in the male and female portions of the central Dalmatian population from the Medieval to the Early Modern periods. If Croat males were the first to leave the region and Ottoman males (Vlach or Serb laborers and soldiers) the first to repopulate the region, then perhaps Ottoman males took local females as wives. In this case, multivariate

statistics should identify clear differences between Medieval and Early Modern males and less pronounced differences between Medieval and Early Modern females.

Skeletal morphological variation and population interaction have been estimated using skeletal metric and non-metric data since the late 19th century. Morphological biological distance is the measure used to interpret relatedness or divergence between and within populations based on polygenic skeletal and dental traits (Larsen, 1997a). Skeletal morphological analysis, using metric and non-metric data, provides an indirect measure of population genetic variation. Inter- and intra-population biological relationships are identified by consideration of multiple traits via multivariate statistical analyses (Larsen, 1997a). Skeletal traits are not only influenced by genetics but also epigenetic and environmental factors (Konigsberg, 2006; Larsen, 1997a; Ubelaker, 1999). Even given these constraints, heritability studies reflect considerable genetic and epigenetic contributions to cranial and dental size and discrete traits (Alt and Türp, 1998; Alt and Vach, 1991, 1998; Biggerstaff, 1970; Cheverud, 1982; Cheverud, et al. 1979; Dahlberg, 1956, 1963; Greene, 1982; Griffin, 1993; Harris and Bailit, 1980; Hemphill, et al. 1995; Konigsberg and Ousley, 1995; Lukacs, 1983, 1989; Lukacs and Hemphill, 1991; Lundström, 1963; Matsumura, 2006; Pietrusewsky, 2006, 2007, 2014; Sciulli, 1990; Sciulli, et al. 1984). The present study uses biodistance analysis to investigate the biological history of the Medieval and Early Modern peoples of the central Dalmatian region of Croatia.

Research hypotheses

This dissertation examines the impact of the Ottoman conflicts as a major disruptive factor in the biology of the population through migration and tests the historically based assumption of a relatively quick and massive out-migration event followed by a prolonged

period of repopulation by Vlach immigration. Historic accounts paint a nearly complete loss of population in Dalmatia region, but it is unlikely that every Croat was capable of leaving or chose to leave; some would have stayed behind or even returned. Therefore, total replacement of the population by Vlach pastoralists is an untested assumption. Through the use of biodistance analysis, this study will explore the extent and nature of population change over time in the study area during a particular period of known disruption. Two separate but related hypotheses were chosen to test historic narratives regarding warfare, migration and population replacement during the Ottoman expansion into Dalmatia.

Hypothesis 1: From the Medieval to Early Modern period, Ottoman activities created substantial phenotypic change, resulting in two populations that can be distinguished using multivariate statistical methods.

Hypothesis 2: As males are more likely to engage in warfare and to migrate, the amount of phenotypic change from the Medieval to the Early Modern Period will be greater in males than in females.

Null hypothesis: No significant phenotypic change between the Medieval and Early Modern periods can be identified.

If there are no observable phenotypic differences between the Medieval and Early Modern populations, then either the population did not change enough to result in identifiable phenotypic change, or the Early Modern population was not distinctly different biologically from the Medieval population.

Organization of the dissertation

The dissertation is organized as follows. Chapter Two presents a discussion of the history

and development of biodistance analysis. The chapter begins with an overview of the historic development of biodistance analysis, and then proceeds with a discussion of cranial and dental development and the heritability of traits. The chapter concludes with a review of previous biological distance studies from Eastern and Southeastern Europe.

Chapter Three provides contextual background on the history and cultural developments of Croatia and the Dalmatian region. Divided into three time periods, Early Medieval, Late Medieval, and Early Modern, each section of the chapter provides an overview of the historic developments of the time period as well as details concerning cultural developments, including changes to material culture, settlement structure and organization, and religious life.

Chapter Four presents an overview of how migration theory can be combined with evidence of warfare to interpret the results of the biodistance analysis. Warfare was a major disruptive factor, causing the migration of the Croatian population. In response, the forced immigration policies of the Ottoman Empire were an attempt to stabilize and repopulate newly conquered territories. The effects of the intertwined nature of migration and warfare are discussed in relation to their biological consequences.

Chapter Five provides background on the archaeological sites included in the analysis. Chapter Six outlines the methods for data collection, preparation and multivariate biological distance statistical analyses. Chapter Seven presents the results of the biodistance analysis.

Chapter Eight interprets the results in relation to both the cultural-historic background and migration theory. The dissertation concludes by summarizing the primary conclusions and providing suggestions for future avenues of research.

CHAPTER II

BIOLOGICAL DISTANCE

Relatedness of human groups has been a major research topic in anthropology. Biological distance, or biodistance, refers to "a measurement of population divergence based on polygenic traits" (Buikstra, et al. 1990:2). The use of biological distance in bioarchaeology is better defined as "the measurement and interpretation of relatedness or divergence between populations or subgroups within populations based on analysis of polygenic skeletal and dental traits" (Larsen, 1997a:302). The underlying assumption of biological distance analyses is that populations possessing more shared attributes (i.e., homologies) are more closely related than populations with few shared attributes. Biodistance analysis is complex, especially when attempting to identify meaningful patterns of biological variation that distinguish groups and meaningful interpretations of those identified relationships. The complexity of multivariate statistical analyses aside, biological distance analysis from human skeletal and dental materials are complicated by the highly plastic nature of human bone and, to some lesser extent, teeth.

The first section of this chapter presents a historic overview of the use of biological distance in biological anthropology. The second section of the chapter introduces the concepts of heritability, growth and development, and the genetic foundation on which biological distance studies are based. The implications of ancient DNA research in relation to traditional biological distance analyses are discussed in the third section of the chapter. The final section concludes with a review of biodistance studies from southeastern Europe.

History of biological distance analyses

Biodistance analysis began with the description of anomalous variants in the human skull, but the field has transformed markedly over the last two centuries. Today, biodistance studies use skeletal morphology to interpret genetic affinity. In addition, biodistance studies now seek to understand the genetics governing trait expression as well as the role of developmental biology on the phenotypic expression of traits. The following section provides a historic overview of biological distance analysis. The section begins with a review of the early foundations of biological distance in the 19th and early 20th centuries, followed by a review of the work in the mid-20th century and the introduction of the new physical anthropology (Washburn, 1951). Finally, the section ends with a summary of the contributions of biological distance studies in the 21st century.

Typological paradigm: classifying individuals

Recently, the specific contributions of early anatomists and anthropologists, such as Samuel George Morton, Aleš Hrdlička, Earnest Albert Hooton, and Georg Neumann have been reviewed by Cook (2006) and Hefner and colleagues (2016), so what follows is a summation of their combined contributions.

Modern biological anthropology was largely founded on the work of 18th and 19th century scholars, anatomists and naturalists. Typological classification was the primary paradigm of early scholars. Beginning with Carl von Linné (Linnaeus) (1707-1778), and Johann Friedrich Blumenbach (1752-1840) the primary objective of early scholars was the classification of humans into distinct "varieties" or "races". In Linnaean classification, the more shared characteristics (homologies) two organisms have in common, the more closely related the two

organisms are to one another: this concept remains an underlying assumption of biological distance studies today. In addition to ranking humans into five races, Blumenbach recognized the continuous nature of human traits (Cook, 2006), and explained differences between "varieties" of humans as the result of degradations from the original-perfect form (the "ideal" type) due to different environments (i.e., climate, nutrition, and modes of life) and migration (Hefner, et al. 2016). Blumenbach's concept of variation in traits was not widely accepted by scholars subscribing to 18th century beliefs of the fixed nature of races and ideal types. Blumenbach did not view humans as fixed entities at the time of biblical "creation"; rather he viewed humans as a single species due to their underlying unifying characteristics (Hefner, et al. 2016).

By the turn of the 19th century, scholars were gradually becoming aware of humanity's extraordinary diversity and variation, but the focus remained on a few phenotypic traits, with little regard for within-group variation (Hefner, et al. 2016). The 19th century was characterized by craniometry. Early anatomists and naturalists studying human variation believed that observed differences between "races" could be systematically measured, and they developed many of the tools for measurement that are used today (Hooton, 1918, 1930; Morton, 1839). However, measurement as a new method was only utilized to validate and support classification based on typology (Broca, 1863; Coon, 1939; Hooton, 1918, 1930; Hrdlička, 1927; Morton, 1839; Neumann, 1952). The usefulness of multivariate statistics, once developed, was ignored; and conclusions were drawn mostly from typological classification and supported with the use of descriptive statistics (means and standard deviations) or simple tabular frequencies (Hooton, 1930; Neumann, 1952). Furthermore, the samples included in such studies were often biased; among other problems, they often systematically excluded crania that did represent "ideal types" (Cook, 2006; Hefner, et al. 2016).

In addition to the flaws inherent within their methods, most of the early 20th century scholars failed to incorporate evolutionary biology into their interpretations of human variation. Charles Darwin (1809-1882) published *On the Origin of Species* in 1859 and changed the nature of scholarly debate concerning human races, fixity of species, and variation in traits. Darwin's concept of evolution by natural selection introduced adaptation and environmental influences as an explanation for variation within and between species. However, Darwin's theories were not widely accepted until Mendelian genetics were re-discovered and integrated into the Modern Synthesis of the 1930s and 1940s.

Even with the flaws inherent within the typological paradigm and the limitations of science available to researchers at the time, early researchers did contribute to later understandings of the role heritability plays in the distribution and explanation of variance in human traits. For example, Morton recognized the link between morphology and ancestry in his 1939 *Crania Americana* (Cook, 2006). Hooton explained similarities between populations from an adaptationist viewpoint (Hooton, 1918), where traits shared by disparate groups were attributed to similar environments rather than shared ancestry. Finally, Neumann included archaeological data in his taxonomical classifications (Hefner, et al. 2016; Armelagos, et al. 1982) that later researchers, like Buikstra (1977), argue was necessary to contextualize skeletal material and provide greater understanding of the significance of skeletal analysis beyond mere biology.

Thus far, the majority of this discussion has focused on the developments in craniometry; this is because skeletal non-metric traits in the 18th and 19th centuries were rarely used to draw inferences regarding the relatedness of human groups, migration, or typology. For the most part, non-metric traits were merely described as "anomalies" by early anatomists.

Thomas T. Kerckring (1640-1693), an anatomist and naturalist, was one of the first to compile and describe several non-metric traits in his 1670 text *Anatomical Gleanings* (Hefner, et al. 2016). By the 1880s, descriptions of skeletal non-metric traits were becoming more common (Blumenbach, 1775; Virchow, 1875). Chambellan's (1883) dissertation *Étude anatomique et anthropologique sue les os wormiens*, was the first scholarly attempt to link skeletal anomalies with anthropological research (Hefner, et al. 2016). Dorsey (1897), following-up Chambellan's work, correlated cranial deformation with the presence of wormian bones (accessory intra-sutural bones).

Scholars of the early 20th century continued describing non-metric traits as anomalies or curiosities, assuming they had little to no value for understanding origins or affinities of populations (Le Double, 1912; Russell, 1900). Wood-Jones (1931) was one of the first to utilize non-metric traits for race identification. His objectives were to better define morphological criteria for nonmetric variants and to call attention to their diagnostic value. Wood-Jones' approach represented an important shift from emphasizing variation within an individual to variation within and between groups (Hefner, et al. 2016).

Dental anatomists first described dental morphological variation in much the same way as skeletal non-metric traits, as abnormal "variants" (Scott and Turner II, 1997). Early dental morphological descriptions include: the Carabelli's trait (von Carabelli, 1842), incisor shoveling (Hrdlička, 1911, 1920a, 1920b, 1921, 1924), Tomes' Root (Tomes, 1914), and other traits (Thompson, 1903). Dental morphological studies had the additional advantage of being able to be studied in living populations. Dental morphological studies shifted from taxonomic classification to the recognition of population variation (Campbell, 1925; Krogman, 1927; Shaw, 1931), and as they did, interest in dental anthropology grew as well.

During the 19th and early 20th centuries, dental metric and dental non-metric analyses remained in the purview of dentists rather than anthropologists. The history of tooth size research (odontometrics) is less well documented. Muhlreiter (1874) is credited as the first scholar to utilize odontometrics on skeletal samples (Kieser, 1990). Flower (1885) followed by evaluating tooth size differences among various populations. The early work in dental metrics established definitions of crown measurements. Muhlreiter (1874) defined mesiodistal diameter as the distance between contact points measured from the buccal surface (Kieser, 1990), and this definition with minor alterations was widely used until the 1950s (Goose, 1963; Hrdlička, 1952; Nelson, 1938; Selmer-Olsen, 1949).

In summary, the typological approach of early physical anthropologists was rooted in 17th and 18th century notions of races and the fixity of species. Throughout the 1930s and 1940s, biological anthropology remained primarily typological, with emphasis on individuals rather than populations. Craniometry was the method of choice, and non-metric traits were considered to be idiosyncratic anomalies rather than reflective of human variation. Even with the racist biases inherent in the typological paradigm, the early typologists contributed to the development and standardization of the measurements and tools used to measure and compare crania and through the description of non-metric "anomalies". In addition, some parts of their explanations for variation are not far off our current understandings. For example, Hooton's (1918) adaptationist explanation of variation is at least partly true in that what we now know as epigenetic factors can affect the final expression of genetic traits even though there is still some genetic control to trait expression.

Discontent with the typological paradigm began to form, specifically around the lack of incorporation of population genetic theory (i.e., the Modern Synthesis of Mendelian genetics and

Darwinian evolution), and the lack of multivariate statistical analyses. Further, discontent was sown by the development of "New Archaeology" (Binford, 1962), and especially the "New Physical Anthropology" (Washburn, 1951). Washburn, like Binford, emphasized hypothesis testing, biochemical mechanisms in human evolution, and other processual explorations of human origins. Washburn's work allowed future studies to link developmental and historical aspects of human evolution and human variation (Hefner, et al. 2016). In particular, Washburn's theoretical foreshadowing laid the groundwork for genetic studies in the 1950s and 1960s involving mice using non-metric traits (Saunders and Rainey, 2008).

A change in thinking: recognition that populations vary

Starting in the mid-20th century, anthropologists have been asking new questions using biodistance data. The focus shifted from classification to how and why populations vary. Simple descriptive statistics were recognized as insufficient for examining the multitude of factors involved in biodistance analyses. Consequently, multivariate statistics became the primary methodology for analysis of biodistance data.

Joseph K. Long (1966) published a devastating statistical critique of the typological approach. Long used multiple discriminant analysis of craniometric data and found nothing to support "Neumann's (1952) explanation of subgroups based on large-scale migrations" (Long 1966:462). Howells (1973,1989,1995) refined the treatment of craniometric data, and championed the use of multivariate statistical analyses for the analysis of craniometric data. Furthermore, Howells' work illustrated that human variation is more the result of geographic relationships than racial type; which aided in overturning the typological race concept.

Grünberg (1952, 1955, 1963) completed groundbreaking research on the genetic variants in mice, which would lead others to apply his results to humans. Laughlin and Jorgenson (1956) examined frequency distributions of eight human cranial non-metric traits to illuminate regional population variations. Laughlin and Jorgenson used historical migration data to hypothesize that the most geographically distant populations would be the more divergent groups and exhibit the greatest differences in trait expression. Not only did the cranial non-metric traits support their hypothesis, but also their work established cranial non-metric traits as a viable proxy for genetic data in biodistance analysis (Hefner, et al. 2016).

Building on the work of Grünberg and of Laughlin and Jorgenson, Berry and Berry (1967, 1971, 1972) argued that analyses utilizing non-metric traits were superior to metric studies because non-metric traits were easier to collect (especially with highly fragmentary remains), were not as affected by environmental factors (e.g., cranial deformation), and correlated little with sex and age. Their assertions have since been critiqued and refined (Cheverud and Buikstra, 1981, 1982; Dodo, 1974; Richtsmeier, et al. 1984; Rightmire, 1972; Self and Leamy, 1978), but their contributions remain influential (Hefner, et al. 2016). Ossenberg (1969) explored patterns of age, sex, asymmetry, inter- and intra-trait correlation, cranial deformation and temporal trends of cranial non-metric traits. She identified both regional and temporal trends among the Dakota Sioux and evolutionary factors (gene flow and drift) influencing trait frequencies. In addition, following the tradition established by Howells, Ossenberg made all her data freely available to aid other researchers and promoted reproducibility of biodistance analyses.

Hauser and De Stefano (1989) published a seminal survey of morphological variants of the human skull, which remains the primary resource on cranial non-metric morphology. Hauser

and De Stefano, using Berry and Berry's (1967) trait list, defined 84 cranial non-metric variants and explored trait heritability and function. Their work also served to standardize the identification and recording of cranial non-metric traits and is summarized in Buikstra and Ubelaker's (1994) *Standards* volume.

Beginning in the 1940s and continuing well into the 1970s, Dahlberg and Pederson formalized the field of dental anthropology by producing works that remain important today (Dahlberg, 1945, 1956, 1963, 1971; Garn and Dahlberg, 1966; Pedersen, 1949; Pedersen and Thyssen, 1942; Pedersen, et al. 1967). Additionally, work by Hanihara (1954, 1955), Kraus (1951, 1959) Lasker (1945, 1950; Lasker and Lee, 1957), and Moorrees (1957) further solidified dental anthropology as an important discipline. In 1963, Brothwell published an edited volume, *Dental Anthropology*, which included many dental topics, including dental metrics and dental morphology. One of the most significant advances in dental morphological variation studies was the establishment of the Arizona State University's Dental Anthropology System (ASUDAS) described by Turner II and colleagues (1991), and further elaborated on in Scott and Turner II's (1997) now-classic volume. The ASUDAS firmly standardized dental morphological data collection that allowed researchers to collect and compare large amounts of data. In 1990, Kieser's *Human Adult Odontometrics* further standardized odontometric studies and reviewed the use of odontometrics in anthropological studies.

Many dissertations and publications have used biological distance analysis to address issues of post-marital residency patterns through the examination of intrasite variation (Buikstra, 1980; Corruccini, 1972; Droessler, 1981; Lane, 1977; Lane and Sublett, 1972; Spence, 1974a, 1974b). The issue with these early intrasite variation studies was that autosomal alleles during meiosis are assigned at random to the sexes in the next generation (zygote), therefore the effects

of differential migration by sex can only be identified in the current post-migration generation (Cadien, et al. 1974; Kennedy, 1981). Therefore, more nuanced models that incorporated population genetics needed to be developed.

In the 1980s and 1990s, biodistance analysis began to fall out of favor among bioarchaeologists. This was mainly due to the field of bioarchaeology's self-reflexive assessment of the role played by early biodistance analysis in scientific racism (Armelagos and Van Gerven, 1971, 2003; Armelagos, et al. 1982; Buikstra, et al. 1990). With the shift away from race-based typologies and toward the examination of population-based variation, physical anthropologists began addressing questions concerning whether cultures (archaeological or ethnographical) arose via *in situ* development or through external migration (Buikstra, 1976, 1977; Corruccini, 1972; Crawford and Smith, 1996; Droessler, 1976, 1979, 1981; Howells, 1973, 1989, 1995; Johnson and Lovell, 1995; Key, 1994; Pietrusewsky, 2006; Sokal and Uytterschaut, 1987; Stothers and Graves, 1985; Stothers, et al. 1994; Stothers and Bechtel, 2000; Turner II and Markoqitz, 1990). Further, the highly mathematical nature of multivariate statistics did not help biodistance analyses' popularity as compared to the simpler statistical methods (Pearson's Chi-square, Fisher's exact test etc.) employed in paleopathological and other frequency-based data analyses. Quantitative traits had fallen out of favor as focus shifted to single locus genetic markers and dissatisfaction arose with metric approaches that appeared to measure environmental rather than genetic differences. A few researchers continued to improve upon biodistance methods and theory, including Relethford and Lees (1982), who proposed two types of analyses: model-free and model-bound. Model-bound analyses attempt to estimate population genetic parameters, while model-free analyses do not estimate population parameters and are more exploratory in nature.

As bioarchaeology shifted focus toward research questions related to health and disease, environmental effects on biological variation began to be used to identify changes in populations through time rather than changes to the genetic structure of a population. Despite the trend to attribute temporal changes in biological variation to the environment and plastic adaptation (e.g., Bogin and Keep, 1998), there are two areas where temporal variation has continued to be explained in evolutionary terms. The first is in geographic areas where there is no clear evidence of short-term environmental change (Jantz, 1973; Jantz and Wiley, 1983; Key, 1983; Key and Jantz, 1981; Konigsberg, 2006). The second examines changes to dental morphology or size, as tooth size and shape are widely accepted as exhibiting fewer plastic responses to environmental change (Konigsberg, 2006).

The 21st century and biological distance

Since the turn of the 21st century biodistance research has continued to examine questions of origins (Hallgrimson, 2004; Mays, 2000; Movsesian, 2013) and population structure (Aubry, 2009; Stojanowski and Schillaci, 2006). Researchers have also begun returning to issues related to migration using biodistance data (McIlvaine, et al. 2014). Although multivariate statistics remain a crucial component of biodistance analyses, researchers have become more critical and selective concerning which statistical tests are best for a given situation or research question (Irish, 2010). In addition, several researchers have begun investigating the effects of intertrait correlation on the data analysis (Kenyhercz, et al. 2014); and have examined the effects of imputation of missing data (Kenyhercz and Passalacqua, 2016; Scherer, 2004; Smith, et al. 2016). Other researchers have examined the usefulness of the continued use of cladistic analyses of biometric and non-metric data (Reed, 2006).

New methods and tools are also being developed, along with an emphasis on reproducibility and accuracy of research. Pilloud and Hillson (2012) developed a new method for the measurement of deciduous teeth. Hillson and colleagues (2005) popularized the use of alternative dental measures. They also developed calipers specifically designed to take cervical measures (Hillson-Fitzgerald calipers). Beyond presenting alternative dental measurements, and developing new tools for measurement, the real significance of the Hillson and colleagues' (2005) study was their analysis of intra- and inter-observer error. In fact, their error analysis is now widely followed, and most current studies directly address error as a part of their methodological designs. Beginning with Howells (1996; https://web.utk.edu/~auerbach/HOWL.htm) and continuing with Ossenberg (2013; http://library.queensu.ca/data/cntd), researchers today are increasingly providing open-access to their research databases in an effort to be more transparent about their methodologies and to encourage reproducibility of research.

Kieser (1990) and Buikstra and Ubelaker (1994) standardized metric data collection methods while Turner II and colleagues (1991) and Scott and Turner II (1997) greatly improved the data recordation of dental non-metrics. Non-metric trait recording remained challenging, especially for novices who have not seen hundreds of dentitions from multiple populations required to really understand the range of variation between expression stages (Edgar, 2017). Furthermore, even though the Hauser and De Stefano (1989) volume is still considered a critical resource for cranial non-metrical data collection, it too is inadequate as a data collection and trait recognition manual for novices. Recently, four new volumes have been published that aim to address this issue for non-metric dental and cranial data collection.

First, Edgar (2017:1) has written *Dental Morphology for Anthropology: An Illustrated Manual*, with the explicit purpose of modernizing and democratizing dental morphological

research. Her goal is to make dental non-metric data collection more approachable and understandable to non-bioarchaeological and non-dental anthropological specialists, including students within these fields. Second, Scott and Irish (2017) have also responded to the need for an update to the ASUDAS system, with their recent publication of *Human Tooth Crown and Root Morphology: The Arizona State University Dental Anthropology System*. The book builds upon the seminal 1991 publication by Turner II, Nichol and Scott, and provides detailed descriptions, and multiple photographs to help guide researchers to make consistent trait observations and reduce observer error. Third, Mann, Hunt and Lozanoff (2016), have published *Photographic Regional Atlas of Non-Metric Traits and Anatomical Variants in the Human Skeleton*. The book has roughly 650 pages devoted to large color photographic images of skeletal non-metric traits. Their goal was not to show the most typical, or most unusual form of a trait, but to illustrate the entire range of variability for the traits (from typical to rare). The book is a beautiful resource for any osteological laboratory and is much akin to Mann and Hunt's (2005) *Photographic Regional Atlas of Bone Disease: A Guide to Pathologic and Normal Variation in the Human Skeleton.* Lastly, an edited volume by Marin A. Pilloud and Joseph T. Hefner (2016), titled *Biological Distance Analysis: Forensic and Bioarchaeological Perspectives*, was published with the goal of providing a comprehensive volume of biodistance analysis, a gap that needed filling.

The use of genetic distance analysis and ancient DNA has become increasingly popular in the study of biological relationships since the 1980s. Cann and colleagues (1987) analyzed modern individuals from five geographic regions by mapping variants in mtDNA using restriction enzymes. They found sub-Saharan Africans to be most isolated from the rest of the world, and they found clustering of individuals from different regions. The oldest cluster with no

African members appeared to have originated 80 kya to 190 kya, marking the separation from Africa within that period of time. Cavalli-Sforza and colleagues (1988, 1996) also found a primary split between Africans and non-Africans, and a second split between North Eurasians and Southeast Asians. The findings of Cavalli-Sforza and colleagues' (1988) allele frequency data (categorical) were found to be consistent with linguistic and archaeological data, as well as with Howells' (1989) results produced using cranial metric data.

Ancient DNA research has also provided insight into the genetic structure of many populations throughout the world. Perez and colleagues (2007) tested the reliability of cranial metric data for tracing genetic relationships, by comparing a paired sample of cranial metric data and molecular data from a sample of 115 crania from the Patagonian region of Argentina. They found comparable and compatible results using both methods, with greater resolution using the DNA data. In addition, they concluded that epigenetic factors did not erase the effects of genetic influences on the phenotype. Manica and colleagues (2007) also found that cranial metric data and genetic data provided consistent results, whereas Hubbard and colleagues (2015) compared nDNA and dental morphological data and found genetic and dental morphological results to highly correlate, but that the genetic data provided finer resolution. The implications of the Perez and colleagues (2007), Manica and colleagues (2007), and Hubbard and colleagues (2015), studies are numerous. First, they provide validation for the continued use of traditional biodistance analyses, in that in all three studies' results from genetic and morphological data were consistent. All three studies found epigenetic effects on phenotype to not completely erase genetic influences. Second, all three studies observed greater resolution using genetic data which is expected since it is well understood that phenotypic data are also influenced by environmental

factors and are a more indirect measure of population relationships, while the genetic data represent a more direct measure.

Today, metric analyses have shifted from simple caliper measurements to include more complex data collection techniques (3-D digitizers), and analyses (geometric morphometrics). Morphometrics have been applied to problems of sexual dimorphism and growth, but few studies using this approach have focused on biodistance (Konigsberg, 2006). Simple caliper measurements remain the primary technique for collecting biometric data, due to their relatively low cost, ease of transport, and simplicity of use. Whether simple or more complex, biometric data are still collected using landmark definitions standardized by the early typologists (Moore-Jansen, et al. 1994; Jantz and Ousley, 2005; Buikstra and Ubelaker, 1994). Debates over the genetic versus the environmental contributions to final trait expression are ongoing. More recent studies are focusing on the assumptions inherent within our methods and the examination of error and reproducibility of research (Hillson, et al. 2005; Ossenberg, 2013)

Heritability of skeletal traits

Biological distance analyses are largely founded on the link between genotype and phenotype expression. Therefore, a rather basic understanding of the concepts of heritability, genetics, and epigenetics are first detailed in this section. A review of heritability studies, as they pertain to cranial and dental morphological data (both metric and non-metric), is also included here to provide background for how anthropologists have previously verified the assumption of a link between morphological phenotypic traits and their use as proxies for genetic relatedness.

Heritability of traits: genotype, phenotype and epigenetics

A phenotype is the physical expression of a genotype. A genotype is the allele variants of a gene (dominant or recessive variants), dictated by their DNA sequence(s). Phenotypes can be coded for by a single genotype (commonly known as Mendelian traits), such as the ABO blood system; or by multiple genes (known as polygenic traits), which usually exhibit a continuous distribution in populations, such as height or skin color. Most cranial and dental phenotypic traits are continuous or quasi-continuous in nature, and therefore are likely polygenetic traits. The phenotype is also influenced by environmental factors (epigenetic), such as nutrition or radiation. Therefore, the final expression of a phenotype is the sum of the accumulation of genetic influences and epigenetic influences (genotype(s) + epigenetics = phenotype).

Heritability is different from inheritance and it often misunderstood and miscalculated. Heritability is the "proportion of the total phenotypic variance that is associated with genetic variance in a specific sample with a specific genetic composition and environmental context" (Vitzthum, 2003:541). Heritability is not a measure of fixed genetic determination. There are two types of heritability: narrow-sense and broad-sense. Broad-sense heritability is used to argue whether genetic factors influence trait expression, while narrow-sense heritability is used to evaluate the extent to which traits are inherited. Typically, heritability studies focus on narrow-sense heritability, but both broad and narrow-sense heritabilities are population specific estimates of inheritance and are dependent upon the genes present within a population as well as the magnitude of environmental variance experienced by a population (Kohn, 1991).

Cranial morphology and heritability

Determining the genetic basis of the cranial morphological features and cranial size is a process that "bristles with difficulties" (Hauser and De Stefano, 1989:5). For the most part, evidence of genetic control for cranial traits has been indirect. Three main areas of study have informed the genetic understanding of cranial morphology: 1) studies among widely disparate human populations and their concordance of the matrices from human morphological data (metric or non-metric) and those based on simple Mendelian traits, such as blood type or mtDNA haplogroups (Cavalli-Sforza, 1991; Cavalli-Sforza, et al. 1996; Howells, 1989, 1995; Szathmary and Ossenberg, 1978); 2) experimental studies on mice (Grünberg, 1952; Doel et al. 1957; Leamy 1974; Self and Leamy 1978) and rhesus macaques (Cheverud and Buikstra 1981, 1982; Richtsmeier et al. 1984; Willmore et al. 2012); and 3) twin and family studies (Arya, et al. 2002; Dahlberg, 1926; Devor, 1987; Devor, et al. 1986a,b; Formby, et al. 1994; Nakata, et al. 1974a; Nakata, et al. 1974b; Sharma, et al. 1984; Susanne, 1977; Vandenberg, 1962; Von Verschuer, 1954). Using family and twin studies, as well as studies using anthropometric data rather than skeletal data may be flawed (Carson, 2006a, 2006b; Hauser and De Stefano, 1989). Chiefly, they assume soft tissue data to be a good proxy for skeletal data and several researchers have pointed out that using soft tissue heritability is unreliable under various circumstances (Bondevik, 1995; Fitzgerald, et al. 1992; Formby, et al. 1994; Garlie and Saunders 1999). Few studies of heritability of skeletal data have been performed on skeletal samples with known pedigrees (Carson, 2006a; Lane, 1977; Rösing, 1986a, 1986b; Sjøvold, 1984).

Lane (1977) was one of the first to attempt to directly relate biological distance to genetic kinship using an archaeological sample. Lane (1977) demonstrated using family material from Allegheny Seneca (for which relationship details had been traced from 1776 to 1948) that a large

proportion of the variance of 33 non-metric traits could be explained by the distribution of mean genetic kinship within the population. Lane suggested that biological distance (which measures differences) was inversely related to the average genetic kinship between groups, because genetic kinship is a measure of similarity. Therefore, biological distance should decrease with increasing kinship.

Sjøvold (1984), showed significant, if low, heritability for a number of cranial non-metric traits and several cranial metric subtenses, radii and fractions; using a regression analysis and a sample of 350 individuals of known pedigrees from Halstatt, Austria. However, he did not include cranial measurements commonly collected for use in multivariate craniometric analyses, like cranial lengths and breadths. Sjøvold also excluded measurements that were highly impacted by the environment and selection, such as the nasal breadth. Finally, his use of linear regression to estimate heritability requires three main assumptions: 1) that there was no correlation between the environment of parents and that of their offspring; 2) that all traits are autosomal and male and female variances are equal; and 3) that linear regressions contribute to the overestimation of genetic variation present for a trait (Carson, 2006a; Falconer and MacKay, 1996).

Rösing (1986 a, b) found suggestive evidence of the aggregation of particular traits from among individuals buried in a single, family grave at an Egyptian Aswan site. Using cranial measurements, discrete traits, and blood groups, he attempted to reconstruct kinship relationships between the individuals from within familial graves, with mixed success (Rösing, 1986b:236). Of the three data-types he analyzed, Rösing found cranial discrete traits performed the best (Rösing, 1986b).

Building on the work of Sjøvold (1984), Carson (2006a, 2006b) examined 298 individuals from the Hallstatt, Austria pedigreed sample. Using maximum likelihood (ML)

variance components analysis, Carson estimated the heritability of 33 cranial measurements, and found craniometric traits to have a low to moderate heritability. Measures of length generally had a higher heritability than measures of breadth, and the facial dimensions are overall less heritable than the neurocranial measures. Carson hypothesizes that this could be related to evolutionary selection on cranial size and a potential shift in diet. Overall, she stresses that the heritability patterns she established only explain the heritability rates within the Hallstatt sample and that research from other populations is needed.

Dental morphology and heritability

Many past studies of dental size heritability did not account for environment, maternal effects, gene interactions, or genotype-environment interactions (Townsend and Brook, 2013). Many studies have examined the genetic effects on dental size and shape. Most of these have come from heritability and twin studies. As a result, we now know that inheritance of dental size is somewhat predictable: monozygotic twins are more similar than dizygotic twins (Kabban, et al. 2001), or full siblings (Lundström, 1948) even when raised separately (Borass, et al. 1988). Examining differences in dental dimensions Garn (1977) found buccolingual and mesiodistal dimensions to be independently controlled by different genes. Potter and colleagues also found an independent control over tooth length and width, as well as over maxillary and mandibular development (Potter and Nance, 1976; Potter, et al. 1976). Biological sex also plays a role in the inheritance and expression of dental dimensions. Garn and colleagues (1965) compared dental dimensions between same sex and mixed sex siblings and found tooth size to correlate between siblings and that siblings of the same sex are more alike than siblings of different sex. Furthermore, sister-sister pairs were more similar than brother-brother pairs, which led Garn and

colleagues (1965) to hypothesize that the X-chromosome may be involved in tooth size development, a finding supported by some studies (Alvesalo, 1971; Lewis and Grainger, 1967), but unsupported by others (Bowden and Goose, 1969; Niswander and Chung, 1965; Potter, et al. 1968; Townsend and Brown, 1978). Bowden and Goose (1969) after examining parent offspring and sibling relationships, suggested a multifactorial genetic inheritance rather than a simple Mendelian one.

Tooth shape is also partially under genetic control (Garn, 1977; Kraus, 1957; Moorrees, 1962). A. C. Berry (1976) used dental morphology from modern European populations and found distances to be consistent with expected documented relationships, concluding that there is at least some level of genetic inheritance of dental morphology. Brewer-Carias and colleagues (1976) found dental morphology useful at identifying differences between Yanomama villages. Hanihara (1957) examined dental morphological variation within Japanese and Japanese-American children. He found that children born to a Japanese mother and either a Japanese-Anglo-American or a Japanese-African-American father, showed traits indicative of the child's non-Japanese ancestry. These early studies demonstrated that tooth morphology is inheritable.

The single-locus (Mendelian) perspective dominated most dental discrete trait research from the 1950s to the 1970s; which led anthropologists to reduce phenotype frequencies to simple modes of inheritance. The assumption of simple inheritance of dental morphological traits was called into question by Sofaer (1970), who critiqued previous research for not looking at individual's relationships within populations but somehow drawing conclusions about inheritance. Sofaer (1970) argued that large samples, composed of different individuals, with a variety of biological relationships, were needed to adequately investigate the mode of inheritance of morphological characters. In addition, Sofaer pointed out that many traits assumed to be

simply inherited were more complex quasi-continuous traits. Quasi-continuous variation assumes that there is an underlying scale and threshold of continuous variation related to the development of the trait. Individuals below the threshold will not express the trait, while those above the threshold will: the higher above the threshold, the more expressed the trait. Sofaer was the first to argue against the simple inheritance of traits, citing the quasi-continuous nature of dental morphological traits and the expression of traits on a gradient as support (Scott and Turner II, 2000).

Goose and Lee's (Goose, 1971) study of British families supported Sofaer's (1970) claim that simple inheritance models were insufficient and that dental morphological traits are polygenetically inherited. Furthermore, Biggerstaff's (1970) twins study also supported Sofaer's arguments, through the examination of concordant traits, heritability, and environmental influences on monozygotic and dizygotic twins. Biggerstaff found variability in dental trait expression between monozygotic twins, which argued against simple inheritance.

Continued investigation into the heritability of dental traits, metric and morphological, is important to our understanding of how morphological characters are inherited. Today, even with the sequencing of the entire human genome, much of the information necessary for understanding the genetic inheritance of dental morphology is still unknown and research shows that no single factor explains dental diversity (Jernvall and Thesleff, 2012). Heritability of dental traits is much better understood than the heritability of cranial and skeletal traits for two primary reasons. First, dental studies can be performed using living research subject, providing researchers with a range of known information from age, sex, ethnicity, to handedness or dietary preferences etc. Second, dental traits develop over a short period of time and are not re-modeled

throughout life; therefore, epigenetic factors do not play as strong of a role in the expression of dental traits.

Summary

Studies of cranial and dental development and the heritability of skeletal and dental phenotypic traits have shown that both cranial and dental metric and non-metric traits are polygenetic and highly heritable. Genetic and epigenetic (environmental) factors influence final trait expression and may even influence traits through common developmental pathways (Kohn, 1991). Genetics clearly play a role in phenotypic trait expression of the cranium and dentition, but the specific details of differential gene action remain unclear, due to limitations of the direct study of skeletal remains and genetic data. Due to the high cost of analysis and issues with degradation and contamination of samples, ancient DNA has contributed only in minor ways to clarifying the relationships between genotypes and phenotypes of common cranial and dental morphological traits and measurements.

Review of biodistance studies in SE Europe

Biological distance analyses within southeastern Europe are not very common, especially in Croatia (Kopp, 2002; Šlaus, et al. 2004). Summarized and presented here are six studies that include biodistance analyses from southeastern Europe. Three are concerned primarily with the question of origins or regional continuity (McIlvaine, 2014; Movsesian, 2014; Šlaus, et al. 2004), one is simply concerned with contextualizing variation of a sample (Kaczmarek, 1992), one asks a methodological question concerning the usefulness of craniofacial compared to neurocranial

measures (Holló, et al. 2010), and one asks if differing historical population movements resulted in dissimilarity between two geographically isolated but adjacent groups (Kopp 2002).

In 1992, Kaczmarek examined the dentitions of 475 adolescents aged 12-15 years, from a modern Polish population, and collected data on dental non-metric traits. Kaczmarek compared the modern dental traits to contemporary Russian, Byelorussian, Ukrainian and Baltic comparative samples, and found Polish dentition to be broadly consistent with these other Eastern European groups.

Kopp (2002) sought to determine, using craniometric data, if the coastal (Dalmatian) and continental (Pannonian) populations of Croatia were morphologically dissimilar due to their differing historical population movements. The coastal sample consisted of a total of 32 individuals: 12 individuals from the Danilo site (900-1500 AD), 10 individuals from the Dubravice site (700-900 AD), and 10 individuals from the Radosinovac/Korlat site (800-900 AD). Representing the continental sample was a total of 50 individuals: 11 individuals from the Nova Raća site (1300-1700 AD), 27 individuals from the Privlaka site (750-850 AD), and 12 individuals from the Stari Jankovci site (650-750 AD). The results of the craniometric data analysis indicated no clear distinction between the coastal and continental samples, but Kopp did identify high Fst values from R matrices between sites. She concluded that differences existed between sites (particularly between the Nova Raća site and the others), but not between regions. However, any differences between the sites identified by Kopp (2002) must be considered tentative due to the very small sample sizes.

Šlaus and colleagues (2004) examined 215 crania from 44 sites from within Eastern Europe, southeastern Europe, and Iran. Using cranial metric data and principal components analysis they identified four distinct groups: a western Danube group, an eastern Danube group,

a Polish group and a Bjelo Brdo group. They used discriminate function analysis to predict group affinity for Early Medieval Croat samples, and found them to most closely align with the Polish group. They concluded that the Croats have a shared Slavic ancestry with medieval Poles.

Holló and colleagues (2010) examined 1,961 adult crania from the Great Hungarian Plain, dating to a period from the 1st-11th centuries AD. They compared measurements of the facial skeleton to those of the neurocranium to see which area of the cranium best differentiated groups. Notably the neurocranial measurements were successful and more conservative of the sets of measures.

McIlvaine and colleagues (2014) examined evidence for long-term migration between the Greek city of Corinth and its colony Apollonia using cranial and dental non-metric biological distance analysis. Using logistic regression, they found the Apollonian colony to most closely resemble the prehistoric Illyrian sample rather than the Greek sample. They concluded that the Illyrians must have contributed greatly to the gene pool at Apollonia. Furthermore, some traits showed low contributions among all groups, which suggested to McIlvaine and colleagues that homogeneity between the Greek and Illyrian populations existed.

Movsesian (2014) examined 32 non-metric traits of 994 crania from Medieval Eastern Slavic tribes from Eastern and Northeastern European sites and compared them to each other as well as Baltic, Finno-Ugric and Chenyakhov culture samples. Her study found a strong affinity between the Eastern Slavic tribes, with small influences from Baltic and Finno-Ugric samples. She concludes that the results support an origin of Slavic culture within Eastern Europe that then spread outward.

In southeastern Europe, aDNA studies have focused primarily on tracing the genetic origins of Europe's Neolithic farmers (using aDNA: Mathieson, et al. 2016; Nikitin, et al. 2017;

Szécsényi-Nagy, et al. 2015; using modern DNA: Barać, et al. 2003; Battaglia, et al. 2009; Peričič, et al. 2005; Primorac, et al. 2011), the contribution of Neandertal DNA to modern human populations (Green, et al. 2008; Green, et al. 2010; Prüfer, et al. 2017), and on tracing the origin and spread of diseases such as plague or leprosy (Andrades Valtueña, et al. 2017; Drancourt and Raoult, 2016; Mitchell, 2003; Watson, et al. 2010). Few studies have focused on the medieval period (Boljunčić, 2007; Csősz, et al. 2016; Novak, et al. 2018; Watson, et al. 2010), and fewer have focused on population structure or biodistance (Boljunčić, 2007; Csősz, et al. 2016).

Boljunčić (2007) examined four individuals from the Medieval Zvonimirovo site in Northern Croatia. Two individuals were buried in a "double-grave" (one adult and a child), and the two other adults were buried near the double grave and shared non-metric and metric trait characteristics. Using autosomal short tandem repeat genotyping, Boljunčić concluded that the two individuals from the double grave were related, and the two females with similar traits were also related, but that the exact nature of their kinship relationship could not be deteremined.

Csősz and colleagues (2016) examined the mtDNA from three samples of individuals from the Great Hungarian Plain and Carpathian basin to examine maternal genetic ancestry and of 10th century Hungarians. They analyzed thirteen individuals from an Avar sample in the Carpathian basin (7th-9th c), 76 individuals from the period of Hungarian conquest, and four Hungarian-Slavic individuals from the 10-12th century. They then compared their results to previously published ancient and modern mtDNA. Their results showed that the Hungarian conqueror gene pool is a mixture of West Eurasian and Central/Northern Eurasian elements. They also found the incoming communities to be mobile due to their small intra-site maternal relations compared to intersite relations.

Recent biodistance studies from southeastern Europe are consistent with biodistance studies in general in their emphasis on origins, migrations, continuity, and methods. Interestingly, in contrast to aDNA studies' focus on Neolithic farmers from southeastern Europe, only one biodistance study from southeastern Europe includes a Neolithic period sample (Šlaus, et al. 2004); more commonly the focus is on identifying Croat origins. For the most part, biodistance studies from southeastern Europe have focused on the use of cranial phenotypic data (metric: Kopp 2002; Šlaus, et al. 2004; Holló, et al. 2004; non-metric: Movsesian, 2014; McIlvaine, et al. 2014), with only two studies utilizing dental non-metric data (McIlvaine, et al. 2014; Kaczmarek, 1992), and no studies have utilized dental metric data. Therefore, by including all four data types (cranial metric, cranial non-metric, dental metric and dental non-metric), the current study can be used to test the results of previous researchers working within southeastern Europe, none of which include the Late Medieval Ottoman period, with the exception of one site included in the Kopp (2002) study. In this respect the current study is unique in the region broadly, as well as unique among Croatian studies. Furthermore, the current study seeks to examine changes to population as a result of warfare and sociopolitical change, whereas recent research has focused mainly on migration and the origins of Early Medieval Croats and Slavs, or migrations of the ancient Greeks.

Chapter summary

Despite the recent prevalence of aDNA analyses, studies using traditional biodistance analysis remain a popular (although often misunderstood) analytical tool. In large part, the techniques of biodistance analysis can be used to calculate indirect biological/genetic relationships using readily available data that is non-destructive and inexpensive to collect and

process. Additionally, the rise in the number of statistical programs (some of which are open-source like R), and the improvement of computer power has greatly improved the data processing of biodistance analyses. Advances in genetics have also aided continued interest in biodistance by contributing new models to explain relationships between individuals or groups that provide exciting diagnostic options for biodistance analyses. Konigsberg (2006) predicted that morphometrics and aDNA analysis would replace traditional phenotypic analyses of metric and non-metric traits of the cranium and dentition. More than a decade later, traditional biodistance analyses utilizing simple caliper measurements and ordinal scales continue to dominate biodistance research. However, morphometric and aDNA analyses are increasingly being used to corroborate and verify the results using cranial and dental data.

CHAPTER III

HISTORIC OVERVIEW

Through the years, the Croatian territories have been almost continuously invaded or controlled by Greeks, Romans, Vandals, Ostrogoths, Huns, Lombards, Mongols, Avars, Croats, Slavs, Franks, Venice, Byzantium, Hungary, the Hapsburgs, the Ottomans, and more recently Nazi Germany. The current chapter begins with a brief introduction to southeastern European and Croatian geography, and then an historical overview of Croatian medieval history is presented. This historical overview begins with the foundations of the Kingdom of Croatia following the collapse of the Roman Empire; continues by presenting the period of Ottoman expansion; and concludes with the history of Ottoman rule and decline. Embedded within the historic narrative are discussions concerning changes to settlement organization, religious life, material culture, and social and cultural developments. While this chapter mainly presents the historic narrative of the Croatian Medieval period and Ottoman threat, it also is informed by archaeology. The chapter concludes with two brief summaries, one focusing on the historic highlights and one on the archaeological highlights.

Geography of Croatia

The Balkan Peninsula is often described as a crossroads, connecting Western Europe to Asia Minor (Reed, et al. 2004). The Balkans are made up of the southeastern portion of the European subcontinent, including the lands along the Black Sea, Aegean, Ionian and Adriatic coasts through Slovenia to European Turkey. The geography of southeastern Europe (Figure 3-1)

is dominated by numerous mountain ranges including: the Balkan Mountains (East), Dinaric/Dinarides and Pindus Mountains (West), Jura/European Alps (NW), Carpathian Mountains (NE), and Rhodopes Mountains (SE), with the Pannonian lowlands in the north (Reed et al. 2004). The Croatian landscape includes a portion of the Pannonian plain (North and East), the Istrian Peninsula and the Dalmatian seaside (South and West), with the Dinaric mountain range separating them (Figure 3-2). The Adriatic Sea, the many rivers, and the fertile soils of the Pannonian plain are all very important to Croatian history.

Figure 3 - 1: A map of geography of southeastern Europe (Wikimedia Commons contributors, 2016a).

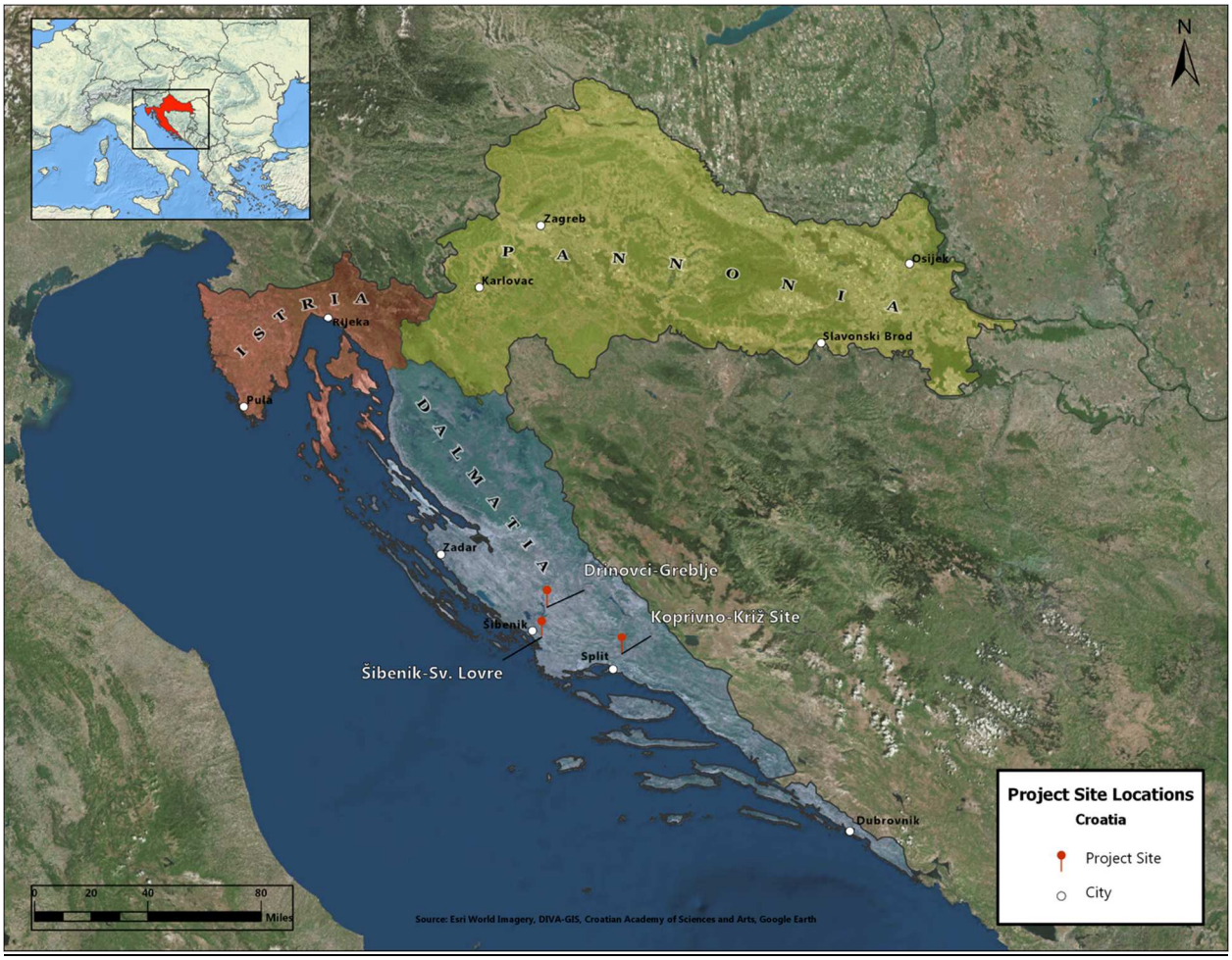

Figure 3 - 2: Modern map of major Croatian geographic regions, with project sites.

Early Medieval period (6th-12th centuries AD) – The Kingdom of Croatia

The Early Medieval period begins with the fall of Rome. The Croatian territories are positioned between Byzantium in the East, the Carolingians in the West and Hungarian, Avar, Mongol and Slavic groups from the Steppes. During the early Middle Ages, the Croatian territories served as frontier regions for Western Europe, included but peripheral (Suić, 1999). At the end of the Late Antique period and beginning of the Early Medieval period, most influences and influx of populations came from the east, in the 9th century influences shifted toward the west. Croat and Slavic peoples entered Pannonia and Dalmatia during the 7th century;

encountering and gradually absorbing the surviving Late Antique Roman-Illyrian peoples (Goldstein, 1999a; Suić, 1999). A series of incursions, wars, and uprisings occurred during the first half of the Early Medieval period in Croatia that mainly involved the Franks, Venetians and the Byzantine Empire. From the 9th century on, economic and cultural developments became increasingly important, especially the conversion to Christianity through the efforts of Byzantine, Italian and Frankish missionaries (Goldstein, 1999b).

Byzantium controlled most of the Dalmatian Islands and the larger coastal urban centers, such as Zadar and Trogir (Goldstein, 1999a). From the 6th century onward Byzantium was less engaged in the active control over its Dalmatian provinces, and for the most part Byzantine centers were autonomous provinces (Goldstein, 1999a). Therefore, the Dalmatian cities actively sought to remain under Byzantine rule in order to avoid falling under the feudal systems of either the Croatian kingdom or Venice (Goldstein, 1999a). By the 11th century, the Kingdom of Croatia had annexed the territory of Byzantine Dalmatia (Goldstein, 1999b).

The Carolingian Empire controlled most of Western Europe and was expanding their influence under the direction of Charlemagne (A.D. 772-804). The Avars occupied the Pannonian plain from 568 until Charlemagne's conquest at the end of the 8th century (Leciejewicz and Valor, 2007; Sokol, 1999). Frankish seizure of Istria and most of Pannonia lead to the eruption of the Byzantine-Frankish war during the first part of the 9th century (Goldstein, 1999a). In 812, the Byzantine-Frankish war ended in a treaty ceding the Dalmatian urban centers to Byzantium and the lands from the Dalmatian hinterland to the Danube River to the Franks (Figure 3-3) (Goldstein, 1999a; Leciejewicz and Valor, 2007; Sokol, 1999). Charlemagne's conquest also ended many years of conflict between the Avars and Croats. With the spread of the

Carolingians came the spread of Christianity and feudalism (Leciejewicz and Valor, 2007; Sokol, 1999).

Figure 3 - 3: Map of southeastern Europe at the end of the ninth century AD (Wikimedia Commons contributors, 2017).

Venice became the new power in the Adriatic following the Byzantine-Frankish war in the early 9th century. Interest in the slave trade motivated Venice to seek control over the eastern Adriatic coast (Goldstein, 1999a). The Venetians saw it as their natural right to sail freely on the eastern Adriatic Sea, while the Croats considered the eastern Adriatic Sea as their territory and felt entitled to attack and rob Venetian ships (Goldstein, 1999a). During the mid-10th century, Venice moved to systematically take over the eastern Adriatic. Their successes were short lived,

and Croatia and Venice continued to struggle over control of the eastern Adriatic coast until the 15th century (Goldstein, 1999 a, b).

During this time the Adriatic region with its Mediterranean influences and the Pannonian region with Central and Western European influences were unified under the rule of the Trpimirović dynasty (Sokol, 1999). From the 10th century onward neither Byzantine nor Frankish empires exerted much influence in Croatia. In Pannonia, during the first half of the 10th century, Hungarian incursions destroyed all state and pre-feudal organizations (Sokol, 1999). The Croatian state survived and the Croatian King Tomislav managed to defeat the Hungarians while simultaneously uniting the Croatian territories (Sokol, 1999). The second half of 10th century was a period of renewal and recovery from war (Sokol, 1999). Even though the Hungarians were defeated, they continued to influence development in the Croatian territories until the end of the 11th century.

Early Medieval settlement organization

Medieval Croatian urban centers have all the requirements of a post-Roman urban town: defenses, planned street systems, markets, mints, legal autonomy, a role as a 'central place', large dense populations, a diverse economic base, plots and houses of urban type, social differentiation, complex religious organization, and judicial centers (Schofield and Steuer, 2007). Avaro-Slav groups making inroads through Pannonia and into Dalmatia were destroying most of the Roman urban centers in Croatia, during the early 7th century AD (Suić, 1999). Only a few coastal urban centers survived and became intermediaries between the influences of Classical antiquity (Greek and Roman), Western and Central Europeans (Celts, Franks, Germans), and eastern Byzantine influences in the generation of Croatian urban culture (Suić, 1999). By the 10th

century urban centers became the locations of population aggregation and development of tertiary activity and production, making urban centers dependent upon their rural agricultural hinterlands, much like urban centers in Western and Central Europe (Schofield and Steuer, 2007; Suić, 1999). Urban and rural settlements were fortified during the Early Middle Ages, and were increasingly found at the foot of hills of earlier hill-forts (e.g., the city of Šibenik) (Suić, 1999). In Pannonia, the beginnings and models of urban centers come from Central and Western Europe, especially from the Carolingian Empire (Suić, 1999). In most cases, urban sites served as centers of trade as well as centers for secular and religious administration (Scofield and Steuer, 2007). In both urban and rural settings, the noble classes were building fortifications (Goldstein, 1999b). Understanding of urban architecture in Croatia is primarily restricted to the examination of existing ecclesial buildings. Little research has been carried out on secular public or private structures.

Rural settlements have not been well researched in Croatia; however archaeologists have identified semi-subterranean houses similar to the subterranean feature buildings (SFBs) of Eastern and Central Europe at Jazbine near Bjelina (Mohorovičić, 1999; Roesdahl and Scholkmann, 2007; Sokol, 1999). Fortified flatland hamlets are known from rural settings in Croatia and date from the 10th-11th centuries, but are mostly known from the 12th century (Sokol, 1999). The violent political interactions of the Early Medieval period are reflected in the large earthwork embankments defending small hamlets (Mohorovičić, 1999; Sokol, 1999). Hamlets and small villages were built along lengths of established roads or waterways (Goldstein, 1999b; Klápště and Jaubert, 2007; Mohorovičić, 1999). Houses in these hamlets were likely built above ground using wattle and daub construction, based on the large quantities of daub recovered from such sites (Sokol, 1999). Wattle and daub construction gradually replaced the Roman rural villa

pattern (Klápště and Jaubert, 2007). Recovered iron artifacts from sites include: tools, nails, locks, fetters, chains, weights, seals, and similar objects that are consistent with inventories from Western and Central Europe (Roesdahl and Scholkmann, 2007; Sokol, 1999). Pottery varies in quality from slow rotation hand thrown pottery to high quality pottery with maker's marks (Sokol, 1999).

In rural environments the clan-based social structure remained strong until the development of a feudal system in the mid-11th century (Goldstein, 1999a; Mohorovičić, 1999; Rauker, 1999). As the *Župans* (landowners) increased in power, the rural inhabitants had difficulty providing for their basic needs and sacrificed their personal freedom to become *servi* (serfs) (Rauker, 1999). Only a few clans, who owned fertile agricultural lands, resisted landowners and retained their titles to inherited lands (Rauker, 1999).

Early Medieval religious and spiritual life

Christianity followed the spread of the Carolingian Empire. The conversion to Christianity was swift and not imposed by force, as there are no historical or archaeological indicators of major attacks by Christian forces (Goldstein, 1999a). The recognition of the Croatian state by Pope John VIII in 879 marked a dramatic increase in the construction and renovation of churches and basilicas throughout Croatia (Goldstein, 1999a; Sokol, 1999). Benedictine monasteries led the way in literacy and cultural advancement (Supičić, 1999). Monasteries also led the development of Latin and Slavonic written culture and literature (Supičić, 1999). In addition to the promotion of literacy, Benedictine and Cistercian monasteries also promoted Romanesque and Gothic artistic development with the commissioning of artwork and architecture (Supičić, 1999): this resulted in the largest concentration of ecclesiastical

structures in Europe, and its contributed significantly to the development of pre-Romanesque architecture and sculpture (Mohorovičić, 1999; Supičić, 1999).

Along with the new churches came new burial grounds and great monastery estates of cultivatable land (Goldstein, 1999b; Klápště and Jaubert, 2007; Sokol, 1999). The conversion to Christianity resulted in the reorganization of the spatial relationship between the living and the dead (Klápště and Jaubert, 2007). The pagan necropolises, located at the periphery of settlements and marking the landscape, often followed roads. These burial places were abandoned, and burials moved to graveyards that were almost always associated with a church or monastery (Sokol, 1999). This is a pattern observed throughout Europe (Meier and Graham-Campbell, 2007).

Subterranean burial chambers and pottery in abundance characterize pre-Christian period (8^{th}-9^{th} centuries) burial customs (Sokol, 1999). One grave good unique to the region are antlers, hollowed and engraved, that illustrate an opposing pair of horned animals facing the tree of life (Sokol, 1999:119). Male burials are elaborate: containing mostly military equipment and weaponry of early and high Carolingian characteristics. These warrior grave goods were often imported and sometimes of high quality and made with precious metals; they include Frankish long swords, belt trappings, belt tongues, and Carolingian thuribles which are metal censers suspended from chains used to burn incense. Other examples of such items include Carolingian winged spears, spurs, and tiny bells worn at the top of the left boot that may indicate military rank (Sokol, 1999). Differences in the quality of weaponry and quantity of grave goods indicate rank and confirm the existence of a Croatian state army operating in the 8^{th} – 9^{th} centuries (Sokol, 1999). Men are also commonly found with bone, metal and stone artifacts such as awls, cotter pins, knives, keys, sickles, razors, and flint fire starters (Sokol, 1999). Whereas male grave

goods are primarily military related, female grave goods consist mostly of jewelry items, including: grape-like filigree earrings, pseudo-S earrings, rings, and torques (a ring-shaped metal neck decoration) (Mohorovičić, 1999; Sokol, 1999). These jewelry items were often made with precious metals and indicate examples of interaction with Byzantine goldsmiths from the Adriatic (Sokol, 1999). Both males and females were buried with coins and utilitarian bone artifacts such as combs, needles, quivers, and knife handles (Sokol, 1999).

The shift to Christian burial forms was swift and effected with little to no social upheaval (Goldstein, 1999a). Pagan necropoli were abandoned and Christian period (mid-9th century) burials were associated with church buildings. The burials can be categorized into two types: simple inhumations without burial chamber or design, wrapped in thick cloth; and formal burial chambers made of round wooden logs or stone block courses, large slabs as floors and covers, and rectangular or elliptical in shape (Sokol, 1999). Burials are oriented in an E-W direction in regular rows from N-S (Sokol, 1999). Christian burials are typically poorly outfitted in terms of grave goods; only standard male-female dress items and no everyday objects are found within graves (Klápště and Jaubert, 2007; Sokol, 1999). Dress items include the following: jewelry, clasps, buttons, small knives, and spurs. Although rare, buttons were typically made of a pearly glass drops set into the bottom of a bead, and are usually only found among female graves from the 9-11th centuries (Sokol, 1999). Men's graves become rather modest while women's graves show tend to contain larger numbers of earrings, necklaces, head ornaments, appliqués, bracelets, and rings (Sokol, 1999). The Šibenik-Sv. Lovre site, included in this study, is typical for the early Christian period with generally few grave goods, and those that are present are jewelry items found in women's or children's graves (Thorson, et al. 2017).

Early Medieval material culture changes

The Early Medieval period in Croatia was witness to many changes in material culture, especially in clothing, jewelry, warrior equipment, burial customs and domestic architecture. The Croatian jewelry industry flourished in the mid-9th century. Jewelry items were made of bronze, gilded bronze, gold, silver and other metals (Sokol, 1999). The most common jewelry items were earrings, followed by temple pendants and rings (Sokol, 1999). Necklaces and bracelets were relatively rare; however metal neckline appliqués were more frequent (Sokol, 1999). An earring type unique to the region used filigree and granulation techniques to create larger hooped earrings with a bead. Known as a temple pendant, these earrings hung from plaited hair or a headband (Sokol, 1999).

Rings were the most widely distributed and most variable jewelry item. The most common form of ring was either fluted or made of twisted silver or bronze wire (Sokol, 1999). Later rings were made using a casting and filigree technique (Mohorovičić, 1999). By the mid-9th century jewelry types began to change, but the production techniques remained similar with the addition of beaten metal sheets and soldering joints (Sokol, 1999). From the end of the 11th-12th centuries, jewelry items become more simplified. Beads are no longer found on earrings, plain hoop and S-shape types increase in popularity, and two-sided comb-like pendants also become more common (Mohorovičić, 1999; Sokol, 1999).

Croatian goldsmiths, associated with both the jewelry industry and the establishment of Christianity, were producing an array of religious artifacts, including caskets, reliquaries, crosses, *plenariums* (medieval liturgical books used in saying Mass), and crucifixes (Sokol, 1999). By the end of the 11th century, goldsmiths were producing stylistic elements in accordance with the new Romanesque artistic era (Sokol, 1999).

During the 8-9th centuries in Slavonia and Pannonia, military items are dominated by Late II Avar Khanate finds. After the Avars' defeat by Frankish forces at the end of the 8th century Carolingian items, such as Carolingian battle-axes and winged spears, replace Avar military material items (Sokol, 1999). Military items are commonly found with individuals buried prior to the 9th century. After the 9th century, Christian doctrines forbid burial goods; most weapons known from this period are the result of isolated finds. Post-Carolingian weaponry was made with stronger forging techniques and weapons often included elements of silver inlay and makers' marks (Sokol, 1999). Early Medieval arrowheads are also common especially around fortifications (De Meulemeester and O'Conor, 2007; Sokol, 1999).

Early Medieval populous – health, stress, conflict

The Early Medieval period in Europe saw the rise of new health problems as a result of urban life. Unhealthy air, polluted water, excessive noise, fires and pestilences were common throughout Europe (Leciejewicz and Valor, 2007). Skeletal examination of populations supports a distinct decline in quality of life from the Late Antique to Early Medieval periods in Croatia: a trend that continues into the Late Medieval period (Šlaus, 2002; Šlaus, et al. 2002).

Distinct changes in dental and nutritional health suggest replacement of Roman populations by Slavic/Croat populations and/or their successful Christianization. Vodanović and colleagues (2012a, 2012b) identified orthodontic differences between Late Antique and Early Medieval populations from Croatia, providing data on hypodontia, tooth crowding, and periodontal disease that they argue supports historic sources indicating Romano populations being replaced by Avaro-Slav populations. In continental Croatia there is an apparently gradual reduction in the number of interproximal caries and an increase in occlusal, buccal and lingual

caries, suggesting a change in diet with softer, less abrasive foods becoming more available in the more recent time periods (Vodanović, et al. 2005).

The rural population from the Istrian cemetery site, Novigrad (5-6th c.), suffered from greater childhood nutritional stress and adulthood physical stress, as evidenced by the remains of lower socioeconomic status burials (Rajić and Ujčić, 2003). A similar trend has been observed by Šlaus (2002), among lower socioeconomic status populations in urban and rural settings. The observed decline in general health standards is attributed to the period's marked political instability (Šlaus, 2002).

Summary of the Early Medieval period

Croats entered the region between the Adriatic Sea and the Pannonian plain in the early 7th century (Goldstein 1999b). The 8th-9th centuries were dominated by battles and the adoption of Christianity. Social development and economic prosperity peaked in the Adriatic during the 10th century and in Pannonia during the 11th century (Goldstein 1999b).

By the end of the Early Medieval period, Croatia had become firmly rooted in the traditions of Antiquity and Western civilization by absorbing the pre-existing and newly arrived migrant populations, and this can be observed in the changes to material culture and skeletal characteristics of health, diet and physiology (Goldstein, 1999a, 1999b; Sokol, 1999; Vodanović, et al. 2012a, 2012b). Urbanization and rural feudalism intensified in both Dalmatia and Pannonia (Mohorovičić, 1999). During this time period the greatest social influences come from the new feudal system and the Catholic church (Mohorovičić, 1999). At the close of the Early Medieval period, Croatia established political union with Hungary (A.D. 1102), handing the Croatian throne to the Hungarian Arpad dynasty (Sokol, 1999).

Croatian history throughout the Early Medieval period experienced oscillations of war and peace, as well as destruction and prosperity due to both internal and external aggressive powers including: the Byzantine-Frankish war, conflicts for control of the Adriatic with Venice, conquest by the Avars, and incursions by the Magyars and Bulgarians (Goldstein, 1999b). All the while, the Croatian nation maintained its cultural integrity and established itself as belonging to western and central European and Catholic spheres (Fine, 2006).

Late Medieval period (12th – 15th centuries AD) – Ottoman expansion

Croatia was a feudal monarchy at the opening of the Late Medieval period (Kurelac, 2008). The Adriatic cities were politically under the control of the Byzantine Empire and continental Croatia was associated with the Arpad Dynasty of Hungary in 1102 (Figure 3-4) (Goldstein, 1999; Matijević-Sokol, 2008; Sokol, 2008). Roman traditional law was conserved among the Adriatic cities and was altered very little, as it was written (Margetić, 2008). Laws in continental Croatia were based on common law, which was more susceptible to economic and social changes (Margetić, 2008). Other than disruptions such as the Mongolian invasions (1242) and the Black Death (1348), the first part of the Late Medieval period (12-14th centuries) was characterized by growth and development (Raukar, 2008). The 12th century Hungaro-Croatian kings granted privileges to continental Croatian cities in an effort to promote reconstruction and further growth (Goldstein, 1999b; Margetić, 2008).

Figure 3 - 4: Map of southeastern Europe c. 1340, at beginning of Croatian Late Medieval period (Wikimedia Commons contributors, 2016b).

The first signs of serious crisis, destruction and disorder occurred in the 15th century (Kurelac, 2008; Raukar, 2008). Venice established its rule over the eastern Adriatic by 1454; largely motivated by a need to control trade and trade routes (Kurelac, 2008; Raukar, 2008). Despite being economically stagnant when tied to Venice, the Adriatic urban centers remained largely autonomous and flourished culturally (Kurelac, 2008; Raukar, 2008).

The 15th century was also a time of diplomatic growth in response to the appearance of the Ottoman threat (Raukar, 2008). When it came to fighting the Ottomans, Croatia was in an unequal position due to their lack of effective ruling support (Raukar, 2008). The Ottoman destruction of material structures and decimation of Croatian and Bosnian populations prompted

society to change its attitudes and by the end of the 15th century Croats were concentrating their efforts on repelling the Ottomans (Raukar, 2008). Many new Croatian fortifications were built at the expense of lower and middle nobility and many Croatian envoys pleaded with Western European courts and the Vatican for assistance, stressing the point of danger to the West, especially Italy, if Croatia were to fall (Raukar, 2008). Croatia was met by general European indifference, with only verbal support provided by various Popes (Kurelac, 2008; Raukar, 2008). In 1493, the Ottomans had severely defeated the Croats in the Battle of Krbava, and in 1526 the Croats and Hungarians suffered another major defeat at Mohács, resulting in the uninterrupted plundering by the Ottomans (Kurelac, 2008). The heavy defeats and the general indifference of western powers, resulted in the exertion of Croatia's political individuality as its diplomats acted independently of the Hungarian king and culminated in the appointment of Ferdinand of Habsburg as the Croatian King in 1527 (Kurelac, 2008; Raukar, 2008).

The 16th century saw the gradual expansion of the Ottoman Empire at the expense of Croatian territory (Raukar, 2008). As the Ottomans systematically expanded, oppression, plundering, war and conflict increased (Kurelac, 2008). The ethnic and social composition changed under the pressure of constant warfare resulting in the decimation of the indigenous Croatian populations by expulsion, migration, imprisonment and slavery (Raukar, 2008). This had further consequences of economic and developmental stagnation for much of continental Croatia and the Dalmatian hinterlands (Kurelac, 2008).

The Habsburgs established a military frontier defense system that was meant to stop further Ottoman expansion but its administrative center was at Graz, Austria, and far removed from the action (Grgin, 2012; Kurelac, 2008; Raukar, 2008). In effect, the Habsburgs made

Croatia their buffer zone against the Ottomans but otherwise they had a limited impact on Croatian culture (Grgin, 2012). Croatia was a true periphery not only in a geographical sense.

The defense system was expensive and Croatian resources could not maintain it; help was lacking, and the defense system was mostly ill equipped: fortresses were run down and food and weapons were scarce (Grgin, 2012:200). The costs of the defense system to the kingdom outweighed the benefits received from Croatia. Ottoman raids and conquests "led to the gradual depopulation of border zones in medieval Croatia that was coupled with gradual process of complete disintegration of medieval social structures. Particularly hard hit during this first period (1463-1490) were the peasants, who were the backbones of every medieval society" (Grgin, 2012:204). 1571 marked a turning point when the Ottomans demanded Cyprus from Venice and the Christian Coalition restored faith in a Christian victory at the Battle of Lepanto and at the Battle of Sisak in 1593, which ended further Ottoman expansion into Croatia (Kurelac, 2008).

Late Medieval settlement organization

Urban centers had their foundations either in Greek and Roman periods or in the Early Medieval period (Marasović, 2008). Under the Hungaro-Croatian kings of the 12th-14th centuries many urban centers were granted privileges as free communes and were able to establish provisions and statutes for maintenance of the city and the collection of funds to build and repair architectural venues (Goldstein, 1999b; Marasović, 2008). Adriatic towns developed characteristics of Mediterranean cities, while continental towns mirrored central European cities (Goldstein, 1999b; Raukar, 2008). Urban populations increased, especially in the number of craftsmen (Goldstein, 1999b; Kurelac, 2008). Roman roads continued to be used, trade routes

were strongly established, and feudalism developed further (Goldstein, 1999b; Mohorovičić, 2008).

Throughout the Early and Late Medieval periods, Dalmatia and Istria retained their urban vitality, structures and customs (Mohorovičić, 2008). The eastern Adriatic has topographical advantages of deep, well-sheltered bays, peninsulas, islands, and a mountainous coastline that was all exploited to the maximum advantage in early urban development (Marasović, 2008). Two types of urban centers appear on the Adriatic: 1) towns and settlements with ties to Classical antiquity and 2) towns and settlements that did not develop out of Classical foundations (Andersson, 2011; Marasović, 2008). Settlements appear most often around ports, on islands or peninsulas, and on hills (Kurelac, 2008; Marasović, 2008). Adriatic urban town planning mostly followed patterns established in Classical antiquity such as rectangular street patterns (Marasović, 2008). Roman buildings were often repurposed, and new buildings were built in Romanesque and Gothic styles. As population increased open spaces and streets were filled in but retained their rectangular grid pattern (Andersson, 2011; Marasović, 2008). Often Christian cathedrals were built over Roman temples and Christian buildings were located at the opposite end of town from the main square (Marasović, 2008). Cities were protected by fortifications consisting of stonewalls, gates, bridges, and trenches (Marasović, 2008).

In continental Croatia, settlements often formed below citadels, at or near trade crossroads and at river fords (Kurelac, 2008; Marasović, 2008; Mohorovičić, 2008). Lowlands were prone to flooding, therefore roads and settlements were built away from rivers at safe distances or at the foot of mountains (Mohorovičić, 2008). Strategic locations on the northern and western frontiers controlled fertile land and important lines of communication and trade and were dispersed approximately 30-70 km apart (Mohorovičić, 2008). Towns were fortified with

city walls and towers of timber or stone, and town layouts were mostly organically developed with a strong Christian presence (Mohorovičić, 2008; Scholkmann, 2011). A few continental cities were built on foundations established in Classic antiquity, such as Sisak, with rectangular grid streets along approaching roads, and large public thermal baths (Mohorovičić, 2008). During the Early Medieval period the number of new settlements increased and by the Late Medieval period urban centers had developed out of crossroad settlements. These urbanized settlements had market squares/exchanges, a church, and a municipal square (Mohorovičić, 2008; Scholkmann, 2011). Continental urban centers were characterized by simple timber houses along a main street with a central square, protected by a city wall, embankments, palisades and water-filled trenches, and were near fertile land or forests (Mohorovičić, 2008; Scholkmann, 2011). Many towns when captured by the Ottomans were completely destroyed, and were not reestablished until the Ottomans were finally expelled from the area in the 18th century (Mohorovičić, 2008). In order to encourage redevelopment, royal free-city status was given to many towns during the Late Medieval period. Free city status granted autonomy to the city in its jurisdiction and organization and freedom from obligations to the ruler of economic and military defense (Goldstein, 1999b; Mohorovičić, 2008).

Little is known archaeologically about the rural human environment in Late Medieval Croatia. However, from historic records it is understood that the number of small villages and hamlets increased dramatically with a similar increase in the population of arable farmlands, free peasants and serfs (Kurelac, 2008; Mohorovičić, 2008). Most of the population was dependent on feudal lords for protection (Mohorovičić, 2008). Rural inhabitants produced and traded various goods, livestock, wine and cereals (Kurelac, 2008). Kings and lords built strong burgs or castles, in strategic locations to protect and defend estates, remotely populated areas, and the

backbone of the economy, agriculture (Mohorovičić, 2008). The preoccupation with security in Late Medieval Croatia is apparent in the archaeological record; over 700 burgs have been identified in the Pannonian region alone (Mohorovičić, 2008).

Late Medieval religious and spiritual life

The Croats were fully converted to Christianity by the 9th century. Thereafter, the Church evolved gradually and established clear diocese by the early 12th century (Raukar, 2008). Monastic organizations were centers of learning and were established throughout Croatia between 1200 and 1600 AD (Raukar, 2008). The monastic orders were possibly the most influential institutions in Croatia during the medieval period and contributed the most to the development of Croatian cultural heritage, from the development of basic infrastructure by the Knights Templar, the commissioning of architecture and works of art, to the advancement of agriculture, education, medicine and public health. Three concepts dominate the monastic orders: 1) withdrawal to solitude practiced by Benedictines and Cistercians, 2) engagement in eminently extramural activities with marked apostolic and missionary goals by the Dominicans, Franciscans, Augustinians and Paulines, and 3) the participation in humanist movements of social, cultural and religious revival practiced by the Jesuits and Capuchins (Šanjek, 2008). The Church provided free education for the poor and was responsible for the establishment of the first Croatian University, *Dominicans General Studies* in Zadar, where students, monks, clerics and laymen, could study philosophy (Šanjek, 2008).

Burial traditions in Late Medieval Croatia followed those established in the Early Medieval period and were primarily simple inhumations in an east-west orientation, with the head to the west (Šlaus, 2002). The memorials, epigraphs and tombstones, reflect social and

political events of the Late Medieval period. The Mongolian and Ottoman invasions were detrimental to the preservation of Latin epigraphic texts in continental Croatia, as both groups destroyed most existing architecture and monuments, however a few examples have managed to survive or have been recovered from archaeological contexts (Matijević-Sokol, 2008). The Croatian situation depicted in inscriptions and epigraphs of Renaissance memorials, testifies to a more relaxed way of life, in keeping with Western European models, but also to the eternal struggle for salvation of the homeland (Matijević-Sokol, 2008).

The stone sepulchral monuments and the stone *stećak* monuments are an interesting mortuary phenomenon present in Adriatic, Istrian and Bosnian regions (Sokol, 2008). These are monolithic tombstones from the 14th and 15th centuries (Šunjić, 2009). Based on the decorations, forms, distribution, and the historical contexts of these monuments, there is evidence for a connection between medieval monolithic tombstones and necropolises placed at sites with prehistoric cairns (Šunjić, 2009). Decorative motifs include vine patterns, shields, cross guards, heraldic portrayals, and motifs of the deer hunt (Šunjić, 2009). Stećak largely disappear after the mid-15th century once the Ottomans control the Dalmatian hinterlands and Bosnian territories. Unfortunately, due to this break with earlier tradition, the importance or significance of these tombstones is still poorly understood.

Catholic Christians were the dominant religious group in Croatia during the medieval period, but they were not the only religion. Protestantism came from Germany in the 14th century with the largest established community in Pannonia (Šanjek, 2008). Luther and Calvin's appeals led to a return to an evangelical ideal of community and supported the use of national languages (Šanjek, 2008). From 1560 to 1564, the Croatia Protestant printing house in Urach was established and ensured the diffusion of Protestant ideas (Hercigonja, 2008). The Protestant

Glagolitic press followed and developed together with the earlier literary and linguistic trends of Glagolitic 15th century writers: there was an awareness of the need to create a common literary language to ensure wider circulation of their texts in a situation of great differences in dialects and local idioms (Hercigonja, 2008). A total of 14 Protestant titles in Glagolitic script were printed but of the 10,900 copies only 139 survived the burning and destruction of Protestant writings that marked the Counter-Reformation (Hercigonja, 2008:211). Many Croatian humanists were labeled Protestants and were executed as heretics in Rome (Šanjek, 2008). But Protestantism never fully established deep durable roots in Croatia, likely due to Croats' preoccupation with resisting the Ottomans and the role that Catholicism played in the establishment of strong ties of unity between the dispersed Croatian peoples (Šanjek, 2008). Furthermore, the Catholic Counter-Reformation was strongly felt in Croatia, with the establishment of schools next to parish churches and within monasteries, better educated priests with the establishment of seminaries, an increased literacy rate, the introduction of the catechism in religious education, the opening and establishment of new universities and seminaries, and the extreme persecution of said 'heretics' and heretical writing (Šanjek, 2008).

Much less well understood is the presence of a Jewish minority population in Croatia. In Europe, Jewish people were often forbidden to exercise a craft, which impeded the production of culturally distinct goods. Denied a craft, Jewish people were often employed as traders, doctors, craftsmen, book printers and farmers (Vossler, 2011:419). Historical sources have documented individual Jewish doctors and surgeons immigrating to Dubrovnik (Grmek, 2008), but the Jewish archaeological presence has either not been investigated or remains unpublished in English.

Late Medieval material culture changes

The number of crafts and artisans increases during the Late Medieval period of Europe (Roesdahl and Verhaeghe, 2011). Artifacts including dies, signet rings, the sarcophagi of St. Simon, melting pots, belt buckles, and bone combs, illustrate tastes and social status as well as the development of goldsmithing and bone carving artisan groups in Croatia (Sokol, 2008). Pottery was made on a fast-rotating wheel and commonly was impressed with a maker's mark (Sokol, 2008). Ceramic production mostly consisted of household utilitarian items and some luxury items such as decorative stove tiles similar to those from Hungary (Sabján, 2011; Sokol, 2008). Decorative stone tiles reflect the remnants of huge stoves, with beautiful floral glazed lace-like gothic impressions found at castle sites such as Medvedgrad, Mrsunjskilug, Gorićgard, and Čazma (Sabján, 2011; Sokol, 2008). Eastern Adriatic cities traded with Murano for glass products until Dubrovnik established its own glass production industry in the 14th century (Sokol, 2008). Glass items commonly included lamps, bottles, cups, pots, and handles (Sokol, 2008).

Not much is known archaeologically about Late Medieval dress in Croatia. However, the work of goldsmiths and jewelers is reflected in the jewelry items recovered from archaeological and burial contexts. It is understood that notched earrings were part of female attire as found in burial contexts, but the notched earrings declines in popularity during the 13th century and are replaced by beaded earrings, known as 'Slavonian earrings,' in the 14th century (Sokol, 2008). During the increasing instability of the Ottoman period, earrings decline in burial contexts (Sokol, 2008). Other recovered jewelry items include rings, pins, brooches, and diadems (Sokol, 2008). In addition to jewelry, gold and gilded belts have been recovered (Sokol, 2008).

As a result of the Crusades in the 12th-14th centuries and the local struggle against the Ottoman Turks in the 15th and 16th centuries, militarism was a part of daily life and can be observed archaeologically in weaponry and armor as well as other artifacts and fortifications. Croats participated in the 5th Crusade (1217-1221) as both warriors and hosts, as crusaders passed through the region on the way to the Holy land. Crusader accounts from the 13th and 14th centuries remark on the beauty of the Croatian landscape, the richness of Croatian cities and the cordiality of their inhabitants (Šanjek, 2008). Material evidence in the form of arms and combat equipment testifies to this period of Croatian history (Sokol, 2008). A new weapon of the period is the "long Crusader's sword," which was made of steel, was longer, and had a longer hilt with a spherical end which made it significantly different than earlier Carolingian or post-Carolingian swords (Sokol, 2008). Sword finds at sites along the rivers Drava, Sava and Kupa reflect an eastern route to the Holy land through Croatia (Sokol, 2008). Another martial innovation was the use of the crossbow for defending feudal forts such as Koprivnica (Sokol, 2008). Halberds (spear-like battle-axes), battle maces, and shields all exhibit changes at this time; and helmets and armor change in shape in response to weaponry advances (Sokol, 2008).

Castles were the primary form of defensive fortification in Europe and were often surrounded by water in Croatia and Slavonia (Meyer, 2011; Sokol, 2008). Mrsunjgard is a rare example of a wooden castle in Croatia (Meyer, 2011; Sokol, 2008). Artifacts reflect the military and the social functions of castles and include: lock mechanisms, padlocks, chains for hanging over fires, iron clamps, and shackles, pins from beams, nails, carpenter's axes, axes, arrow tips (including ordinary ones and those used in crossbows), iron ladles, knives, woodworking tools, and bronze weights (Meyer, 2011; Sokol, 2008). With the advent of firearms and artillery

weapons, the 16th century saw corresponding changes in protection and fortification very similar to those seen in the rest of Europe (Meyer, 2011; Sokol, 2008).

The role of money increased and became associated with the influence and needs of the lower nobility (Kurelac, 2008). Dalmatian urban communities were the first to start minting their own coins (Sokol, 2008). The monetary system of the continental region was unified under Hungarian rule and in the 12th century small silver circular coins with a crescent and stars motif were minted in Zagreb (Sokol, 2008). Trade commodities included salt, wine, olive oil, wool, textiles, arts and crafts; while agricultural products included livestock, meat, metals, lumber and other products (Raukar, 2008; Šunjić, 2009). Croatia played an active role in north-south and east-west trade routes (Raukar, 2008). Hispano-Moorish Majolica imports indicate trade with Moorish Spain (Sokol, 2008). Thanks to their geopolitical position, Adriatic towns adopted more advanced technology, especially in trade and navigation (Raukar, 2008). Dubrovnik was a forerunner in maritime law and established trade rules that dispersed the cost of a lost cargo by sharing the burden among all parties: cargo owners, captain and crew (Margetić, 2008). Dubrovnik's economy was centered on trade and craft production (Stipetić, 2008). Dubrovnik also introduced quality controls on its industries to ensure the quality of its exports and established itself as having the best wool and fine textiles in the world (Stipetić, 2008).

Late Medieval social and cultural developments

The first universities founded in the Adriatic promoted scientific intellectual development and social and cultural activities (Raukar, 2008). For the first time, as intellectuals formed a new social group termed humanists, class stratification and conflict increased (Kurelac, 2008).

Croatian literary writers sought new hope in their struggle against the Ottomans through an increase in religious and humanist writings of non-liturgical poetry and prayers (Šanjek, 2008).

All over Croatia, health conditions improved until the Ottoman incursions of the 15th century (Grmek, 2008). Each town had its own hospital, more a charitable institution than a medical one: that served as a poor home and shelter (Grmek, 2008). Hospices were often next to churches and monasteries (Grmek, 2008). Usually, hospices held only 20 beds, and could serve one or both sexes (Grmek, 2008). Those suffering from infectious diseases such as leprosy would be sent to an established leprosarium on the outskirts of settlements (Grmek, 2008). The orphanage established in Dubrovnik (1432) was the first in Europe and served abandoned children to the age of five (Grmek, 2008:400; Scholkmann, 2011). The health services in Dubrovnik and other Dalmatian cities were the most advanced (Grmek, 2008). In the 14th-15th centuries many cities established statutes or regulations of the duties of civil servants, doctors and pharmacists; public sanitation requirements including the cleaning of rubbish and fesses from city streets; prohibitions regarding free-ranging pigs, chickens and dogs; and regulated food markets by establishing public grain silos, controlling butcher and fish monger shops, and requiring market food to be fresh (Grmek, 2008).

Contagious diseases of the Late Medieval period were all present in one form or another in Croatia. Plagues of spotted typhoid fever, small pox, dysentery, and influenza all passed through Croatia (Grmek, 2008). In 1348, the Black Death ravaged the region with disastrous demographic and economic consequences (Grmek, 2008). In 1377, Dubrovnik established the first quarantine in Europe as an epidemiological measure (Grmek, 2008). A malaria outbreak in 1459 in Stan and Rijeka was caused by stagnant water and was relieved by the cleaning of river channels and draining of marshes (Grmek, 2008). As they do today, people of the Late Medieval

period also suffered from benign neoplastic tumors such as osteochondromas (Šlaus, et al. 2000). As evidenced by paleopathological analyses of human skeletal remains of Late Medieval cemetery samples are affected by high frequencies of alveolar bone disease, most probably as a result of somewhat longer average life span (around 41 years) compared to the Early Medieval period, and very poor oral hygiene (Novak, 2011). Dental caries data are consistent with a mixed diet evenly based on meat and cereals (Novak, 2011). High frequencies of cribra orbitalia, dental enamel hypoplasia and periostitis suggest frequent episodes of physiological stress, likely the result of hunger and epidemics of infectious diseases, and may indicate a relationship between stress events and reduced life expectancy among children and women (Novak, 2011; Šlaus, 2000, 2002). Trauma evidence suggests a high degree of interpersonal violence (Novak, 2011).

Summary of the Late Medieval period

The Late Medieval period in Croatia was characterized by social, cultural and economic development, followed by crisis and stagnation. Dalmatian cities had the greatest opportunity for spiritual, intellectual, and material prosperity; continental cities were more obliged to defend their homeland and protect Europe (Matijević-Sokol, 2008). The political subdivision of Croatia by the Ottomans, Venetian Republic and the Habsburgs did not derail Croatian cultural development (Raukar, 2008). Cultural development was largely promoted by various ecclesiastical intuitions that commissioned Romanesque, Gothic and Renaissance art, sculpture and architecture, promoted the education and literacy of the public, and promoted the Glagolitic language and literary development. However, increasing Ottoman raiding and conquests led to the development of a "Croatian desert," due to depopulation by Ottoman enslavement and a lack of security and economic opportunities that led to a mass exodus of the Ottoman occupied

territories in the 15th and 16th centuries (Kurelac, 2008). At close of the 16th century, Croatia was mostly in ruins and large portions of the population had been lost to slavery or migration. A period of stagnation and false peace began while Croatia continued to fight for its ethnic identify if not political preservation. Threatened and broken by the Ottomans and other European forces Croatia was carved up by the Ottoman Empire, the Habsburgs, and Venice.

Early Modern period (15th-18th centuries AD) – Ottoman control and decline

The Early Modern period in Europe is usually described as beginning during the Renaissance period or with Columbus' discovery of the Americas at the end of the 15th century and ending with the French Revolution in 1789. Themes of this incredibly complex time period include, but are not limited to, the 'Age of Discovery', development of global colonialism, the Reformation(s), the Enlightenment, capitalism and the industrial revolution, economic and technological advancement, and the advent of modern warfare. Many of these developments also affected the lives of Croatians from the 15th to 18th centuries. In Croatia, a peak in Ottoman-Austrian-Venetian military campaigns, the development of trade and manufacture, and the gradual dissolution of the feudal system characterize this period.

From the mid-15th century on, political boundaries in Croatia were shifting frequently between the Venetians, Ottomans and Habsburgs. Ottoman forces first entered Europe in 1345; by the mid-fifteenth century they held the entire area south of the Danube (Wiesner-Hanks, 2013). In 1453, they conquered Constantinople, renamed it Istanbul and made it the capital of the Ottoman Empire (Goffman, 2002). The Ottomans had expanded southward around the Mediterranean as well as into Europe, engaging in naval and land wars with Mediterranean powers (including Venice, Genoa, Egypt, Syria and Iraq), before turning their attention back

northwards to conquer Bosnia, Croatia, Romania, Ukraine and Hungary (Goffman, 2002; Moačanin, 2008; Wiesner-Hanks, 2013). Bosnia fell to the Ottomans in 1463, which then caused an increase in Ottoman raids upon Croatian territories leading to the Hundred-Year Croatian-Ottoman war from 1493-1593. Early in the 16th Century, Croatian humanists, keenly aware of the impeding spread of the Ottoman Empire, began pleading with Rome and Western European powers for assistance in resisting Ottoman forces (Goldstein, 1999b). In 1521, the Ottomans conquered Belgrade, Serbia, and soon launched a campaign further north.

Using a huge army and siege cannons, the Ottomans were victorious at the battle of Mohács, Hungary, in 1526, after crushing the Hungarian nobility's forces (Goldstein, 1999b; Wiesner-Hanks, 2013). Hungary and Croatia were then divided between the Ottomans in the east and the Habsburgs to the west (Wiesner-Hanks, 2013). The Croatian nobility elected the Austrian Archduke Ferdinand Habsburg as their king in 1527, but this change in dynastic rule did not make much difference. 1550-1690 was the period of the most expansive Ottoman rule (Goldstein, 1999b; Moačanin, 2008). It appeared as if nothing could stop the Ottoman offensive until they were halted by a combination of defeats at the Battle of Lepanto (1571), the Battle of Sisak (1593) and the need to confront the reinvigorated Saravid army in Iraq (1578-1590) (Goffman, 2002; Wiesner-Hanks, 2013).

In 1558, at a time of extreme weakness, the center of the Croatian state moved from Dalmatia to Zagreb in the north. Zagreb continued to gain in importance, and the northern Adriatic ports of Rijeka and Senj were developed as safe harbors (Goldstein, 1999b). The boundaries between the Ottomans and Western Europe stabilized in the 1570s (Figure 3-5), leaving the Ottomans as rulers of approximately 1/3 of Europe and half the Mediterranean shoreline for the next 300 years (Wiesner-Hanks, 2013).

Ottoman expansion also affected Dalmatia by narrowing the Venetian-controlled territory to a very narrow strip (Figure 3-5) (Goldstein, 1999b). In the 16th and 17th centuries, close to 50% of present day Croatia was under Ottoman rule, including most of Dalmatia with the exception of the remaining Venetian controlled cities, and the northwestern regions that were controlled by the Habsburgs (Figure 3-5) (Moačanin, 2008). Croatia fell into economic and demographic decline, partly due to the Ottoman presence, but also because of a general European trend of neglect of the Mediterranean region and a shift in power to the Northern and Atlantic European states (Goldstein, 1999b; Wiesner-Hanks, 2013).

Figure 3 - 5: Map of Croatian territories with late 16th century Habsburg, Ottoman and Venetian political boundaries. Red pins identify relevant battle and occupation dates. Political boundaries sourced from Magocsi (2002:14).

The development of nation states was largely dependent upon the development of standing armies (Wiesner-Hanks, 2013). The Ottoman janissary corps was the first established standing army and it was largely responsible for the great military success of Ottoman expansion (Goffman, 2002). At the time of the Battle of Mohács, the army of the Ottoman Sultan Süleyman, who ruled from 1521 to 1566, regularly consisted of 150,000 or more troops equipped with huge siege cannons (Goffman, 2002; Wiesner-Hanks, 2013). Partly due to fear of the Ottoman Turks and partly due to Western and Central European infighting, armies throughout Europe grew in size during the 16th century.

Beginning in the second half of the 16th century, Ottoman expansion in Croatia began to slow as efficient organized defense was developed using Habsburg money and as better equipped and more numerous mercenaries were drafted to defend the frontier (Goldstein, 1999b). Garrisoned castles were constructed along the frontier and centered on the newly constructed, six-pointed star fortress at Karlovac (Figure 3-5) (Goldstein, 1999b). The Ottomans launched another offensive in the 1580s-1590s, and pushed the frontier from the river Una to the river Kupa (Goldstein, 1999b). In 1593, the Ottoman army was defeated at Sisak by the combined force of the Croatian-Slavonian-Austrian army (Figure 3-5). After the battle at Sisak, few territorial advances were made but the initiative shifted to the Christian forces (Goldstein, 1999b). The Habsburgs transformed the frontier region into a separate province under direct Austrian military administration (Goldstein, 1999b).

Life under Ottoman rule

The Ottoman conquest of the Balkans is often portrayed as a suspension of the region's history as society was immobilized by several centuries of slavery, tyranny and foreign

occupation (Goffman, 2002). Conventionally the Ottomans have been portrayed as persecutors of Christians, but the Balkans during this time period could just as easily be characterized as a haven for those fleeing from fiercely intolerant Christian Europe (Goffman, 2002). Conquered lands were organized into districts, which in turn were organized into a hierarchy of larger units, under the authority of a trained official (Moačanin, 2008; Wiesner-Hanks, 2013). An increasing land base fueled the Ottoman Empire with taxes paid by conquered peoples (Moačanin, 2008). Instead of totally replacing the established systems of government, conquered people and lands were often allowed to keep their own laws and traditions, including religion, which helped to facilitate an easy incorporation into the Empire (Goffman, 2002; Moačanin, 2008; Wiesner-Hanks, 2013). There were several motivations for the religious tolerance of the Ottomans. Besides not regarding religious uniformity as critical to effective governance, the Ottomans also charged higher taxes to non-Muslims and were not eager to have all their subjects convert and lose a substantial portion of their tax base (Goffman, 2002; Wiesner-Hanks, 2013).

Only during the initial conquest were there heavy demographic, political, social and economic consequences, mostly due to plundering and raiding (Moačanin, 2008). Depopulation was caused by panicked migration, imprisonment, enslavement, warfare and disease (Raukar, 2008). The magnitude of these raids is evident in the number of prisoners taken, with historical sources estimating some 60,000 were taken from a single raid in 1469, and 30,000 from a raid in 1471 (Šlaus, 2002). Once Ottoman administration was established, the population gradually increased and little actually changed for the rural classes (Goldstein, 1999b; Moačanin, 2008). Christians from the interior of the Balkans settled uncultivated lands (Goldstein, 1999b). Overall, conditions were relatively favorable through the late 16th and early 17th centuries under Ottoman rule. Peasants and serfs still had to pay high taxes and rents; however, rents were actually based

on production within a specific area rather than specific arrangements with the ruling nobility (Moačanin, 2008). In this manner, social stratification stabilized in Ottoman Croatia: the nobility had become a caste of their own with few 'free-men' who were not nobles (Goldstein, 1999b). Religious orders were allowed to serve their members, roads and towns were built or repaired that encouraged transport and trade (Goffman, 2002; Goldstein, 1999b; Šanjek, 2008; Wiesner-Hanks, 2013).

From the 1400s forward, Ottoman sultans centralized institutions, created more specialized bureaucracies, and expanded and modernized their army and navy (Goffman, 2002; Wiesner-Hanks, 2013). They maintained a trained army and core of administrative and tax officials, often co-opting existing local and religious authorities rather than replacing them (Wiesner-Hanks, 2013). Thus within the Ottoman Empire regional territories maintained their identities (Wiesner-Hanks, 2013).

The historical narratives present the Ottoman Empire as the ultimate evil aggressors, but life under Ottoman rule was sometimes better than in Christian Europe. The Ottoman Empire openly welcomed non-Islamic peoples. To practice their faith of choice people had only to pay additional taxes, or convert to Islam, but they were not driven out of settlements or burned at the stake for practicing their faith. As non-Muslims were taxed at a higher rate, the Ottoman government did little to encourage conversion to Islam for primarily economic reasons and Islamicization of villages was less common (Moačanin, 2008). According to historic documentary evidence, Muslims never constituted more that 5-7% of the population in Croatia, with the exception of the Požega Valley (in Eastern Pannonia) with a 60% Muslim population (Moačanin, 2008). Conversion to Islam was made for several factors, including economic and

social prestige. Economically Muslim converts benefited from a reduction in taxes, but they also could gain social and material prestige by joining the Ottoman army.

Local lords were the ultimate local authority in their territories and had little interference from royal officials; they used their influence to restrict the rights of peasants and towns people (Wiesner-Hanks, 2013). The military class and mid to upper nobility bought and seized land and collected taxes for the state. Like any bureaucracy this system was prone to corruption, and by the 17th century officials and nobility began to intimidate and threaten financial and administrative clerks to make huge profits, and violence was often enacted on the peasant classes (Moačanin, 2008). Responses to these new hardships included massive emigration (often over frontiers or to other parts of the empire), thievery, and armed rebellion (Moačanin, 2008).

The Ottomans practiced slavery, but the Ottoman slave culture was different from that established in the Americas and other parts of Europe, "not so much that the select of society owned slaves (although they certainly did) as that they *themselves* often were slaves;" that is the imperial family owned the viziers and pashas that ran the realm (Goffman, 2002:Loc 806). In a process called *devşirme*, Ottoman officials went to Serbia, Bosnia and Croatia and took a human "tithe" of young Christian boys to become the sultan's servants (Goffman, 2002). Ottoman military officers took boys, aged 8-18, from their families to be raised to serve the Ottoman state. They were taught to believe in Islam, rather than Christianity, to speak Turkish rather than Serbo-Croatian and affirm their loyalty to the Sultan. As compensation, these young boys were often lifted out of provincial impoverishment and oppressed conditions and placed into the ruling class of one of the most powerful polities in the world (Goffman, 2002). The most able of them were trained for military service and conscription into the Janissary core. Devşirme was only

enforced on Christian subjects of southeastern Europe and Anatolia, and it was practiced until the mid-17th century.

In the late 16th and early 17th centuries, the Ottoman *Sanjaks,* or administrative centers, quickly resettled uncultivated and depopulated lands with Christians from the interior, usually Orthodox Vlachs or Serbs, through a system called *sürgün* (forced migration) (Fine 1994; Goffman, 2002; Goldstein, 1999b; Kurelac, 2008; Raukar, 2008). The sürgün system served two purposes. First, it removed recalcitrant communities from their supporting environments, and second, it replenished under-populated regions and cities. In addition, after conquering new territories the Ottomans replaced the political elite with Turkish loyalists. Turkish soldiers often remained near active military fronts as well as in and around newly controlled territories to act as enforcers of the new political regime.

War of liberation - reclaimed territories and stabilized borders

Croatian nobles' light cavalry and their associated armies assisted the Habsburgs in the Thirty Years War (1618-1648) (Goldstein, 1999b). French and German forces came to identify Croatian soldiers with violent behavior and the Croatian costume (which is where the *cravat*, or neck tie originates) (Goldstein, 1999b). In 1683, the Ottomans marched on Vienna but were forced to retreat. Over the course of the next 16 years much of northern Croatia was freed, from Sisak eastward to Zemun (a suburb of Belgrade) (Goldstein, 1999b). This stabilized the border between Slavonia (Pannonia) and Bosnia at Strijem, where it has remained to the present day (Goffman, 2002; Goldstein, 1999b). In the mid-17th century, Venice began to push the Ottomans out of the Dalmatian hinterlands, and late in the century Venice joined forces with Austria (Goldstein, 1999b). By 1718, they had gained territory, establishing a new frontier on what is

today the border between Croatia and Bosnia-Hercegovina, and the term Dalmatia acquired its present meaning (Goldstein, 1999b). The historical provinces of Croatia and Dalmatia, which were separated by the Ottomans for nearly 200 years, were once again united.

Muslim populations living in Ottoman Croatia either fled or converted to Christianity, as Austrian-Habsburgs and Venetians reclaimed territories (Goldstein, 1999b). Soon Ottoman architectural and social features also disappeared as mosques and other structures were pulled down or put to different use (Goldstein, 1999b; Mohorovičić, 2008). In Slavonia, fortresses and towns were built on a grid pattern with a central main square, and the nobility built stately residences with French-styled gardens (Goldstein, 1999b; Mohorovičić, 2008). In Dalmatia, wealthy families build elegant summerhouses, and old dilapidated town houses were replaced by rows of Baroque mansions and citizen's houses (Goldstein, 1999b; Marasović, 2008).

The great war of liberation at the end of the 17th century ended an important period of Croatian history. A time of nearly continuous warfare with frontiers that changed frequently was followed by a period of flourishing economic and cultural contacts between Ottomans, Austrians, and Venetians. Positive development was fostered during the successive years of calm, most prominently evidenced by an upsurge in baroque art and architecture (Goldstein, 1999b; Mohorovičić, 2008). The population began to rebound from the previous century's decimation and a marked change from high to low birth and death rates began in the 18th century in Dubrovnik, extending to the rest of Croatia by the 19th century (Goldstein, 1999b).

Early Modern material culture changes

One of the most important changes from the medieval period to the Early Modern period was in the area of warfare. Cannons and gunpowder were developed in eastern Asian and

introduced to Europe by the Mongols in the 12th century. By the 14th century weapons were being manufactured throughout Europe that created a greater demand for metals and mining (Wiesner-Hanks, 2013). Cavalrymen formed the core of 15th century armies. Cavalry soldiers, mainly from the nobility, wore full plated armor and who charged into battle with lance and sword as frontline troops (DeVries, 2006;Wiesner-Hanks, 2013). In the 15th century heavy cavalry was considered the most important arm of the military; but the development of pikes which were deadlier than bows, and portable firearms such as harquebus (short wheel-lock firing mechanisms) and muskets (lighter and easier to reload than the harquebus, with flintlock firing mechanisms), led to the infantry becoming the heart of Early Modern armies (Wiesner-Hanks, 2013). With the advent of heavy artillery weapons, military tactics changed. As cannons that fired rocks and cannon balls became highly effective at collapsing high fortification walls, defensive fortifications became low, thick earthen ramparts that stood up well to siege engines (Wiesner-Hanks, 2013). Sieges grew longer and the starvation of a besieged population behind the walls of a city became an important tactic (Wiesner-Hanks, 2013).

Early Modern social and cultural developments

Most people living in Europe in the middle of the 15th century rarely traveled very far from their home village (Wiesner-Hanks, 2013). They may have gone to a nearby market town but they could walk there and back within a day (Wiesner-Hanks, 2013). Mentally their worlds were also locally oriented focusing around family, weather, crops, village politics, neighborhood saints, and community relationships (Wiesner-Hanks, 2013). The world came to them in the form of peddlers bringing products and news, soldiers bringing damage and destruction, germs bringing illness and death (Grmek, 2008; Wiesner-Hanks, 2013): A “sense of belonging to

something beyond their village was provided by religion, not language or politics" (Wiesner-Hanks, 2013:Loc 2142).

The most important invention of 15th century, possibly more important than gunpowder, was the printing press with moveable type (Wiesner-Hanks, 2013). Most early works dealt with religious subjects and were often written in local dialects rather than Latin, in both Europe in general and Croatian (Glagolism) more specifically (Hercigonja, 2008; Matijević-Sokol, 2008; Wiesner-Hanks, 2013). The printing of books led to an increase in literacy and further development of institutions of education, including universities that taught new areas of study such as science and medicine (Wiesner-Hanks, 2013). Printing and an increase in literacy aided in the spread and development of the Protestant and Catholic Reformations (Wiesner-Hanks, 2013). The Protestant reformation took strong root in neighboring Slovenia, but in Croatia it only appeared in fringe areas and was crushed by the Counter-Reformation in the early 17th Century (Goldstein, 1999b). The Jesuits played an important role in this Counter-Reformation. When they arrived in Croatia in the mid-16th century they took over education, including grammar schools and universities (Goldstein, 1999b). At the beginning of the 17th century, the *sabor* (like a governor) allowed the banishment of Protestants, and the Catholic faith was proclaimed the only permitted religion, in contrast to the tolerance toward different religions in Ottoman territories (Goldstein, 1999b).

The 16th and 17th centuries in Croatia are characterized by stagnation in cultural development. Trade between Eastern Adriatic and Continental Croatia was disrupted during the peak of Ottoman control; established trade routes were abandoned, many towns lost their autonomy to local nobles, and money depreciated (Šlaus, 2002). The great artistic developments of the 15th century in Dalmatia were stifled by the growing political and economic crisis.

Croatian artists, architects, and sculptors accomplished their greatest achievements in other European countries, having fled the endangered and poverty stricken Dalmatian cities (Goldstein, 1999b). By the 16th century, Venetian Dalmatia was already peripheral to Western Europe, but by the 17th and 18th centuries Dalmatia was "squeezed between Venice and the Ottoman empire, which resulted in economic slowdown, and its loss of the necessary hinterland in the Croatian interior" (Goldstein, 1999b: 42). 18th century Habsburg rulers encouraged economic development by abolishing internal customs, proclaiming free navigation along the Adriatic (1717), abolishing serfdom and introducing general taxation (Goldstein, 1999b). Venetian domination of the Adriatic was over.

Industrialization was developing in Western Europe by 1600 (Wiesner-Hanks, 2013). Textile production – followed closely by mining – was one of the first types of production in Europe to be integrated into a capitalist system of manufacture (Wiesner-Hanks, 2013). In Croatia, early attempts at industrialization were established first among the textile industry, followed by leather and silk factories and later a sugar refinery in Rijeka from 1751-1828 (Goldstein, 1999b). However, despite these early attempts, industrialization in Croatia was largely unsuccessful. The Habsburg government favored development of the central parts of the empire (Goldstein, 1999b; Wiesner-Hanks, 2013). Furthermore, Croatia was crippled by higher customs taxation, owners and the most skilled workers were foreigners, and the Hungarian-estates system was also an impediment (Goldstein, 1999b). This patriarchal community was reluctant to renounce its privileges and resisted change and innovation (Goldstein, 1999b). Serfs suffered the most from crushing obligations of rent and taxes to the Croatian nobility and they attempted several uprisings that were brutally suppressed (Šlaus, 2002).

Between 1730 and 1755 the frontiersmen occupying the once militarized zone led seven revolts that were suppressed by the nobility but resulted in the governmental intervention between lords and serfs (Goldstein, 1999b). Private arrangements between lords and serfs were replaced by communal regulations that abolished the worst forms of feudal exploitation and established minimum holdings for serfs and maximum demands of the lords (Goldstein, 1999b). While many Croatian scholars, writers, artists and scientists continued to reside abroad, the enlightenment did impact Croatia in the form of authors who championed progress against backwardness, suppression, prejudice and bad Ottoman habits (Goldstein, 1999b).

The health of populations from continental Croatia during the Early Modern period, surprisingly showed a decline in nutritional stress levels as indicated by enamel hypoplasias and cribra orbitalia (Šlaus, 2002; Šlaus, et al. 2018). Sex differences are present in dental pathology frequencies, vertebral osteoarthritis, and Schmorl's node depressions, possibly reflecting differences in resource access and differential activity patterns, which may be related to differences in social status (Šlaus, 2000). This period is also witness to the first recorded osteological case of venereal syphilis in Croatia (Šlaus and Novak, 2007). Comparisons between Continental and Adriatic sites have identified greater physiological stress and growth disruption in Continental sites than in sites on the Adriatic (Novak, et al. 2007; Pinhasi, et al. 2013).

Summary of the Early Modern period

Throughout the entire Early Modern period in Croatia, and with roots in the end of the Late Medieval period, Croatia was a true periphery to the developing nation-states of Atlantic and Northern Europe as well as to the Ottoman Empire (Goldstein, 1999b; Moačanin, 2008). Western European powers, primarily the Austrian Habsburgs and Venetians, used Croatian

territories as a buffer between themselves and the Ottomans. The Ottomans consumed more and more territory to feed the growing empire. The Habsburg, Venetian, and Ottoman powers exploited as much product from the Croatian territories as possible including agricultural products, people, primary and secondary livestock products, wood, minerals, and money; providing little in return and leaving local governments (on both sides) to essentially fend for themselves. The primary historical narrative of this period in Croatia follows the big men and big events. Little is known historically regarding the everyday experiences of people outside the noble castes, and this is one area in which archaeology and bioarchaeology can make significant advances in our understanding. Although Croatia may have lagged behind due to political and economic crises it experienced many of the same advances and developments as western and central Europe. Croatia may have even passed some things on to western and central Europe from the Ottomans, possibly including a relaxation of religious intolerance, as trade and economics rather than ideology spread as the primary political factor linking nation states.

Summary of Croatian historic overview

Croatia's geopolitical location made it critically important for the maintenance of political, social and economic control across Europe, especially during the Ottoman Empire's expansion (ca. 1299-1683) into Southeastern Europe. From A.D. 1490-1593, the Ottomans engaged in a systematic conquest of Croatia. Following the Ottoman victory at the Battle of Mohács (Hungary) in 1526, the Ottomans conducted unimpeded invasions and raids into Croatia, which led not only to an increase in social conflict but also to depopulation and a decline in economic activity (Kurelac, 2008). Within the context of prolonged war with the Ottoman Empire, historical documentary evidence suggests a considerable amount of change in

population composition. In addition, there were frequent changes in political borders resulting from a complex series of migrations, wars, plagues, famines, religious reformations and impressive urban population growth during the Late Medieval (11^{th}-15^{th} centuries) and Early Modern (15^{th}-18^{th} centuries) periods in Croatia and throughout Europe (Goldstein, 1999b).

The changing geopolitical environment of the 15th to 17th centuries caused dramatic changes in the population of the central Dalmatian region (Chapman, 1996; Curta, 2006; Fine, 1991, 1994; Goldstein, 1999b; Raukar, 2008; Tanner, 2001). Raiding parties often carried off thousands of local inhabitants to be enslaved as soldiers or laborers for the empire (Goffman, 2002; Mijatović and Čavar, 2000; Raukar, 2008). Between several hundred thousand and one million people were taken prisoner and enslaved (Kurelac, 2008). Many more people emigrated in fear and panic from the areas of most intense conflict to find new homes in Austria, Hungary, Italy, Southern Dalmatia, Istria, and Central Croatia (Chapman, 1996; Kurelac, 2008; Raukar, 2008; Tanner, 2001). The resulting depopulation of entire regions led to economic stagnation. Depopulation due to out-migration, warfare, famine and disease would have reduced the size of the population gene pool, leading to changes in genotype frequencies due to genetic drift.

According to documentary sources, the Ottoman administrative system of sürgün quickly resettled uncultivated and depopulated lands with Christians from the interior, usually Orthodox Vlachs or Serbs (Fine, 1994;Goffman, 2002; Goldstein, 1999b; Kurelac, 2008; Raukar, 2008). These Ottoman policies of systematic emigration could have introduced new disease vectors, further reducing population size and variation; as well as introducing new genotypes, increasing variation. By the end of the 16th century, Croatia was mostly in ruins, its population had been decimated by endemic warfare, enslavement and migrations; politically it was controlled by three states: the Ottoman Empire, the Habsburg Empire, and the Republic of Venice. These

depopulation and resettlement events could have dramatically changed the phenotypic expression of genetic traits within a relatively short period of time. However, changes to the population composition have not been well studied using archaeological or bioarchaeological methods nor has the manner in which the population changed been systematically analyzed.

Summary of Croatian medieval archaeology

Archaeologically, population change is often studied using material culture from burial contexts, where the artifacts are physically associated with an individual. Most archaeological investigations of population change in Croatia have focused on the material culture change associated with the Late Antique to Early Medieval transition, known as the Great Migration Period (approximately A.D. 300-700) throughout Europe (Curta 2010a, 2010b, 2010c; Curta and Kovalev, 2008; Dzino, 2009, 2014; Hines, et al. 1999). The examination of material culture change in Late Medieval and Early Modern contexts has been largely ignored due to a characteristic lack of burial goods among Christian, Jewish, and Muslim burials (Sokol, 2008). Overall, there have been very few Early Modern archaeological studies throughout southeastern Europe. The major exception is work done in Greece on landscape and material changes in non-burial contexts (Bintliff, 2007a, 2007b, 2008; Bintliff and Stöger 2009). Further, the investigation of population change and migration using material artifacts is complicated by the need to differentiate between down-the-line trade and actual movement of people (Wicker 2002).

Even given the paucity of reported material culture studies (in the English language) of the Medieval and Early Modern Dalmatian region, Sokol (2008) has written a broad overview of Croatian archaeological material objects of the Late Medieval period. Unless otherwise noted, the following information was obtained from Sokol (2008). Jewelry and coins are the most

frequent archaeological finds from cemetery contexts dating to the medieval period of Croatia. Filigreed three-bead earrings, known as "Slavonian earrings," are common among medieval female graves from the Adriatic to the river Sava in northern Croatia (Sokol, 2008:91). Slavonian earrings were most popular during the second half of the 14th century; by the first half of the 15th century they take on baroque shapes but begin to disappear from the archaeological record with the increase in instability of the Ottoman period (mid-15th to 16th centuries). Other types of medieval jewelry include rings, decorative pins, brooches, and belt buckles and are quite similar to those found throughout Western Europe during the Middle Ages. Goldsmithing artifacts, crucibles and dies, have been found in urban contexts, such as Zadar and Dubrovnik (Peković and Topić, 2011; Sokol, 2008). Ceramics were hand or wheel thrown and kiln fired, and ranged from utilitarian objects to elaborate stove tiles (much like the Hungarian type) (Carver and Klápště, 2011). Glass production was another prominent activity in Croatia; glass was commonly imported from Murano and Venice, but Croatian-produced glass was equally common.

Large monolithic stone blocks, called *stećak* (pl. *stećci*), which covered burials outside churches are unique to the Dalmatian coastal region and its hinterlands during the Late Medieval period (Sokol, 2008; Šunjić, 2009). These stećak are no longer used during the Ottoman period (Sokol, 2008:101), and parts of them are sometimes re-used in Ottoman period burials to form the walls of the grave (Gjurašin, 2005).

The crusades passed through Croatia during the 12th and 13th centuries accompanied by material objects such as Carolingian swords, crossbows, gunpowder and other military related material objects (Ágoston, 2014; Bilogrivić, 2009; Sokol, 2008). By the 16th century, cannons were commonly found among military items (Ágoston, 2014; Sokol, 2008).

Skeletal remains provide a link to understanding just how much populations can change

over time. However recent bioarchaeological investigations of Ottoman period skeletal samples from Croatia have focused solely on the examination of the effects of endemic warfare on population health (Novak, 2011; Novak and Šlaus, 2012; Novak, et al. 2007; Šlaus and Novak, 2007; Šlaus, et al. 2010). To date, there have only been five biodistance studies using metric data from skeletal samples within Croatia (Kopp, 2002; Ross, 2000, 2004; Šlaus, 1993; Šlaus, 2002; Šlaus, et al. 2004) (see previous chapter for details on these studies).

CHAPTER IV

MIGRATION AND WARFARE

Migration is a complicated human behavior. Migration studies often deconstruct the various factors that play a role in decisions of whether or not to move, where to move, how to get there, who should go, and when to go. It has been recognized that multiple factors are often working synergistically to cause migration. Researchers have focused on the examination of migration as a process with identifiable, although highly contextualized components that not only signal when migration has occurred in the past, but also how it proceeds (Anthony, 1990, 1992, 1997; Burmeister, 2000). At times, archaeologists have abandoned migration theory as a hopelessly inexplicable behavior (Renfrew, 1982), as something that could not be properly understood and therefore had little interpretive value in archaeology (Adams, et al. 1978). Some have continued to pursue migration as a worthy subject of study, particularly cultural anthropologists, linguists, sociologists and cultural geographers. Biological anthropologists never fully abandoned migration theory as an explanation for human biological variation, but they did shy away from the use of biological distance analyses due to their foundations in racial typology.

Eventually, archaeology came back to migration theory following arguments for its utility and the need for further development as an explanatory model for cultural change as laid out in Anthony (1990). Following Anthony's call for the reexamination of migration and continuity models, many archaeologists remained either unwilling or uninterested in engaging migration as an area of study (Chapman and Dolukhanov, 1992), until the advent of direct genetic assays for prehistoric skeletal remains (Konigsberg, 2006). After advances made in bioarchaeological

methods and the incorporation of genetic theory (Relethford and Lees, 1982; Relethford and Harpending, 1994), biological anthropologists increasingly began examining human variation in light of migration theory. The new biogeochemical and molecular (mtDNA, Y-chromosomal DNA, aDNA) methods helped to solidify migration as an explanation of not only the movement of people but also as an explanation of human biological variation (Bentley, 2001; Bentley, et al. 2002; Cann, et al. 1987; Cavalli-Sforza, et al.1996; Groves, et al. 2013; Haak, et al. 2005, 2008; Knudson, et al. 2004; Mathieson, et al. 2018; Mitchell and Millard, 2009; Oppenheimer, 2012; Perez, et al 2007; Price, et al. 2001; Price, et al. 2004; Relethford and Crawford, 2013; and others). Human remains provide direct evidence of the movement of people in the past. Furthermore, advances in theory, particularly the incorporation of evolutionary theory and cross-disciplinary approaches, aided in the return of migration theory. Not only could migration be directly identified from human skeletal remains and biogeochemical, morphological, and genetic analyses; but the effects of population movement and interaction on gene pools were also recognized, along with the antiquity of human movements. As Campbell and Crawford (2012:1) have stated, "an activity as deeply rooted and ubiquitous as migration must be imbedded in our human nature and genes." Migration is now increasingly recognized as a fundamental attribute of human behavior (Baker and Tsuda, 2015; Cabana and Clark, 2011b, Crawford and Campbell, 2012; Lucassen, et al. 2010; Manning, 2012) with implications for understanding culture change and interaction.

Many researchers have attempted to define migration. Very simply, migration is the movement of people from one place to another. However, there is no typical form of human migration and therefore this simplest and broadest of definitions is often insufficient. It is

perhaps better to begin by recognizing that there are different types of migration, each applicable to particular contexts and more or less useful for particular research questions.

The number of types of migration is often variable. Wells and Stock (2012) defined ten types of migration, while others have chosen to discuss migration types in broader categories. Commonly, the distance traveled serves to distinguish between migration types: either long-distance or short-distance migrations (Adams, et al. 1978; Caban and Clark, 2011a; Cameron, 1995; Duff, 1998; Rouse, 1986). Short-distance migrations, however, are difficult to identify using traditional archaeological and bioarchaeological evidence, due to the similar biology and culture of migrants and hosts at short distances from one another (Tsuda, et al. 2015). However, using aDNA accumulation of genetic variability in one subset of a population can be identified, for example when women always leave their natal villages to marry even if they do not move far – after hundreds of generations this mobility can be identified in mtDNA diversity (Arnold 2005). Migration types may also be categorized based upon the length of time spent away: long-term or short-term migrations (Adams, et al. 1978; Anthony, 1990; Beekman and Christensen, 2003; Bolnick, 2011; Burmeister, 2000; Chapman and Hamerow, 1997; Cabana and Clark, 2011a; Clark, 2001; Duff, 1998; Fix, 2011; Rouse, 1986). However, similar to the issues for short-distance migrations, temporary migrations are also difficult to identify archaeologically or bioarchaeolgically. Due to their ephemeral nature, there is less opportunity for identifiable changes, archaeologically or biologically, to accumulate within the host or migrant populations. Migration types also have been divided according to their primary influences: economic, environmental/ecological, socio-political, or biological. These influences have been alternatively considered as push or pull factors affecting the decision to migrate, causes or consequences of migrations, as both mechanisms and primary agents of change, as affecting direction or pathway

of migration, migration as a selective factor, or as disruptions related to migrations (Anthony, 1990; Burmeister, 2000; O'Rourke, 2012; Campbell and Crawford, 2012; Baker and Tsuda, 2015).

Economic models of migration are often strongly associated with behavioral ecology and world systems theory (Upham, 1982; Trigger, 1984; Kohl, 1987; O'Rourke, 2012; Rouse, 1986). Individuals play a stronger role, and individual decisions about when and where to move are linked to economic efficiencies that enhance individual fitness (O'Rourke, 2012). Conceptually an economic model explains inequalities in the economic success of individuals or groups as leading to the migration of poorer individuals to richer areas, and for the exploitation of resource rich areas by outside groups (Beekman, 2015; Castles and Miller, 2003; Cornelius, 1998; Martin, et al. 2006; Massey, et al. 1993; Tsuda, 1999b, 2007). Economic models tend to focus on the development, expansion and spread of material culture (Childe, 1950; Johnson, 1977; Schortman and Urban, 1987).

Ecological models of migration are often associated with environmental determinism. In ecological models, the environment dictates whether people stay or go (Ahlstrom, et al 1995; Beekman, 2015; Cabana, et al. 2008; Cameron, 1995; Clark, 2001; D'Andrea, et al. 2011; Palkovich, 1996; Storey, et al. 2002). When the environment is rich in resources and stable, there is little push to move, however once the environment is destabilized the push to move is greater. Environmental change is usually slow and therefore allows humans time to adapt and respond to environmental changes (Tsuda and Baker, 2015; Unruh, et al. 2004). Once changes to the environment begin to cause economic stress, environmental factors will provide an impetus for migration, although this is usually secondary to the economic factors (Afifi 2011; Bardsley and Hugo 2010; Dun 2011; Hugo 1996; Kolmannskog 2009). However, in cases of natural

catastrophe, where drastic changes occur over a short period of time, environmental factors may provide a primary modus for migration (Black et al. 2011; Castles 2006; Lonergan 1998; Renaud et al. 2011).

Socio-political models of migration are often centered on conflict within or between groups. Often conflict is in the form of warfare and violence, but could also be in the form of ethnocentrisms, religious persecution, racism, or any context where one subgroup exerts their dominance over another (Bernardini, 1998; Chapman and Hamerow, 1997; Clark, 2001; Cowgill, 2015; Fowler, 2011; Hamerow, 1997; Storey, et al. 2002). Socio-political conflicts are an important source of migrations today, as in antiquity. Socio-political models of migrants tend to have clear motives for migration, as well as clear consequences. During times of violent conflict, refugee migrants flee to escape persecution, instability, wars, and other struggles (Black, et al. 2011), and violent conflicts commonly also affect economic and socio-cultural factors that help to shape the response to conflict and migration (Ager, 1999; Lubkemann, 2008a, 2008b; Lucassen, et al. 2010).

Biological models of migration are often associated with evolutionary theory. They focus on the biological consequences and signatures of migration, as well as tracing the origin and spread of migrations. Biological models tend to stress "genes as one of the most important markers of migration that can be used to link patterns of the past with those of the present" (Campbell and Crawford, 2012:2). Biological models typically explain human success at migrating and populating new areas as the result of our biological plasticity, generalized biology and generic adaptations (Wells and Stock, 2012). As a species, humans are characterized by a high degree of genetic unity and a large amount of non-adaptive or neutral selection (Wells and

Stock, 2012). Repeated and regular migration has shaped our biology and phenotypic variation is indicative of our history of bottlenecks and population rebounds.

Migration and disruption

Among the recent models available for the investigation of migration, the framework in Tsuda and colleagues (2015) which discussed the dual impact of disruptions and migration is most appropriate for the examination of warfare as a disruptive factor causing migration in the Late Medieval period of Croatia. In the Tsuda and colleagues model, disruptions can be both a cause and a consequence of migration, and vice versa. They recognize that migration in the past can often be attributed "to upheavals resulting from natural perturbations or political, economic, or religious change" (Tsuda, et al. 2015:16), which are all historically identified in Late Medieval Croatia. This framework was developed for use in the study of migratory distributions in specific societies at specific times (Tsuda, et al. 2015:16). The authors recognize that their model may not be applicable to every migratory situation, but they argue that "vast generalizations…are always suspect" (Tsuda, et al. 2015:16). As a cross-disciplinary group of archaeologists, linguists, cultural anthropologists and biological anthropologists, the authors defined and agreed upon a set of unifying concepts that could be applied to investigations of both modern and ancient migration, using disruption as a framework.

Disruptions

Tsuda and colleagues (2015:17) define disruptions, "as substantial interruptions that disturb the accustomed activities of a society and have a significant structural impact from the macro level of civilizations, nations, and cities to the meso-level of ethnic groups/tribes,

institutions, and families." The rate and scale of disruptions can be variable and applicable to both the sending and receiving societies. Disturbances can be positive or negative, and are distinguished from disasters, which are extreme and severe events.

Tsuda and colleagues (2015) identify two broad types of disruptions: environmental and social. Environmental disruptions affect the habitat and availability of natural resources and can be the result of natural processes or human activity. Social disruptions include economic systems and subsistence strategies, political systems, social structures, and cultural systems. Additionally, environmental and social disruptions are recognized as interconnected. For example, warfare, a type of social disruption, can often create detrimental impacts to the environment, and environmental impacts can often impact subsistence and ultimately lead to conflict over resources. Additionally, dramatic changes to population size or structure, or disruptions that affect mental health may be related to both environmental as well as social circumstances.

Disruptions are also socially relative (Tsuda, et al. 2015:18). The group or population's resilience and ability to cope with disruptions are a key factor in whether a group migrates. Environmental or social disturbances may be very disruptive to more vulnerable groups or populations, causing them to migrate. However, the same disturbance among more resilient groups will not lead to migration. Tsuda and colleagues (2015:24) define resilience as "the ability to withstand and recover from a disruption by returning to a state of stable equilibrium." Typically the more severe or extreme the change (either in intensity, scale, duration etc.) the more clearly and objectively it can be identified as a disruption. Warfare, as internal social/ethnic conflict or as state-level conflicts, political collapse, disease, high mortality, population loss from death or movement, and economic collapse are all easily recognized as causing significant

disruption to the "accustomed activities of a society and have a significant impact" (Tsuda et al 2015:17).

In the context of the present study, the primary disruptive factor is the approximately two hundred years of Ottoman conflict with Hungary and Croatia in the central and Pannonian regions of Croatia and with Venice in the Adriatic regions of Croatia. After the fall of Bosnia to the Turks in 1463, Turkish raiding parties began regularly penetrating into Croatia. Each raiding party returned with large numbers of captives, sometimes numbering into the thousands (Fine, 1994:590). In 1493, the Croats were defeated at the battle of Krbava Field. Subsequently, the Ottoman incursions into Croatia increased, as did the number of smaller raids for plunder from the Muslim inhabitants of Bosnia (Fine, 1994). The end of the Croatian-Ottoman war is typically identified as the defeat of the Ottomans at the Battle of Sisak in 1593 (Goldstein, 1999b). However, this event only established the Hapsburg military frontier and the end of the Ottoman Empire's acquisition of Croatian territories; it did not result in pushing the Ottomans or the borders back, and raiding continued (Goldstein, 1999b). Historically, the Ottoman wars are known to have affected population size, resource exploitation by the Ottomans, including both material resources as well as human resources, changes to political heads of state, as well as loss of territories (Goffman, 2002; Goldstein, 1999b; Fine, 1994; Tanner, 2001). Ultimately, this led to the out-migration of Croats from the immediately affected areas. Once the Ottomans had gained control of an area they would institute sürgün policies, which via coercion resulted in the migration of orthodox Vlachs and Serb pastoralist from deep in the interior of the Ottoman held territories to the vacated frontier-zones. Sürgün policies were enforced in an effort to make uncultivated and abandoned lands profitable once again.

Migrations

Tsuda and colleagues (2015:19) define migration as "the movement of people across significant sociocultural, political, or environmental boundaries that involves uprooting and long-term relocation." Some may find their definition too restrictive because it does not include internal/localized movements within a boundary: for example, moving from one urban area to another urban area within the same state or province. Tsuda and colleagues' definition also does not include cyclical movements, seasonal, or temporary movements. Tsuda and colleagues (2015:19) argue that methodologically, archaeologists relying on the material and skeletal record "can generally only detect major, long-term population movements over significant boundaries that create significant change in a region's material culture or settlement patterns (Clark, 2001:6) or affect a population's skeletal morphology or genetic composition (Bolnick, 2011)." Short-term or localized migrations therefore are hard if not impossible to identify archaeologically, and are often of limited concern to modern migration scholars (Tsuda, et al. 2015:20).

In the context of the current study, there are two historically attested migration events. The first is out-migration of Croats in response to the Ottoman incursions and raids. The Croats fled initially to larger urban centers and from there to other cities or nations. The second is the coerced migration of mainly orthodox Vlachs and Serbs under the Ottoman sürgün policies to repopulate and work previously abandoned areas recently taken under Ottoman control (Goffman, 2002). There is a third form of population movement occurring at this time period as well: captives taken from raids and young boys taken to fulfill devşirme levy obligations. Ultimately these captives and boys would serve as slaves to the Ottoman Empire. In this context, the remaining Croatian population can be viewed as both a sending and a receiving population of migrants.

Boundaries and borders

Boundaries separate environmental, cultural, linguistic, economic, or political areas and generally permit flexible movement across them (Tsuda, et al. 2015). A border is a political boundary separating polities, nation-states, and empires that are generally less fluid as states tend to try and prevent crossing of their territorial borders. Tsuda and colleagues' definition of migration requires migrants to move across significant boundaries. They argue that migrations that do not cross a political border can still be migrations if they cross a significant ecological, economic or social boundary, for example rural to urban migrations (Tsuda, et al. 2015:20).

In the context of Ottoman period in Croatia, multiple boundaries can be identified. The most significant boundaries involved are political borders. During this time period, not only are political borders being regularly violated by armies from both sides of the conflict, as they advanced and retreated; but the border locations are often changing in response to the outcomes of major battles. In addition, when the political borders changed, there was not always a commensurate change in the environmental or social boundaries. In the central Dalmatian region of Croatia, the political border between Venetian controlled and Ottoman controlled territories resulted in a rivalry between these two states for control of the "floating population on the borders" (Bracewell, 1996:330). The floating population consisted mainly of Vlach pastoralists practicing a transhumant stock-herding subsistence, as well as agriculturalists whose familial lands were divided by the political borders. To cope with bans prohibiting people from working land on the other side of the border, some people allegedly settled half their family on either side of the border (Bracewell, 1996:330, citing Stanojević, 1987:9-10). In addition to political boundaries, the Dinaric mountain range, Pannonian plain and eastern Adriatic archipelago are all ecological boundaries that are being crossed regularly by both armies and fleeing citizens.

Types of migrants

The impact of migration on sending and receiving populations is dependent upon the type of migrants involved. Tsuda and colleagues (2015) have proposed five types of migrants: conquerors, colonizers, elite migrants, commoner migrants, and refugee migrants. Conquerors are "migrants who intend to seize power politically/culturally/socially and dominate the host society" (Tsuda, et al. 2015:21). Colonizers are defined as "migrants who remain for the long term, if not permanently, but do not intend to seize power" (Tsuda, et al. 2015:21). Tsuda and colleagues' definition of colonizers is narrow in comparison to other settler colonialism definitions, in that it separates the exercising of political dominion from building settler colonies (Veracini 2013:314). However, in the context of the present study, the Tsuda and colleague definition will suffice because the balance of power between remaining Croat populations and incoming Vlach migrants would have been relatively equal. Elite migrants are "those who are from the political ruling class and/or are economically well-off (including those called high-skilled/professional migrants in the modern migration literature)" (Tsuda, et al. 2015:21). Commoner migrants are "those who seek better economic opportunities and livelihoods elsewhere (currently called unskilled migrants or economic migrants)" (Tsuda, et al. 2015:21). Finally, refugee migrants are "those who, under duress, flee ethnopolitical conflict or persecution or environmental disaster" (Tsuda, et al. 2015:21). Some types of migrants are more disruptive than others. For example, invaders and conquerors, even with small numbers, are more disruptive than labor migrants, since conquerors seek to seize political power through warfare and violence as well as impose their customs on the host population and they seek to establish their control quickly (Tsuda and Baker, 2015).

There are three primary migrant types in the present study. Conqueror migrants would include the Turkish-ruling elite and military soldiers. Vlach and Serbian migrants, forced to relocate due to Ottoman sürgün policies, and settled in the lands vacated by Croatian subjects could be considered colonizers. Additionally they could also be considered commoner migrants because the Vlach and Serbian migrants were pastoralists and those that were not forcibly moved to the area came for the chance at landownership (Bracewell, 1996). Croatian subjects living in or near an active military zone who fled to safer Venetian, Hungarian or Austrian territories and other neighboring regions would be considered refugee migrants. There is one more type of migrant in the Ottoman context, that does not quite fit into any of the categories defined by Tsuda and colleagues (2015), and that is the large number of captives as well as the young men and boys taken in devşirme levies to serve the Ottoman empire. Whether taken from raids or from devşirme levies, these people were removed from Balkan households and sent to serve as slaves to the empire and constitute a historically and culturally specific class of migrants.

Disruptions and the causes of migration

While not all migrations result from a singular type of disruption, it is clear one way human populations cope with disruptions is through migration. The severity of the disruption and the resilience of the population to withstand it determine whether out-migration will occur (Tsuda, et al. 2015:22). The importance of any given disruption in the decision to migrate must then also be considered alongside other forces that influence migratory patterns, including pull factors (Tsuda, et al. 2015). Variables affecting the magnitude or severity of a disruption include size and scale, duration, and frequency (Tsuda, et al. 2015). Size and scale refer to the number of people affected and/or the extent of damage. Duration refers to how long the disruption lasts,

while frequency is how often the disruption occurs. Additionally, a population's resilience or vulnerability to a disruption also contributes to whether or not a specific disruption will result in out-migration. Finally there are other factors that can encourage or discourage people to migrate, such as ease of transportation, permission, costs, kin/social connections at destination, safety etc. Ultimately, the relationship between disruption and migration is not as simple as cause and effect; rather it is usually more complex.

Beyond the disruption of warfare causing socio-political out-migration, multiple other factors can be seen to contribute to the decision to migrate. The number of people affected by the Ottoman raids typically numbered in the hundreds to thousands. One example from Venetian records in 1499 illustrates the significant effect of raiding parties on local communities, "Zadar officials reported that Skeder-paša of Bosnia had carried off 37,987 head of large and small livestock, and that the district had lost 674 men and 1,314 women and children" (Bracewell, 1996:312). For coastal cities, like Zadar, and their rural hinterlands, losing almost 2000 people in a single raid would drastically affect not only the size of the surviving population but would also contribute to economic decline. The loss of livestock would have affected the available food resources leading to famine. The loss of human capital would have also contributed to poor agricultural yields and famine if no imports could be obtained from Ottoman territories or Venice. There were notable famines in 1500, 1525, 1559, 1570, 1596 among other episodes (Bracewell, 1996:313). Epidemics, usually of the plague, also contributed to a decline in the population. Outbreaks are known from 1500, 1525, 1530, 1619, 1631, and 1636 (Bracewell, 1996:312). In addition to the disruption caused by warfare, captivity, death, out-migration, frequent famine and outbreaks of plague, and stress to mental health would have reduced the population's resiliency and increase the vulnerability, providing additive incentives to migrate.

In addition to the primary conflicts with the Kingdoms of Hungary and Croatia, the Ottomans also engaged in six separate wars with Venice from 1409-1797 (Bracewell, 1996). The approximately two centuries of conflict experienced by Croats living in Dalmatia and other parts of Croatia had drastic effects. Not only was there a decline in the population, but there were also changes to the administrative systems, economies and social structures during this extended period. In the mid-16th century, Venice began to push the Ottomans out of the Adriatic coastal region. Late in the 16th century Venice joined forces with Austria and by 1718 they had regained territory and established the frontier with the Ottomans at what is today the state border between Croatia and Bosnia-Hercegovina (Goldstein, 1999b). The Ottoman military strategy emphasized continual small debilitating raids, seizing captives and livestock, and pillaging the countryside, before the armies were brought in to besiege towns (Bracewell, 1996). Although the entire conflict period spans a period of approximately 200 years, from the fall of Bosnia in 1463 until the early 1700s, warfare was not a permanent state; there were periods of intermittent peace. However, even during times of peace "the population was subject to smaller raids, for it was generally agreed on both sides that such actions were an everyday occurrence on the border, and that a peace was not broken until artillery was brought in to attack the towns" (Bracewell, 1996:312). It can therefore be assumed that these raiding conflicts equally affected populations in both Ottoman and Venetian held territories, in Dalmatia.

Barriers to migration also existed in medieval Croatia. Prior to the Ottoman incursions, the Croatian kingdom was a feudal society controlled by ruling-elite landlords (župans) and a rural serf labor class (Rauker, 1999). It is entirely possible, that serfs were restricted from leaving their lands or were forced to serve in their lords' militia in defense of the Croatian territories. Out-migration may only have been an option for certain portions of the population. Furthermore,

rural populations tend to be poorer and to have less opportunity to migrate (Tsuda and Baker, 2015). If they do migrate it is usually for shorter distances (Tsuda and Baker, 2015). Significant pull factors for rural Croat populations to migrate out of the region included safety from violence, as well as economic stability without needing to worry about raiders disrupting subsistence strategies.

Disruptions as consequences of migration

The sending, the migrant, and the receiving populations can all feel the consequences of migration. From the perspective of the receiving society, the influx of alien populations has the potential to overburden limited economic and environmental resources and cause sociopolitical and ethnic conflict and instability (Tsuda, et al. 2015:23). However, the influx of new people does not have to cause significant or long-term disruptions. The impact of migratory disruption is dependent upon its severity and the resilience of the host society (Tsuda, et al. 2015). The severity of migration disruptions is also dependent upon the size, scale, duration, frequency, and type of migrant involved. An influx of alien migrants is more disruptive if it is large, lasts longer and occurs more often. In addition, migrants are more likely to be disruptive if they are, or are perceived to be, different from the host society; if they speak different languages, have a different culture and ethnicity, religion, socioeconomic status, subsistence strategy etc. (Tsuda, et al. 2015). Immigrants that retain their differences and/or are unwilling or unable to assimilate into the host society are generally more disruptive.

Certain types of migrants are inherently more disruptive than others (e.g., conquerors, refugees, illegal migrants) (Tsuda, et al. 2015). Furthermore, the characteristics of the receiving society are also important to whether or not a disruption is caused by migration, especially their

resilience. Even when migration is initially disruptive, the long-term effects may not be disruptive. First, the effects of the initial migration may be reversible. Second, the initial disruptions may be incorporated into the activities of the host society, resulting in a return to equilibrium. As Tsuda and colleagues (2015:24) put it "a short-term disruption may lead to a nondisruptive, transformative structural change over time." When a host society is unable to return to equilibrium following a migration disruption, it may then be threatened by long-term disorder and decline (Tsuda, et al. 2015).

Croats, from the Dalmatian hinterlands, would have first migrated to larger urban centers and from there to other regions. Cities like Ancona, Italy, and "other towns on the western shore of the Adriatic would develop large colonies of Dalmatian refugees in this period" (Bracewell, 1996:312). Although the effects of Croat migration on their host societies is beyond the scope of this study, with its specific geographic focus in central Dalmatia, some of them, particularly Romantic humanist writers began championing the Croatian cause to world leaders such as the Pope Leo X, who referred to Croatia as *Antemurale Christianitatis* (Bulwark of Christianity) (Goldstein, 1999b).

The disruptions caused by the depopulation that resulted from out-migration can be identified. The slow demographic "recovery can be seen in frequent Venetian complaints of under population and administrative efforts to encourage further immigration" to the central Dalmatian region (Bracewell, 1996:310). The combination of warfare and out-migration hurt the adult male population most. Ottoman raiders targeted men for service as soldiers; in addition men were also being recruited into the Croat and Venetian armies (Bracewell, 1996). In addition, the consequences of the forced migration of Vlachs and Serbs into the central Dalmatian region by Ottoman sürgün policies can also be identified. Only through the combined efforts of the

Venetian and Ottoman immigration programs, did the decline in the population resulting from the early years of conflict (mostly the early 16th century) begin to rebound toward the end of the 17th century. The prolonged period of immigration from the Ottoman interior as well as return migration may have reduced the likelihood of in-migration to cause disruption, simply due to the need to occupy and work abandoned lands. Laborers in particular were highly desired by both the Ottoman and Venetian rulers.

The Vlachs were Orthodox Christians, while the Croats were primarily Roman Catholics, their common Christian based religions may have made it easier for Vlachs to assimilate into the rural Croat society, and for Croats to accept the Vlachs. Had the Vlachs been primarily Islamic, there might have been more conflict between the host society and migrants. Furthermore, the Vlachs were mobile stock-herding populations utilizing a transhumant subsistence strategy (Bracewell, 1996; Goldstein, 1999b), raising mostly sheep and goats, but also cattle and oxen. Although some appear to have abandoned their transhumant lifestyle, settling into a mixed economy of agriculture and stock herding in the Dalmatian lowlands, they may have contributed to the emphasis on stock herding in the lowland economies (Bracewell, 1996:328). The intensification of stock herding in the Dalmatian lowlands is also documented historically to have led to environmental degradation, including important grasslands (Bracewell, 1996:329, citing *Commissiones*, viii, 95).

Biological disruptions and migration

Based on the historical evidence, the disruption/migration model proposed by Tsuda and colleagues (2015) is useful when studying migration in the central Dalmatia region. What is not evident from the historic data, nor is it clearly discussed in the Tsuda and colleagues model, is

the impact that the disruptions of warfare and migration had on the biology of the population. Although biological factors can and have been incorporated into the disruption/migration model, it is helpful in the context of this study to examine the consequences of migration on human biology more explicitly. Campbell and Crawford (2012) recognized that social and cultural factors of migration are intertwined with our biology. In addition, Campbell and Crawford identified an underemphasized aspect of human migration: that migrants transfer not only new ideas, institutions, job skills, or goods, but also their own bodies, which "carry an imprint of their original surroundings" (Campbell and Crawford, 2012:1). The biological aspects (physiological, metabolic, physical health, demographics, and disease) of a sending, migrant, or receiving populations, can both contribute to the causes of migration as well as to the consequences of migration. Therefore, the biology and health of a population can be considered a disruptive factor resulting in or from the movement of people.

Physiological traits of a population are the result of genetics. Genetically, migrants may become imbedded in their host societies, and may increase genetic diversity of a population through gene flow. Migrants could also out-number the host population (i.e., colonization), and the migrants' genes could therefore overwhelm or even replace the host population's contribution. If not accepted or incorporated into the host society due to actual or perceived differences too great for either hosts or migrants to overcome, migrants could also remain genetically isolated from their hosts. These genetic changes to the populations involved can potentially be identified using skeletal biodistance analyses.

Metabolic disease stress is often reflected in the nutritional health of a population, and in turn can reflect both the social and environmental stress of a population. A sudden reduction or increase in population size resulting from the in-flow or out-flow of migrants can result in

famines, due to a reduction in labor forces and agricultural yields or an increased demand upon local resources. Thus, metabolic stress indicators, such as cribra orbitalia or porotic hyperostosis, could be used to identify disruptions to a population's health status, resulting in or from migration.

Physical health can also be used to identify changes resulting from or contributing to migrations. In particular, changes in osteoarthritis patterns and entheseal changes can be used to identify changes in subsistence strategy or even religious practices (Zakrzewski, 2011, 2015). Additionally, individuals with low physical health, such as the elderly, will be less capable of migration.

The demographics of populations disrupted by migration can be affected significantly, depending on the primary motivation or cause of the migration event. For example, populations with high densities may be under greater stress due to an imbalance between demands and resource availability, thus prompting some people to seek better circumstances elsewhere. However, migrant sources are not just from areas of high population density (O'Rourke, 2012). Age is another demographic factor that affects migration populations. The elderly are often less capable of migration due to physical and physiological stresses of the migration process and the reduced resiliency in the face of these stressors with increased age. Younger unattached individuals tend to be the most likely to migrate. Under certain circumstances, sex can also be a factor in migration. Young men tend to migrate first, and are later followed by women and children (Anthony, 1990, 1997). However, in circumstances where the male-female ratio has been disrupted (i.e., post-war), young unmarried females may need to migrate for personal, economic and social subsistence reasons, or to provide for families left behind. Regardless of the cause, the demographics of the sending, migrant and receiving populations can be disruptive

factors. Paleodemography can be utilized to study the disruption at the point of origin as well as at the point of migration.

Disease vectors are another area of biology carried by migrants from sending societies to host societies. During the Middle Ages, the establishment of quarantines, sanatoriums and leprosariums were all measures established to halt the spread of people and diseases; and together highlight the dramatic effects of population movements on the spread of disease. The study of paleopathology in past populations can be used to examine the role of slowly progressive infectious disease (such as treponemal disease, tuberculosis or leprosy), as a disruptive factor associated with migration.

Biology can be a significant disruption in the context of migration. The biological factors affecting migration discussed above primarily act to change the genetic balance of a population, via the introduction of new genes (gene flow), the reduction of populations (drift), and the introduction of infectious disease that the host society lacks physiological traits to cope with (natural selection).

Utility of the model

State-level warfare, can be a primary cause of migration. Not only is state-level warfare a disruption in itself, but also it has been documented to cause additional disruptive factors such as deterioration of the environment, and economic systems (Martines, 2013). Standing armies need to be fed, they need fires to keep warm, and so they often decimate local environments (Martines, 2013). War disrupts economic systems most by disrupting trade routes, subsistence activity and through depopulation and lack of laborers (Martines, 2013). Little to no research on migration has focused upon the rise of state-level societies and warfare, a fact recognized by

Tsuda and Baker (2015) as a limitation in their edited volume. Furthermore, few studies have focused on a single locality where both out-migration and in-migration are historically documented. In this study we can examine the consequences of Croats leaving as well as Vlachs arriving at the same locality. Therefore, we can observe migration from a locality viewpoint as well as from a population viewpoint.

The present study examines the impact of the Ottoman conflicts as a major disruptive factor in the biology of the population through migration, and tests the historically based assumption of a relatively quick and massive out-migration event, followed by a prolonged period of repopulation by Vlach immigration. Historic accounts paint a nearly complete loss of population in Dalmatia region, but it is unlikely that every Croat was capable of leaving or chose to leave, some would have stayed behind or even returned. Therefore, total replacement of the population by Vlach pastoralists is an untested assumption. Through the use of biodistance analysis, this study will explore the extent and nature of population change over time in the study area during a particular period of known disruption.

CHAPTER V

MATERIALS AND SITE CONTEXTS

The following chapter is divided into three sections. The first section provides information on the criteria for sites used in this study. The second section provides background details for each site included in this study. The final section summarizes the site samples.

Criteria for site selection

Materials for this project were selected based on their relative geographic proximity, sample size, temporal separation, and accessibility for research. In order to ensure environmental continuity, the sites needed to be located within the central Dalmatian region of Croatia and its hinterlands. The sites are all located within 75km of one another (Figure 5-1). In order to test hypotheses concerning a changing population over time, sites needed to be dated either solidly prior to the Ottoman expansion into Dalmatia (mid-15th century), or during the Ottoman administration of the Dalmatian hinterlands (1522-1688). In order to ensure a sufficient final sample size for the multivariate statistical comparisons, sample sizes needed to be close to 100 individuals for both the pre-Ottoman and Ottoman period samples. Sites were also selected based on their availability for research at the Croatian Academy of Sciences and Arts – Anthropology Center, in Zagreb, Croatia. Ultimately, three sites were selected from the Central Dalmatian region of Croatia: Šibenik-Sv. Lovre, Koprivno-Križ, and Drinovci-Greblje (Figure 5-1).

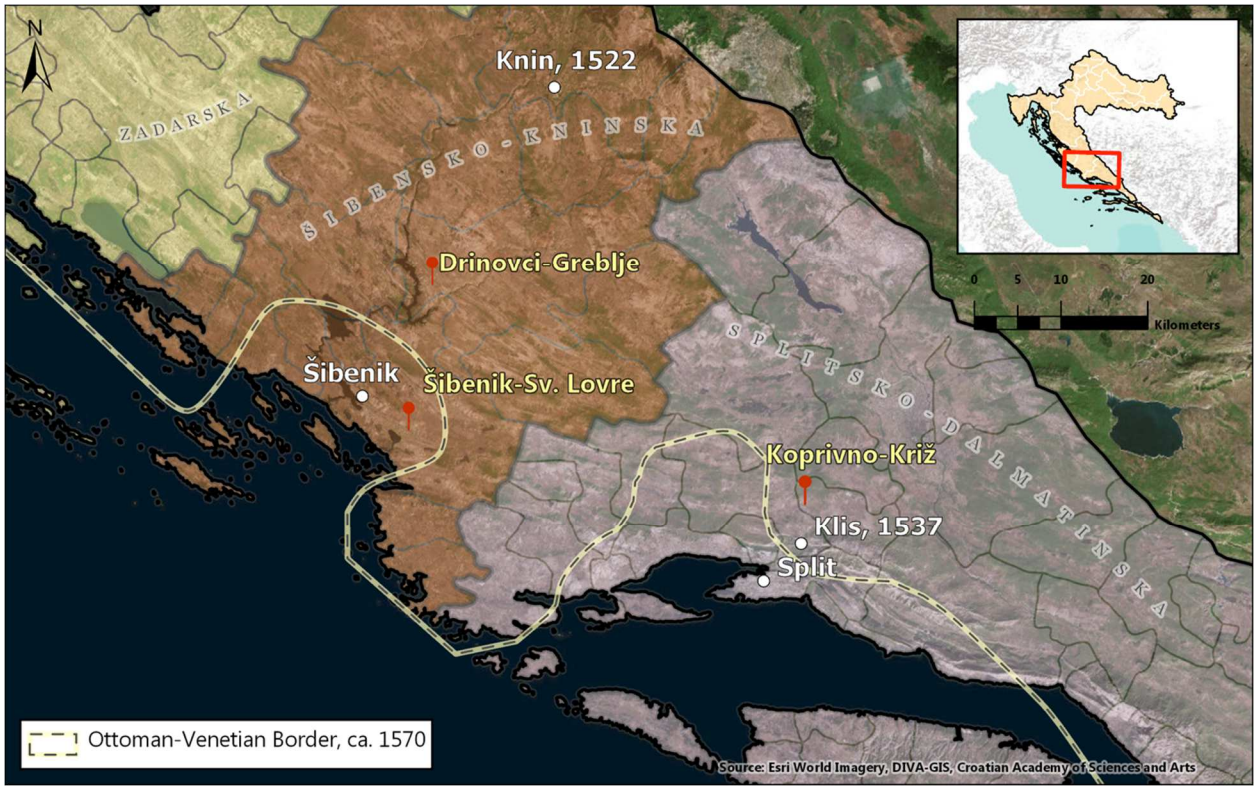

Figure 5 - 1: Regional map illustrating location of project sites, the Ottoman-Venetian political border around 1570, and locations of modern cities of Šibenik, Split, Klis, and Knin. Klis and Knin include the dates of Ottoman acquisition and occupation. The Ottoman-Venetian border is based-on a map by Magocsi (2002:14).

Site contexts

The following section provides relevant background information for each site included in the biodistance analyses.

Šibenik – Sv. Lovre

Šibenik-Sv. Lovre is an Early Medieval "Croat" site and was chosen as a temporally distinct pre-Ottoman conflict site. The site is located approximately 9 km east of the coastal city of Šibenik in central Dalmatia (Figure 5-2) (Krnčević, 1997; Šlaus, 2008). The Šibenik site is a rural necropolis for the church of St. Lawrence (Sv. Lovre). The Šibenik-Sv. Lovre site is a multicomponent site. The deepest/oldest layer dates to primarily to the 9th-11th centuries, with the

upper/younger layer burials dating to 12-15th centuries. In addition, but not included in this analysis, two ceramic urns with cremains were discovered below the lower layer burials that date to the 7th-8th centuries (Krnčević, 1995).

Figure 5 - 2: Site map of the Šibenik-Sv. Lovre site. The Church of St. Lawrence (Sv. Lovre) is still visible today. Insets identify location of Šibenik-Sv. Lovre site in the central Dalmatian region. Aerial photograph illustrates open excavated burials in the field north of the church. Burial map areal sourced from Petrinec (2009:86).

Excavation of the cemetery at Sv. Lovre began in 1935, and continued in 1977; but the skeletal material housed at the Anthropology Center was excavated between 1995 and 2000 by Željko Krnčević (Krnčević, 1995, 1997, 1999, 2000). Krnčević identified 101 graves north of the Church, but only 85 were systematically excavated. Tombs at the site were typical of the early Christian period in Croatia and were built using dry-stone construction with irregular stone slabs that served as the walls, base and cover. Three tombs were covered by stećak (monolithic stone

slabs) (Krnčević, 1997, 1999). Hands were usually placed along the body or folded on the pelvis. Grave inclusions from the site were rare but include silver rings, silver and bronze anklets, filigree earrings, several four-bead earrings, various other earrings, appliques shaped in the form of a four-leaf clover, a fish-gutting knife with handle worked in bone and a decorated bone case, and spolia (repurposed building stones) from stone church furniture. The jewelry mostly dates to the 9th-11th centuries with a few items from a younger layer dating to 12-15th c (Krnčević, 1995, 1997, 1999). Ninety individuals were recovered from the 85 excavated burials (n=90; 23 males, 32 females, 2 indeterminate adults, and 33 indeterminate subadults) that date to the pre-Ottoman period (Table 5-1).

Koprivno – Križ

Koprivno-Križ is a large multicomponent rural necropolis located in the village of Nazlić, at a place called *kod križa* ('by the cross'), near the village of Koprivno, northeast of the modern city of Klis (Gjurašin, 2005) (Figure 5-3). The village of Koprivno is approximately 32 miles (52km) as the crow flies from the village of Drinovci, and 34 miles (55km) from the modern city of Šibenik. The village of Koprivno was first mentioned in historic documents in 1371 (Gjurašin, 2005). After the fall of Bosnia to the Ottoman Turks in 1463, Turkish invasions and raiding into the area around Klis and Koprivno become a regular occurrence. By the end of the 15th century most of the rural poor have immigrated to coastal cities, most of which are under Venetian control; those who remained had to accept Turkish rule (Gjurašin, 2005). After the fall of Knin in 1522, and Klis in 1537, the Turks inhabited the village of Koprivno until the end of the 17th century (Gjurašin, 2005). The first to repopulate the village were Vlachs, while in the 17th century a Croat population from southwestern Bosnia and western Herzegovina moved into the

area around Koprivno (Kužić, 2001). The primary subsistence base of the population around Koprivno during Ottoman occupation was transhumant pastoralism combined with some agriculture (Jurin-Starčević, 2008; Sarić, 2008).

Figure 5 - 3: Koprivno site map illustrating relative locations of Phase I and Phase II site components, with burial map overlays. Burial maps sourced from Gjurašin (2005).

The Koprivno-Križ material was recovered in 2001 and 2002 during archaeological rescue excavations on a section of the Split-Zagreb high-speed motorway (Gjurašin, 2005). Excavations were conducted by the Conservation Department from Split and the Museum of Archaeological Monuments in Split, led by Dr. H. Gjurašin. Two distinct necropoli and a Bronze Age stone mound burial that was disturbed by the Late Medieval necropolis were uncovered (Gjurašin, 2005). The two necropoli are distinct temporally and spatially (Figure 5-3).

The Koprivno-Križ Phase I graves are located 70 meters west of the Phase II graves (Figure 5-4). Gjurašin (2005) named this necropolis "Koprivno – Groblje uz ogradu Jakova Nazlića" (Koprivno – Cemetery near Jakova Nazlic's fence). For simplicity and clarity, I refer to this necropolis as Koprivno-Križ Phase I.

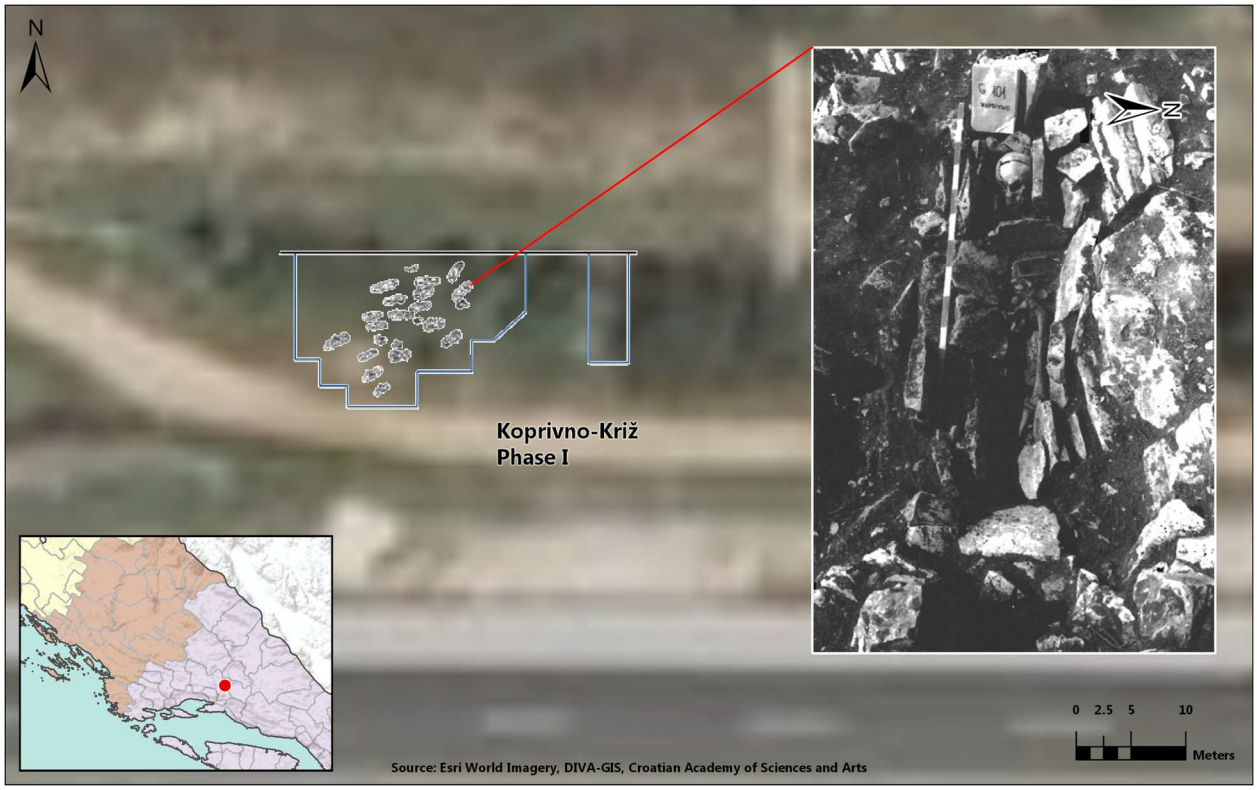

Figure 5 - 4: Koprivno-Križ Phase I burial map overlaying aerial map of the site illustrating location of burials along the Jakova Nazlić fence. Inlays illustrate location of Koprivno site in region, and Phase I burial 10. Burial map and photograph sourced from Gjurašin (2005).

A third of the Phase I graves are buried in soil, the rest are cut into the bedrock. All but four graves have stećak architecture, with stone slabs and amorphous rocks used to line and cover the grave. Only a few artifacts were recovered from female graves, including three-bead earrings, rings with coiled thickenings, and Veronese coins. Based on known evidence from the Verona town in which these coins were minted, Phase I can be dated from the end of the 13th to

the end of the 14th centuries (Gjurašin, 2005). Phase I is represented by 23 graves containing the remains of 28 individuals (n=28; 8 adult males, 2 adult probable males, 9 adult females, and 9 indeterminate subadults) that date to the Late Medieval period (13th-14th centuries) (Table 5-1).

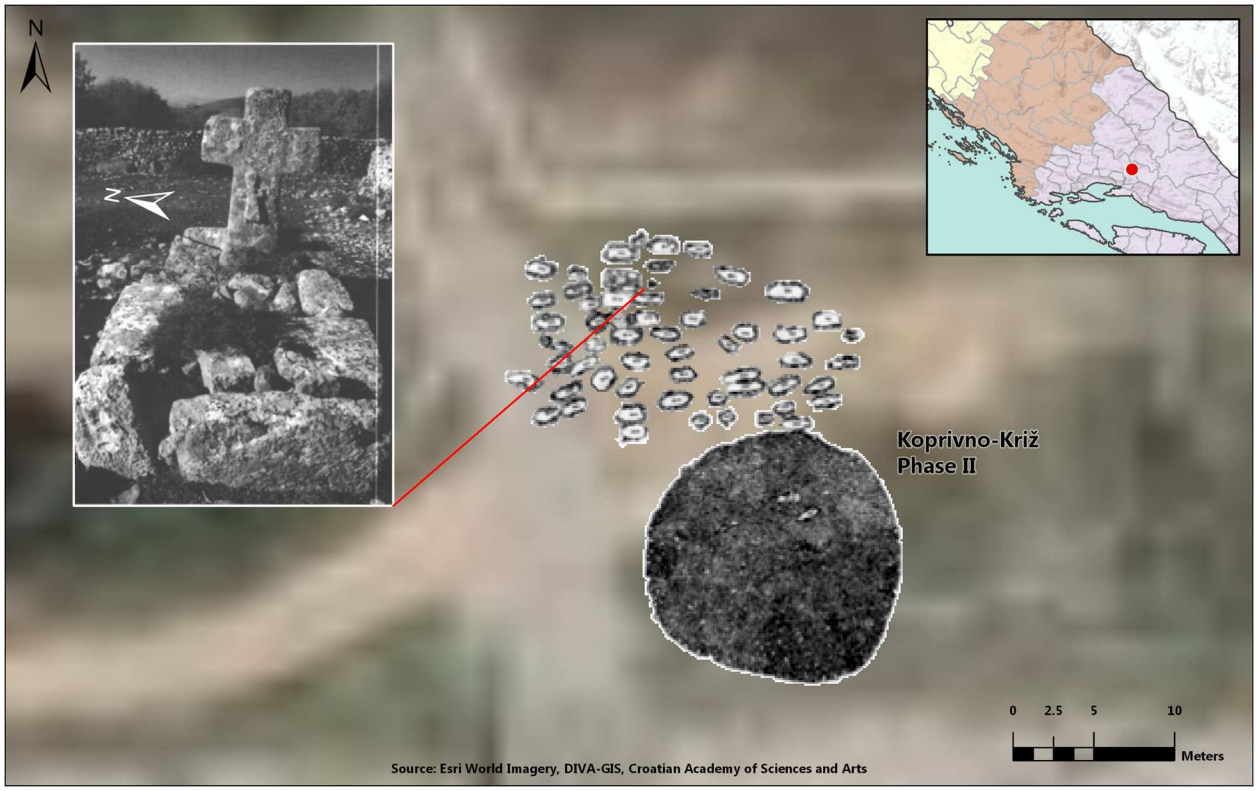

Figure 5 - 5: Koprivno-Križ Phase II burial map overlaying aerial map of the site. Illustrating location of burials as they spread SW toward the Bronze Age burial mound, and NE under the village path. Inlays illustrate location of Koprivno site in region, and the "Kod-Križa" tomb. Burial map and photograph sourced from Gjurašin (2005).

The Koprivno-Križ Phase II necropolis was designated "Koprivno kod križa," (Koprivno – By the Cross) by Gjurašin (2005) due to the visible tomb decorated with a crescent moon and stars motif on its western end, and a large upright stone cross with an anthropomorphic motif on its eastward face (Gjurašin, 2005:180, fig. 2 and 3). The Koprivno-Križ Phase II necropolis spread southeast from the cross tomb over a stone mound that contained a Bronze Age flexed

burial, and north and west under a village path (Gjurašin, 2005) (Figure 5-5).

Most often the graves were carved into the bedrock, then lined and covered with stone slabs or semi-finished stone. A dry-stone crown, oval or rectangular, marked most of the graves. Some graves had headstones. The most common grave goods recovered were iron needles (28 in total), clothing clasps (14 total), buttons (14 total) and 3 pairs of press-studs for clothing (Gjurašin, 2005). Also found were three pairs of shoe-sole guards and coins including six perforated coins of the Spanish King Carlos II (1665-1700) from a child's grave; five silver Turkish coins – the akche; and two Roman coins (Gjurašin, 2005). The Turkish coins were likely minted in Bosnia in the 16th century. Turkish silver coins, remains of wool clothing with buckles, and dry-stone crowned graves, along with historical sources, indicated to the excavator that Phase II of the cemetery could be attributed to the Vlachs, Turkish subjects who settled the deserted area of Dugopolje-Koprivno in the first half of the 16th century (Gjurašin, 2005). Phase II is represented by 97 graves containing the remains of 142 individuals (n=142; 25 adult males, 6 adult probable males, 25 adult females, 4 adult probable females, 2 indeterminate adults, and 80 indeterminate subadults) that date to the Ottoman period (late 15th – early 18th centuries) (Table 5-1).

Drinovci-Greblje

The *Drinovci-Greblje* site is a partially excavated rural cemetery from the Early Modern period (16-17th centuries) that is located approximately 12 miles (20 km) northeast of the city of Šibenik, in the village of Drinovci at a place called Greblje (Figure 5-6). The site was excavated in 2012 through the joint efforts of the Museum of Croatian Archaeological Monuments and the Archaeological Museum of Zagreb and was led by Mate Zekan and Dr. Željko Demo. Twenty-

five graves were exposed during the excavation, 22 of which were systematically excavated and contained the remains of 22 individuals (n=22; 10 adult males, 8 adult females, and 4 subadults).

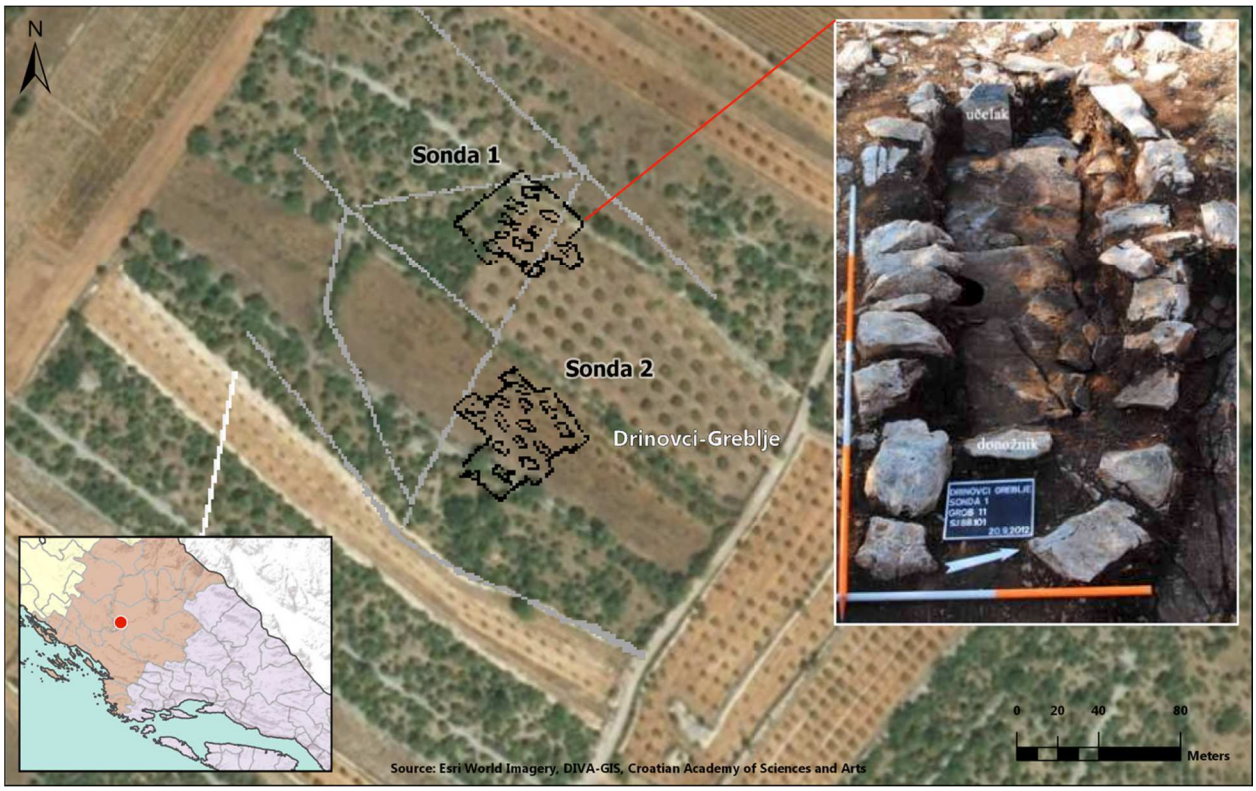

Figure 5 - 6: Drinovci-Greblje site location with burial map overlay. Inlays illustrate location of Drinovci-Greblje site in region, and grave 11 from the Sonda 1 excavation unit. Burial map and photograph sourced from Demo (2013).

According to Demo (2013), the few artifacts recovered included button pendants, hairpins, iron needles, a ring, and five halved silver coins. The excavated graves were carved into the bedrock, and then lined with large stone slabs, with the deceased placed in a supine position, unclothed or clothed in a simple shift and wrapped in cloth that was sewn prior to burial with an iron needle (Demo, 2013). Non-functional grave goods are rare but include a ring found behind the head of one older woman and a few coins used as obols (Demo, 2013). Five graves included a halved silver coin (Demo, 2013). Four of these five coins were precisely halved, very worn

akche (a silver Turkish coin of the 14-17th centuries) (Demo, 2013). The fifth coin was a halved silver Venetian coin minted in 1565 during the rule of the Venetian Doge Girolamo Priuli (1559-1567) (Demo, 2013). Therefore, 1565 is the *terminus post quem* of the burial and the surrounding burials and dates the excavated individuals to the second half of the 16th century. This is a period in which the Ottomans controlled the Drinovci area (1522-1688) (Demo, 2013).

Summary of materials

Drinovci-Greblje (n=22 individuals) and Koprivno-Križ phase II (n=142) are suspected migrant populations settled in Croatia by the Ottoman Turks (Demo, 2013; Gjurašin, 2005), and combined represent the Ottoman period (mid-15th to 17th centuries, n=164) (Table 1). Koprivno-Križ phase I (n=28), and Šibenik-Sv. Lovre (n=90) represent the pre-Ottoman period (9th to mid-15th centuries, n=118) (Table 1). It is noted that Drinovci-Greblje and Koprivno-Križ phase I both have small total sample sizes. Consequently these sites are included more for exploratory purposes when discussing differences between sites and are combined with the larger sites (Šibenik-Sv. Lovre and Koprivno-Križ Phase II) when discussing broader temporal differences. Table 5-1 contains the preliminary demographic profiles of the sites included in the analysis (prior to removal of individuals due to low trait observations).

Table 5 - 1: Preliminary demographic profiles by site name, prior to data reduction. Probable male and probable female individuals are included with the male and female counts.

	# Graves Excavated	Adult Male	Adult Female	Adult Indeterminate	Subadult Indeterminate	Total MNI
Šibenik – Sv. Lovre (9-11th c.)	85	23	32	2	33	90
Koprivno-Križ I (13-14th c.)	23	10	9	0	9	28
Koprivno-Križ II (15-18th c.)	97	31	29	2	80	142
Drinovci-Greblje (16-17th c.)	25	10	8	0	4	22
Totals	230	74	78	4	126	282

CHAPTER VI

METHODS

Four types of data are analyzed in this study: cranial metric, dental metric, cranial non-metric (morphological) and dental non-metric. Due to differences in the statistical treatment and preparation of these types of data, the chapter is divided into three sections. The first section outlines the procedures for data collection and database formatting. The second section outlines the procedures for data preparation. Finally, the third section outlines the primary statistical procedures.

Data collection and database formation

Accessory data

Permission for data collection was obtained from Dr. Mario Šlaus, director of the Anthropology Center of the Croatian Academy of Sciences and Arts. Features including the auricular surface (Lovejoy, et al. 1985), pubic symphysis (Brooks and Suchey, 1990, Todd, 1920), and cranial suture closure (Meindl and Lovejoy, 1985) were all considered, when available, to estimate adult age. Dental eruption and occlusion (Ubelaker, 1999), tooth development (Moorrees, et al. 1963), epiphyseal union (McKern and Stewart, 1957; Buikstra and Ubelaker, 1994), and diaphyseal length (Schaefer, et al. 2009), were considered, when available, to estimate subadult age. Age estimates were then grouped into broad age categories (see Table 6-5) for comparative purposes.

While important to most bioarchaeological analyses, age itself is not typically of concern

in biodistance studies. However, age can affect environmental changes to the phenotype. The age variable in this study was limited to its use as a control and for exploratory analysis investigating the impact of age on the metric and nonmetric observations. Of particular concern is the effect of dental wear and pathologies on the observation of both metric and non-metric analyses. Dental wear and dental pathology can have a significant effect on the recording and analysis of metric and nonmetric dental data (Hillson, 1996a). Dental pathologies such as wear and caries tend to increase with age, and are sometimes associated with sex (Hillson, 1996a). Dental pathology and wear data were recorded following the procedures outlined by Smith (1984) and Buikstra and Ubelaker (1994).

Teeth with moderate to heavy wear (Smith, 1984) were systematically excluded from the metric analysis following the criteria outlined by Jacobi (2000). MD crown diameter scores were only retained for incisors with wear stage 3 (of Smith 1984) or less for occlusal attrition. For the other tooth classes, the MD diameter was only retained if wear did not exceed Smith stage 4 (Smith 1984). Beyond these stages occlusal wear begins to affect the maximum MD and BL crown dimensions (Hillson, et al. 2005). Morphological data affected by wear was also removed depending upon the trait. For example, the anterior fovea of the first mandibular molar can be affected by a minimal amount of wear, but the groove pattern (Y, X or +) between cusps is less affected by wear. Since the effect of dental wear on the observation of dental non-metric traits is more variable, data collection followed the procedures outlined by Turner II and colleagues (1991) and Scott and Turner (1997) for when to not record data due to wear. During data collection, data were not recorded for dental non-metric traits, if dental pathology (i.e., caries) interfered with the trait observation (or measurement in the case of metric data).

Sex estimation was made following the pelvic and cranial sex estimation techniques

outlined by Buikstra and Ubelaker (1994). In addition, generalized robusticity and size differences along with some skeletal and dental metrics were noted when appropriate (Buikstra and Ubelaker, 1994; De Vito and Saunders, 1990; Hassett, 2011; Kieser, 1990; Koppe, et al. 2009; Schaefer, et al. 2009; Scheuer and Black, 2000). Sex estimates (as well as age estimates) had been previously recorded by Dr. Šlaus and colleagues. In cases of disagreement between Dr. Šlaus' estimates and those recorded for this study, the individual was re-examined by either Dr. Vlasta Vyroubal or Dr. Željka Bedić of the Anthropology center. Sex was of direct concern for testing Hypothesis 2 using both metric and nonmetric variables. While crown morphology has been shown to exhibit little sexual dimorphism (Turner II, et al. 1991; Scot and Turner II, 1997), considerable sexual dimorphism has been observed for dental and cranial metric variations (Howells, 1973, 1989, 1995; Garn, et al. 1967; Oxnard, 1987; Ross, 2004; Sciulli, 1990; Kieser, 1990). Most biodistance studies using metrics either separate the sexes or standardize the measurements. Both procedures are followed in this study; the measurements were first standardized (based on sex) for use in testing Hypothesis 1, while the male and female data were also analyzed separately for testing Hypothesis 2. For non-metric traits, the standard protocol is to test for correlations between sex and trait expression, and then remove variables that show a significant relationship; which was the procedure followed in this study.

Dental metrics

Maximum crown and cementum-enamel junction (CEJ) measurements were taken on all available teeth (including permanent and deciduous teeth) in both mesial-distal and buccal-lingual dimensions, for a total of 4 measurements per available tooth (Hanihara and Ishida, 2005; Hillson, et al. 2005; Jacobi, 2000; Kieser, 1990; Pilloud and Hillson, 2012). CEJ measurements

were included due to the potential effects of dental wear on archaeological samples. CEJ measurements are taken where the root and crown meet and are therefore minimally affected by dental wear.

Maximum crown diameters followed those described by Hillson and colleges (2005), which follow the descriptions of Tobias (1967). Hillson and colleges (2005:417) found these crown measurements "to be easiest to use in practice."

Maximum mesial-distal (MD) crown diameter was defined as the distance taken parallel to the occlusal plane from the most mesial to most distal points of the crown. These positions correspond to the contact points between the anterior teeth, but not necessarily so for the posterior (cheek teeth) (Hillson, et al. 2005). In the case of malalignment, the measurement was taken as if the tooth were in the normal position. If the tooth was chipped or showed interproximal wear affecting the normal morphology of the tooth crown, the measurement was taken slightly buccal or recorded as not available (NA).

Maximum buccal-lingual (BL) crown diameter was defined as the distance between the most buccal (labial) point of the crown and the most lingual point on the crown (Hillson, et al. 2005). On anterior teeth this is usually located near the cervical region. On maxillary molars this measurement is usually taken across the anterior molar cusps (paracone to protocone), as these two cusps are generally considered the most genetically stable (Jacobi, 2000). On the mandibular molars the BL measurement is usually taken across the distal molar cusps (hyoconid and entoconid) (Jacobi, 2000). The BL diameter is often not far off of perpendicular from the MD diameter (Hillson, et al. 2005). In the case of malalignment, the measurement was taken as if the tooth were in the normal position.

For all cervical diameters the caliper tips were placed on the enamel surface just occlusal to the cement-enamel junction (CEJ) (Hillson, et al. 2005). The mesial-distal (MD) CEJ diameter in anterior teeth (incisors and canines) is defined as the "distance between the most occlusal points of the cement-enamel junction curve on the mesial and distal sides" (Hillson, et al. 2005:418). For the premolars and molars, the mesial-distal CEJ diameter the measurement point is defined "as midway along the cement-enamel junction on the mesial and distal sides of the crown" (Hillson, et al. 2005:418). There is usually a concavity at this point, so the measurement is actually a minimum rather than a maximum (Hillson, et al. 2005).

The buccal-lingual (BL) CEJ diameter of incisors, canines and premolars was defined as the "maximum measurement at the cement-enamel junction from labial/buccal to lingual/palatal" (Hillson, et al. 2005:418). The BL CEJ diameter for molars was defined as the measurement "taken on the cement-enamel junction at points midway along the buccal and lingual/palatal sides" (Hillson, et al. 2005:418). When there was a large enamel extension, the measurement was taken on one side or the other of the extension; whichever provided the larger measurement (Hillson, et al. 2005).

A digital paleo-tech dental caliper (a specialized caliper with fine tips that fit between teeth and around the bulbous crown) was unavailable for this study, however a standard Helios needlepoint dial caliper, accurate to 0.001mm, was borrowed from the Hamline University Osteology Laboratory. Only those measurements that could be obtained without interference of adjacent teeth were taken with preference given to measuring loose teeth. Both left and right antimeres were measured. When antimeres differed by more than .15mm, each was re-measured in order to ensure that the difference was a true reflection of asymmetry rather than measurement error. Summary statistics are provided in Table 6-1.

Table 6 - 1: Dental metric summary statistics.

	n	NA	Min	1st Qu	Median	Mean	3rd Qu	Max
MD Crown RUM3	53	229	7.27	7.94	8.45	8.57	9.13	11.50
MD Crown RUM2	91	191	7.65	8.88	9.28	9.34	9.73	11.20
MD Crown RUM1	105	177	8.82	9.77	10.10	10.10	10.40	11.80
MD Crown RUP4	67	215	5.35	6.22	6.48	6.49	6.75	7.75
MD Crown RUP3	66	216	5.60	6.35	6.71	6.71	7.04	8.29
MD Crown RUC	75	207	6.63	7.25	7.58	7.58	7.87	9.14
MD Crown RUI2	42	240	5.83	6.18	6.50	6.60	6.91	8.05
MD Crown RUI1	43	239	6.98	8.00	8.34	8.44	8.88	9.67
MD Crown LUI1	44	238	7.13	8.15	8.54	8.57	8.90	10.10
MD Crown LUI2	46	236	5.43	6.34	6.67	6.70	6.98	8.08
MD Crown LUC	69	213	6.74	7.29	7.55	7.62	7.89	8.74
MD Crown LUP3	78	204	5.76	6.42	6.68	6.71	6.96	8.57
MD Crown LUP4	66	216	5.60	6.13	6.49	6.48	6.71	7.87
MD Crown LUM1	101	181	8.46	9.75	10.10	10.10	10.50	11.80
MD Crown LUM2	87	195	7.80	9.00	9.40	9.41	9.82	11.20
MD Crown LUM3	56	226	7.29	8.29	8.77	8.74	9.22	11.30
MD Crown RLM3	62	220	8.75	9.95	10.40	10.40	10.80	12.50
MD Crown RLM2	87	195	8.75	9.93	10.40	10.40	10.80	11.80
MD Crown RLM1	102	180	8.85	10.40	10.80	10.80	11.30	12.20
MD Crown RLP4	92	190	5.86	6.50	6.79	6.83	7.10	8.50
MD Crown RLP3	95	187	5.34	6.47	6.73	6.74	7.04	7.73
MD Crown RLC	106	176	5.81	6.38	6.70	6.68	6.92	7.83
MD Crown RLI2	74	208	4.82	5.65	5.92	5.91	6.22	7.86
MD Crown RLI1	56	226	4.36	5.11	5.34	5.29	5.46	6.07
MD Crown LLI1	56	226	4.24	5.11	5.36	5.35	5.65	6.26
MD Crown LLI2	76	206	4.92	5.71	5.88	5.90	6.11	6.60
MD Crown LC	101	181	5.67	6.40	6.69	6.66	6.92	7.75
MD Crown LLP3	98	184	5.92	6.51	6.73	6.76	6.99	7.71
MD Crown LLP4	88	194	5.80	6.65	6.84	6.89	7.20	7.87
MD Crown LLM1	103	179	8.81	10.50	10.80	10.80	11.30	12.30
MD Crown LLM2	82	200	8.75	9.85	10.20	10.40	10.90	12.10
MD Crown LLM3	57	225	8.80	9.86	10.40	10.50	10.90	13.00
BL Crown RUM3	53	229	8.99	9.80	10.30	10.50	11.10	12.70
BL Crown RUM2	88	194	8.77	10.60	11.10	11.10	11.60	13.60
BL Crown RUM1	106	176	6.50	10.70	11.10	11.10	11.50	12.80
BL Crown RUP4	68	214	7.55	8.51	8.88	8.93	9.36	10.60
BL Crown RUP3	69	213	6.39	8.42	8.82	8.84	9.35	10.20
BL Crown RUC	78	204	6.81	7.74	8.21	8.16	8.53	10.00
BL Crown RUI2	53	229	5.28	5.84	6.14	6.22	6.66	7.75
BL Crown RUI1	54	228	3.55	6.76	7.03	6.98	7.29	8.69
BL Crown LUI1	53	229	5.02	6.65	6.91	6.94	7.20	8.50
BL Crown LUI2	64	218	4.62	5.91	6.16	6.27	6.61	8.04

Table 6-1 Cont'd: Dental metric summary statistics.

	n	NA	Min	1st Qu	Median	Mean	3rd Qu	Max
BL Crown LUC	68	214	6.78	7.69	8.18	8.14	8.46	10.00
BL Crown LUP3	78	204	7.30	8.54	8.82	8.87	9.24	10.30
BL Crown LUP4	63	219	6.06	8.55	9.01	8.95	9.39	10.20
BL Crown LUM1	101	181	8.36	10.70	11.10	11.10	11.50	12.70
BL Crown LUM2	87	195	9.79	10.50	11.00	11.10	11.50	12.80
BL Crown LUM3	55	227	8.50	9.95	10.30	10.40	10.80	12.40
BL Crown RLM3	64	218	8.14	9.13	9.54	9.48	9.92	11.20
BL Crown RLM2	85	197	8.54	9.35	9.79	9.84	10.20	11.40
BL Crown RLM1	103	179	7.82	9.82	10.20	10.20	10.60	11.90
BL Crown RLP4	89	193	6.29	7.57	7.93	7.94	8.29	9.83
BL Crown RLP3	99	183	6.32	7.23	7.46	7.50	7.85	8.87
BL Crown RLC	105	177	6.11	7.11	7.45	7.50	7.86	9.32
BL Crown RLI2	92	190	5.13	5.79	6.15	6.16	6.45	7.22
BL Crown RLI1	62	220	4.86	5.43	5.74	5.75	6.01	6.77
BL Crown LLI1	63	219	4.54	5.46	5.70	5.80	6.13	7.42
BL Crown LLI2	92	190	4.83	5.90	6.13	6.15	6.46	7.24
BL Crown LC	100	182	6.43	7.18	7.50	7.51	7.85	9.16
BL Crown LLP3	97	185	6.40	7.19	7.45	7.51	7.85	8.75
BL Crown LLP4	91	191	6.50	7.69	8.03	8.00	8.34	9.39
BL Crown LLM1	102	180	7.57	9.86	10.20	10.10	10.50	11.80
BL Crown LLM2	83	199	8.10	9.34	9.77	9.80	10.30	11.40
BL Crown LLM3	57	225	8.18	9.08	9.51	9.54	10.00	11.00
MD CEJ RUM3	48	234	5.25	6.03	6.70	6.60	7.07	8.63
MD CEJ RUM2	95	187	6.00	7.00	7.34	7.37	7.73	9.86
MD CEJ RUM1	114	168	6.45	7.41	7.76	7.80	8.05	11.50
MD CEJ RUP4	87	195	3.61	4.40	4.63	4.65	4.93	5.55
MD CEJ RUP3	83	199	3.61	4.33	4.63	4.65	4.92	5.81
MD CEJ RUC	99	183	4.73	5.30	5.61	5.66	5.95	7.51
MD CEJ RUI2	69	213	4.04	4.54	4.80	4.84	5.11	6.09
MD CEJ RUI1	72	210	5.13	5.91	6.27	6.31	6.56	7.97
MD CEJ LUI1	71	211	5.06	5.92	6.35	6.31	6.68	7.91
MD CEJ LUI2	80	202	3.56	4.49	4.80	4.79	5.04	6.39
MD CEJ LUC	92	190	4.59	5.35	5.60	5.72	6.04	7.75
MD CEJ LUP3	96	186	3.91	4.37	4.70	4.74	4.99	7.35
MD CEJ LUP4	82	200	3.74	4.42	4.66	4.76	4.95	8.29
MD CEJ LUM1	105	177	6.66	7.45	7.72	7.74	8.06	8.96
MD CEJ LUM2	87	195	5.63	7.02	7.40	7.46	7.82	10.00
MD CEJ LUM3	55	227	5.18	6.35	6.74	6.77	7.14	9.04
MD CEJ RLM3	58	224	7.48	8.27	8.74	8.69	9.12	10.10
MD CEJ RLM2	98	184	7.10	8.48	8.84	8.89	9.25	10.60
MD CEJ RLM1	116	166	7.38	8.47	8.80	8.86	9.30	10.70
MD CEJ RLP4	105	177	4.07	4.70	4.95	5.02	5.25	7.81

Table 6-1 Cont'd: Dental metric summary statistics.

	n	NA	Min	1st Qu	Median	Mean	3rd Qu	Max
MD CEJ RLP3	112	170	4.15	4.63	4.84	4.91	5.11	7.74
MD CEJ RLC	125	157	4.05	4.99	5.26	5.28	5.59	6.88
MD CEJ RLI2	106	176	3.02	3.70	3.95	4.00	4.18	7.79
MD CEJ RLI1	80	202	2.92	3.30	3.50	3.54	3.70	6.34
MD CEJ LLI1	86	196	2.46	3.32	3.53	3.59	3.77	7.49
MD CEJ LLI2	107	175	2.79	3.70	3.91	3.94	4.13	5.62
MD CEJ LC	123	159	3.93	4.95	5.16	5.23	5.64	6.33
MD CEJ LLP3	113	169	3.96	4.62	4.84	4.90	5.10	6.80
MD CEJ LLP4	108	174	4.14	4.75	4.97	5.00	5.24	6.12
MD CEJ LLM1	119	163	7.45	8.50	8.85	8.91	9.32	10.30
MD CEJ LLM2	94	188	6.68	8.41	8.82	8.88	9.33	10.60
MD CEJ LLM3	55	227	6.92	8.28	8.60	8.71	9.16	10.90
BL CEJ RUM3	52	230	7.65	9.12	9.73	9.80	10.40	11.90
BL CEJ RUM2	92	190	8.21	10.10	10.50	10.60	11.10	13.30
BL CEJ RUM1	105	177	8.16	10.30	10.70	10.70	11.20	12.40
BL CEJ RUP4	82	200	5.57	7.66	8.00	8.03	8.35	9.93
BL CEJ RUP3	82	200	6.37	7.62	8.06	8.07	8.47	9.63
BL CEJ RUC	97	185	6.37	7.36	7.85	7.81	8.30	9.70
BL CEJ RUI2	69	213	4.58	5.35	5.77	5.75	6.09	6.65
BL CEJ RUI1	74	208	5.61	6.05	6.29	6.39	6.73	8.03
BL CEJ LUI1	70	212	5.21	5.94	6.31	6.30	6.64	7.76
BL CEJ LUI2	79	203	4.47	5.32	5.70	5.67	6.04	7.20
BL CEJ LUC	89	193	6.46	7.34	7.79	7.84	8.26	9.50
BL CEJ LUP3	95	187	4.25	7.64	8.04	8.04	8.47	9.46
BL CEJ LUP4	78	204	6.45	7.65	8.11	8.15	8.60	11.20
BL CEJ LUM1	105	177	9.26	10.30	10.70	10.80	11.20	12.60
BL CEJ LUM2	87	195	7.43	10.20	10.60	10.60	11.10	12.70
BL CEJ LUM3	54	228	6.21	9.31	9.79	9.80	10.40	11.80
BL CEJ RLM3	43	239	6.54	7.69	8.29	8.27	8.79	10.20
BL CEJ RLM2	71	211	7.14	8.26	8.82	8.77	9.11	10.40
BL CEJ RLM1	102	180	7.33	8.65	9.00	8.98	9.30	10.50
BL CEJ RLP4	101	181	4.87	6.64	7.05	7.00	7.41	8.44
BL CEJ RLP3	105	177	5.08	6.36	6.71	6.72	7.05	8.18
BL CEJ RLC	118	164	4.60	6.98	7.45	7.38	7.90	9.11
BL CEJ RLI2	96	186	3.24	5.60	5.97	5.98	6.36	7.76
BL CEJ RLI1	69	213	3.32	5.19	5.42	5.45	5.70	6.62
BL CEJ LLI1	78	204	2.85	5.20	5.50	5.49	5.81	6.73
BL CEJ LLI2	97	185	3.00	5.62	6.00	5.92	6.36	7.12
BL CEJ LC	119	163	4.70	7.03	7.40	7.38	7.79	9.03
BL CEJ LLP3	108	174	3.88	6.32	6.67	6.67	7.10	8.59
BL CEJ LLP4	102	180	5.98	6.85	7.14	7.16	7.39	8.57
BL CEJ LLM1	111	171	7.91	8.63	8.99	9.00	9.27	11.20

Table 6-1 Cont'd: Dental metric summary statistics.

	n	NA	Min	1st Qu	Median	Mean	3rd Qu	Max
BL CEJ LLM2	64	218	7.32	8.40	8.87	8.86	9.30	10.50
BL CEJ LLM3	40	242	6.43	8.07	8.48	8.39	8.86	10.70

Dental non-metrics

The forty-three dental non-metric traits included in the analysis (Table 6-2) were those developed by the Arizona State University Dental Anthropology System (ASUDAS) (Scott and Turner II, 1997; Turner II, et al. 1991). Scott and Turner II (1997) and Turner II and colleagues (1991) describe in detail each of the 43 dental nonmetric traits utilized in this study, and therefore descriptions of each are not included here. The ASUDAS traits have an overall high genetic component (Alt and Türp, 1998; Alt and Vach, 1991 1998; Irish, 2010; Larsen, 1997b; Scott, 1973; Scott and Turner II, 1997) that make them ideally suited for biodistance analysis (Larsen 1997a); and they are assumed to be selectively neutral (Scott and Turner II, 1997). Additionally ASUDAS has been reliably used in many previous studies (Haddow, 2012; Haddow and Lovell, 2003; Haeussler, et al. 1988; Irish, 1993, 1994, 1997, 1998a, 1998b, 1998c, 1998d, 2000, 2005, 2010; Irish and Friedman 2010; Irish and Guatelli-Steinberg, 2003; Irish and Hempholl, 2004; Irish and Konigsberg, 2007; Irish and Nelson, 2008; Irish and Turner II, 1990; Jackes, et al. 2001; McIlvaine, et al. 2014; Movsesian, 2013; Scott, 1973, 1980; Thompson, 2013; Turner II, 1985a, 1985b, 1987, 1990, 1992; Turner II and Markowitz, 1990; Zejdlik Passalacqua, 2015). A reference plaque set of the dental non-metric traits was borrowed from the Hamline University Osteology Laboratory for the study. The descriptions of the traits and scoring procedures outlined by Scott and Turner II (1997) and Turner II and colleagues (1991), the ASUDAS plaque set, along with high quality digital photographs of the plaques obtained from Haddow (2012), were used as reference for scoring the dental non-metric traits. Dental

traits concerning tooth root variations were only recorded if either the tooth could be removed from its socket or if the socket was preserved well enough to clearly judge the root trait based on the empty socket.

Cranial metrics

Thirty-two standard cranial, facial and mandibular metric measurements, as described and defined by Buikstra and Ubelaker (1994) and established by Howells (1973, 1989, 1995) were taken on all complete and mostly complete crania and mandibles identified among the samples (Table 6-3). Every available measurement was taken. In the case of broken cranial elements, pathologies and traumas, the measurement was recorded as not available (NA). Cranial metrics were recorded using a standard spreading caliper (provided by the Croatian Academy of Sciences and Arts - Anthropology Center) and a Mitutuyo digital sliding caliper. Summary statistics are provided in Table 6-3.

Cranial non-metrics

Eighty-three cranial non-metric traits (from left, right and medial locations on the skull) were recorded (Table 6-4) (Berry and Berry, 1967; DiGangi and Hefner, 2013; Hauser and De Stefano, 1989; Hefner, 2003, 2007, 2009; Shipman, 1982). Cranial non-metric traits were recorded on either a presence absence basis using the "individual count" method, where individuals are recorded as having the trait, regardless of whether or not the trait appears bilaterally (Buikstra and Ubelaker, 1994; Sutter and Mertz, 2004); or cranial nonmetric traits were recorded on a ranked scale in accordance with standard procedures (Berry and Berry, 1967; Hauser and De Stefano, 1989).

Table 6 - 2: Dental non-metric trait list.

	Grade Scale	Maxillary	Mandibular
Shoveling	8 (0-7)	UI1, UI2, UC	LI1, LI2, LC
Double Shoveling	7 (0-6)	UI1, UI2, UC	
Labial Curvature	5 (0-4)	UI1, UI2	
Tuberculum Dentale	8 (0-7)	UI1, UI2, UC	LI1, LI2, LC
Interruption Grooves	5 (0-4)	UI1, UI2, UC	LI1, LI2, LC
Winging	5 (1-5)	UI1	
Variants	6 (0-5)	UI2	
Peg Shaped	2 (0-2)	UI2, UM3	LI2
Mesial Ridge	4 (0-3)	UC	
Distal Accessory Ridge	6 (0-5)	UC	LC
Double Root	4 (0-3)		LC
Congenital Absence	2 (0-1)	UI2, UP4, UM3	LI1, LP4, LM3
Root #	4 (1-4)	UI1, UI2, UC, UP3, UP4, UM1, UM2, UM3	LI1, LI2, LC, LM1, LM2, LM3
Radical #	8 (1-8)	UI1, UI2, UC, UP3, UP4, UM1, UM2, UM3	LI1, LI2, LC, LM1, LM2, LM3
Accessory Ridge - Mesial	2 (0-1)	UP3, UP4	LP3, LP4
Accessory Ridge - Distal	2 (0-1)	UP3, UP4	LP3, LP4
Accessory Marginal Tubercles	4 (0-3)	UP3, UP4	
Odontomes	2 (0-1)	UP3, UP4	LP3, LP4
Distosagittal Ridge	2 (0-1)	UP4	
Multiple Lingual Cusps	11 (0-10)		LP3, LP4
Tricuspid	2 (0-1)	UP3, UP4	
Enamel Extension/Pearl	6 (0-5)	UP3, UP4, UM1, UM2, UM3	
LP3 Tome's Root	6 (0-5)		LP3
Carabelli's Cusp	8 (0-7)	UM1, UM2, UM3	
Metacone (Cusp 3)	7 (0-6)	UM1, UM2, UM3	
Mesial Paracone Tubercle	2 (0-1)	UM1, UM2, UM3	
Protoconule Tubercle	2 (0-1)	UM1, UM2, UM3	
Mesial Accessory Tubercle	2 (0-1)	UM1, UM2, UM3	
Lingual Paracone Tubercle	2 (0-1)	UM1, UM2, UM3	
Parastyle	7 (0-6)	UM1, UM2, UM3	
Hypocone (Cusp 4)	7 (0-6)	UM1, UM2, UM4	
Metaconule (Cusp 5)	6 (0-5)	UM1, UM2, UM5	
Hypoconulid (Cusp 5)	6 (0-5)		LM1, LM2, LM3
Cusp #	3 (4-6)	UM1, UM2, UM5	LM1, LM2, LM3
Entoconulid (Cusp 6)	6 (0-5)		LM1, LM2, LM3
Metaconulid (Cusp 7)	7 (0-6)		LM1, LM2, LM3
Groove Pattern	4 (1-4)		LM1, LM2, LM3
Protostylid Buccal Pit	2 (0-1)		LM1, LM2, LM3
Protostylid	6 (0-7)		LM1, LM2, LM3
Deflecting Wrinkle	4 (0-3)		LM1, LM2, LM3
Anterior Fovea	5 (0-4)		LM1, LM2, LM3
Distal Trigonid Crest	2 (0-1)		LM1, LM2, LM3

Table 6 - 3: Cranial metric summary statistics.

	n	NA	Min	1st Qu	Median	Mean	3rd Qu	Max
Maximum Length (g-op)	143	139	122.0	175.0	182.0	180.0	187.0	202.0
Maximum Breadth (eu-eu)	145	137	108.0	138.0	143.0	142.0	148.0	164.0
Bizygomatic Breadth (zy-zy)	79	203	105.0	128.0	133.0	133.0	139.0	149.0
Basion-Bregma (ba-b)	125	157	111.0	132.0	137.0	136.0	141.0	153.0
Cranial Base Length (ba-n)	124	158	76.0	100.0	104.0	104.0	108.0	197.0
Basion-Prosthion Length (ba-pr)	108	174	65.5	91.3	95.2	95.1	99.1	115.0
Maximum Alveolar Breadth (ecm-ecm)	148	134	42.2	57.0	60.5	60.2	63.9	79.6
Maximum Alveolar Length (pr-alv)	150	132	29.7	46.4	50.9	49.5	54.0	61.0
Biauricular Breadth	138	144	92.1	117.0	122.0	121.0	126.0	135.0
Upper Facial Height (n-pr)	133	149	37.0	60.6	65.0	64.3	69.9	78.9
Minimum Frontal Breadth (ft-ft)	167	115	63.2	93.5	97.2	96.2	100.0	111.0
Upper Facial Breadth (fmt-fmt)	169	113	62.9	99.8	104.0	102.0	108.0	117.0
Nasal Height (n-ns)	136	146	25.8	45.6	49.3	48.5	52.0	79.5
Nasal Breadth (al-al)	143	139	15.0	21.7	23.5	23.3	25.4	28.0
L Orbital Breadth (mf-ec)	130	152	25.4	37.1	38.9	38.7	40.7	47.9
R Orbital Breadth (mf-ec)	129	153	26.9	37.9	39.8	39.4	40.9	48.5
L Orbital Height	130	152	24.8	30.6	32.0	31.9	33.1	37.4
R Orbital Height	129	153	23.9	30.4	31.8	31.7	33.0	37.9
Biorbital Breadth (ec-ec)	120	162	73.0	92.7	95.8	94.6	98.6	105.0
Interorbital Breadth (mf-mf)	162	120	13.2	21.4	23.2	23.2	25.1	30.3
Frontal Chord (n-b)	167	115	66.0	105.0	110.0	109.0	113.0	126.0
Parietal Chord (b-l)	168	114	82.4	106.0	111.0	110.0	116.0	133.0
Occipital Chord (l-o)	161	121	68.6	91.4	95.8	95.7	100.0	111.0
Foramen Magnum Length (ba-o)	139	143	26.9	34.8	36.5	36.6	37.7	83.2
Foramen Magnum Breadth	136	146	23.5	28.8	30.3	30.3	31.8	35.3
L Mastoid Length	167	115	11.0	24.6	28.1	26.9	30.5	36.4
R Mastoid Length	160	122	10.7	24.9	28.2	27.5	31.0	39.5
Chin Height (gn-id)	182	100	13.4	25.1	28.6	28.2	31.9	39.2
L Body Height at Mental Foramen	187	95	13.2	24.6	28.2	27.6	31.2	39.2
R Body Height at Mental Foramen	180	102	12.4	25.6	29.2	28.1	31.7	39.7
L Body Thickness at Mental Foramen	193	89	7.8	10.1	11.4	11.4	12.7	16.2
R Body Thickness at Mental Foramen	186	96	7.1	10.0	11.3	11.4	12.7	16.4
Bigonial Diameter (go-go)	149	133	25.0	90.4	97.2	95.2	103.0	118.0
Bicondylar Breadth (cdl-cdl)	111	171	72.7	109.0	117.0	114.0	123.0	134.0
L Minimum Ramus Breadth	170	112	16.1	28.8	31.2	31.0	33.8	44.1
R Minimum Ramus Breadth	157	125	18.8	28.9	31.3	31.0	34.1	42.2
L Maximum Ramus Breadth	140	142	18.2	39.0	42.2	41.4	45.5	61.0
R Maximum Ramus Breadth	133	149	23.1	38.8	42.0	41.1	45.1	53.6
Mandibular Length	144	138	40.8	70.4	76.2	74.5	81.3	104.0
L Ramus Height	60	222	21.2	48.6	61.0	56.9	67.7	82.0
R Ramus Height	25	257	30.8	42.5	60.3	56.6	65.8	76.0

Table 6 - 4: Cranial non-metric trait list.

	Grade Scale	Categories
Metopic Suture	2 (0-1)	A, P
Metopic Fissure	2 (0-1)	A, P
Supranasal Suture	2 (0-1)	A, P
Frontal Grooves*	4 (0-3)	A, Single, Bifurcated, Multiple
Supratrochlear Notch*	4 (0-3)	A, Blurred, Sharp, Many
Medial Supraorbital Notch*	3 (0-2)	A, Blurred, Sharp
Lateral Supraorbital Notch*	3 (0-2)	A, Blurred, Sharp
Nutrient Foramen in Notch*	2 (0-1)	A, P
Supratrochlear Foramen*	5 (0-4)	A, P1, P2, P3+, Porosities
Medial Supraorbital Foramen*	4 (0-3)	A, P1, P2, P3+
Lateral Supraorbital Foramen*	4 (0-3)	A, P1, P2, P3+
Anterior Ethmoid Foramen*	4 (0-3)	A, P1, P2, P3+
Posterior Ethmoid Foramen*	4 (0-3)	A, P1, P2, P3+
Trochlear Spine (Spur)*	2 (0-1)	A, P
Nasal Foramen*	4 (0-3)	A, P1, P2, P3+
Infraorbital Suture*	2 (0-1)	A, P
Accessory Infraorbital Foramen*	4 (0-3)	A, P1, P2, P3+
Zygomaxillary Tubercle*	4 (0-3)	A, Small, Moderate, Large
Zygomatico-Facial Foramen*	5 (0-4)	A, P1, P2, P3, P4+
Marginal Tubercle*	4 (0-3)	A, Small, Mod, Large
Parietal Foramen*	2 (0-1)	A, P1, P2
Symmetrically Thin Parietals*	3 (0-2)	A, P
Coronal Ossicle*	2 (0-1)	A, P1, P2
Sagittal Ossicle	3 (0-2)	A, P1
Ossicle at Bregma	2 (0-1)	A, P
Lambdoid Ossicle*	2 (0-1)	A, P1, P2, P3+
Ossicle at Lambda	4 (0-3)	A, P1, P2+
Inca Bone	3 (0-2)	A, Incomplete, Complete
Occipital-Mastoid Ossicle*	3 (0-2)	A, P
Occipital Foramen	2 (0-1)	A, P1, P2, P3+
Ossicle at Asterion*	4 (0-3)	A, P
Condylar Canal*	2 (0-1)	A, P1, P2, P3+
Double Condylar Facet*	3 (0-2)	A, P
Hypoglossal Canal Bridge*	3 (0-2)	A, Spurs, Bridged
Intermediate Condylar Canal Bridge*	2 (0-1)	A, Spurs, P
Jugular Foramen Bridge*	4 (0-3)	A, Spurs, Bridged
Precondylar Tubercle*	4 (0-3)	A, Small, Moderate, Large, 2 Present
Pharyngeal Tubercle	2 (0-1)	A, Trace, Weak, Medium, Large, Other
Pharyngeal Fovea	3 (0-2)	A, Shallow, Medium, Deep
Median Basilar Canal Foramen	3 (0-2)	A, External, Ex & In, Internal
Craniopharyngeal Canal	3 (0-2)	A, P
Tympanic Dehiscence*	5 (0-4)	A, P
Postglenoid Foramen*	6 (0-5)	A, P
Oval Foramen Incomplete*	4 (0-3)	A, P
Foramen of Vesalius*	4 (0-3)	A, Slit, Oval, Round, 2 Round
Spinosum Foramen Open*	2 (0-1)	A, P
Basilar-Sphenoid Bridge*	2 (0-1)	A, Trace, Incomplete, Complete
Accessory Lesser Palatine Foramen*	2 (0-1)	A, P1, P2, P3+
Palatine Bridge	2 (0-1)	A, Incomplete, Bridged
Palatine Torus	5 (0-4)	A, Trace, Medium, Strong, Excessive
Maxillary Torus	2 (0-1)	A, Small, Large

Table 6 – 4 Cont'd: Cranial non-metric trait list.

	Grade Scale	Categories
Retromastoid Process*	4 (0-3)	A, Trace, Weak
Paracondylar Process*	4 (0-3)	A, Small, Medium, Strong
Sella Bridges	3 (0-2)	A, P
Flexure of Superior Sagittal Sulcus	5 (0-4)	Right, Left, Both, None
Auditory Torus*	3 (0-2)	A, P
Suprameatal Spine*	3 (0-2)	A, Small, Medium, Large
Suprameatal Depression*	4 (0-3)	A, Shallow, Deep
Inferior Squamous Foramen*	2 (0-1)	A, P1, P2, P3+
Superior Squamous Foramen*	4 (1-4)	A, P1, P2, P3+
Inferior Parietal Foramen*	2 (0-1)	A, P1, P2, P3+
Bipartite Parietal*	4 (0-3)	A, P
Bipartite Temporal Squama*	3 (0-2)	A, P
Bipartite Zygomatic*	4 (0-3)	A, P
Biasterionic Suture*	4 (0-3)	A, At Asterion, Above Asterion, Below Asterion
Mastoid Foramen Extrasutural*	4 (0-3)	In suture, Occipital, Temporal, No Foramen
Accessory Mastoid Foramen*	2 (0-1)	A, P1, P2, P3, P4+
Squamomastoid Suture*	2 (0-1)	A, Center, Intermittent, Process, Notch, Complete
Parietal Notch Bone*	4 (0-3)	A, P1, P2
Epipteric Bone*	4 (1-4)	A, P1, P2
Frontotemporal Articulation*	5 (0-4)	A, P
Squamous Ossicle*	6 (0-5)	A, P1, P2, P3+
Mandibular Torus	3 (0-2)	A, Trace, Marked
Accessory Mental Foramen*	4 (0-3)	A, P1, P2, P3+
Mylohyoid Bridge*	3 (0-2)	A, Spurs, P
Mental Spines	6 (0-5)	A, 2 Vrt Spines, 2 Sup 1 Inf, Single Spine, 2 Sup Spines, 2 Sup 2 Inf
Median Pit	5 (0-4)	A, Single, Sup & Inf, Sup Vrt Pit, 2 Inf
Retromolar Foramen*	4 (0-3)	A, P1, P2, P3+
Molar Foramen*	5 (0-4)	A, P1, P2, P3, P4+
Canal de Serres Foramen*	2 (0-1)	A, P
Canal of Robinson*	4 (0-3)	A, P1, P2, P3+
Rocker Mandible	2 (0-1)	A, P
Atlas Bridging	2 (0-1)	A, P
Double Articular Facet of C1	2 (0-1)	A, P
Septal Aperture	2 (0-1)	A, P

* Indicates a bilateral trait

Intraobserver error

A total of 28 individuals were reanalyzed approximately one year after the original data recording, in order to test for intraobserver error prior to final data analysis. Due to dental wear and growth and development complications, preference was given to young adult and adolescent individuals with near complete datasets. These 28 individuals represent approximately 10% of the total available sample. The demographic profiles of the total available sample (Table 6-5)

and the error sample (Table 6-6) are provided below. To test for intraobserver error the initial and second measurements for the 28 individuals included in the intraobserver study were compared.

Table 6 - 5: Demographic profile of the total sample.

	Female	Male	Indeterminate	Sum
Infant (0-2)			60	60
Child (2-6)			32	32
Juvenile (6-10)			18	18
Adolescent (10-18)	8	5	13	26
Young Adult (18-34)	19	16		35
Middle Adult (35-49)	26	30	1	57
Old Adult (50+)	25	23	1	49
Indeterminate Adult			1	1
Sum	78	74	126	278*

* An additional adult and three subadult individuals from the SSL site were unavailable for analysis and are not included in the numbers above.

Table 6 - 6: Demographic profile of error sample.

	Female	Male	Indeterminate	Sum
Infant (0-2)				
Child (2-6)				
Juvenile (6-10)			2	2
Adolescent (10-18)	1	3	1	5
Young Adult (18-34)	10	4	1	15
Middle Adult (35-49)	3	2		5
Old Adult (50+)		1		1
Indeterminate Adult				
Sum	14	10	4	28

Database format

All data collection was recorded on data forms at the Croatian Academy of Sciences and Arts – Anthropology Center, rather than directly input into a digital database because the Anthropology Center lacks the space as well as Internet resources for computer-based data entry on site. Upon return from data collection, all data were entered into an Excel data spreadsheet before data manipulation and input into the statistics program R. All original data were placed into a single master spreadsheet. To reduce error and increase consistency of nonmetric data

entry, the nonmetric data cells were converted into drop-down menus with the appropriate category choices. Categorical data were not entered as numerical scores but rather as a short descriptive label (see Table 6-4). The master spreadsheet was then copied, and all data manipulation was done on the copied versions of the master spreadsheet. This was done so as to always have the original data for reference, in case of mistakes made during data manipulation. The original master spreadsheet was also password protected from editing.

Data preparation and reduction

The large numbers of non-metric and metric traits were included in order to prevent potential biases due to trait selection (Harris and Sjøvold, 2004; McIlvaine, et al. 2014). However, most multivariate statistical tests use fewer variables and require complete datasets. Therefore prior to running the multivariate statistical analyses, the metric and non-metric data were subjected to a series of data manipulation processes in an effort to both reduce the total number of variables as well as to control for factors that have the potential to affect the final results (e.g., accuracy of observation, age or sex). Data preparation included reduction to left-sided data, testing metric data for a normal distribution, testing for age and sex correlations, dichotomization of non-metric variables, examining the data for consistency of observation via an intraobserver error analysis, elimination of variables with too many missing values, elimination of non-metric variables with low variability (i.e., low (<5%) or high (>95%) presence), and elimination of variables due to redundancy. In order to accommodate sample size considerations and missing data, after reducing the data sets missing values for the remaining variables were estimated through multiple imputation (MUIP). Finally, the metric data were standardized (scaled) to account for sexual dimorphism. All statistical analyses were conducted

using the statistics program *R: A language and environment for statistical computing* (R Core Team 2017). The R package, *knitr* (Xie, 2013a, 2013b, 2014), was used to track the R code script of the analysis and aid in the reproducibility of the analysis. The following section outlines the data preparation processes.

Asymmetry and individual count method

The individual constitutes the unit of analysis. Therefore, all metric data were first tested for asymmetry using a paired student's *t*-test. If asymmetry tests were insignificant, then right-sided measurements were substituted for any missing left-side measurements (Haddow and Lovell, 2003). Only one measurement (BL CEJ LP4) showed a significant difference between the left and right sides, so for this measure the right-sided data were not substituted for any missing left measures. Table 6-7 presents the cranial and dental asymmetry *t*-test results.

The individual count method was followed for the nonmetric data; the side with the highest score was retained (Haeussler, et al. 1988; Hanihara, 2008; Irish, 1997, 2010; Shipman, 1982; Thompson, 2013; Turner II and Scott, 1977; Zejdlik Passalacqua, 2015). Hence, an individual was assigned a score "trait present" if the trait was expressed bilaterally or only unilaterally (Shipman, 1982). When a trait could only be observed on one side, some information may have been lost, however this was not a major problem since the crania and dentitions included are relatively complete for an archaeological sample.

Table 6 - 7: Asymmetry student's *t*-test results.

	n left	n right	t	df	*p*-value
Orbital Breadth (mf-ec)	130	129	-1.772	255.74	0.078
Orbital Height	130	129	0.664	256.11	0.507
Mastoid Length	167	160	-0.879	324.79	0.380
Body Height at Mental Foramen	187	180	-0.832	363.96	0.406
Body Thickness at Mental Foramen	193	186	0.033	376.22	0.744
Minimum Ramus Breadth	170	157	0.001	324.78	0.999
Maximum Ramus Breadth	140	133	0.298	270.85	0.766
Ramus Height	60	25	0.081	48.345	0.936
MD Crown UM3	56	53	-1.090	106.56	0.278
MD Crown UM2	87	91	-0.740	175.56	0.460
MD Crown UM1	101	105	0.008	201.36	0.994
MD Crown UP4	66	67	0.089	131.00	0.929
MD Crown UP3	78	66	0.013	136.72	0.990
MD Crown UC	69	75	-0.418	141.14	0.676
MD Crown UI2	46	42	-0.879	85.85	0.382
MD Crown UI1	44	43	-0.958	84.87	0.341
MD Crown LM3	57	62	-0.524	110.13	0.601
MD Crown LM2	82	87	0.055	165.9	0.956
MD Crown LM1	103	103	-0.705	202.01	0.481
MD Crown LP4	88	92	-0.963	176.41	0.337
MD Crown LP3	98	95	-0.333	186.02	0.740
MD Crown LC	101	106	0.196	204.89	0.845
MD Crown LI2	76	73	0.152	130.47	0.879
MD Crown LI1	56	55	-0.736	97.61	0.463
BL Crown UM3	55	53	0.460	104.48	0.646
BL Crown UM2	87	88	0.592	170.2	0.554
BL Crown UM1	101	106	0.243	203.03	0.808
BL Crown UP4	63	68	-0.155	125.89	0.877
BL Crown UP3	78	69	-0.321	137.94	0.749
BL Crown UC	68	78	0.160	139.32	0.873
BL Crown UI2	64	53	-0.490	112.47	0.625
BL Crown UI1	53	54	0.302	99.74	0.763
BL Crown LM3	57	64	-0.423	114.87	0.673
BL Crown LM2	83	85	0.353	164.71	0.725
BL Crown LM1	102	103	0.490	202.24	0.625
BL Crown LP4	91	89	-0.738	175.77	0.462
BL Crown LP3	97	99	-0.035	193.26	0.972
BL Crown LC	100	105	-0.149	202.66	0.882
BL Crown LI2	92	92	0.215	181.46	0.830
BL Crown LI1	63	62	-0.660	120.49	0.511
MD CEJ UM3	55	48	-1.170	100.95	0.245
MD CEJ UM2	87	95	-0.880	169.71	0.380
MD CEJ UM1	105	114	0.848	202.92	0.397
MD CEJ UP4	82	87	-1.430	133.25	0.155
MD CEJ UP3	96	83	-1.272	176.71	0.205
MD CEJ UC	92	99	-0.675	182.5	0.500
MD CEJ UI2	80	69	0.647	146.61	0.519
MD CEJ UI1	71	72	0.009	140.95	0.993
MD CEJ LM3	55	58	-0.142	106.57	0.887
MD CEJ LM2	94	98	0.141	187.25	0.888
MD CEJ LM1	119	116	-0.639	231.28	0.524
MD CEJ LP4	108	105	0.292	187.27	0.771
MD CEJ LP3	113	112	0.130	218.19	0.897

Table 6 – 7 Cont'd: Asymmetry student's *t*-test results.

	n left	n right	t	df	*p*-value
MD CEJ LC	123	125	0.870	245.62	0.385
MD CEJ LI2	107	106	0.880	195.27	0.380
MD CEJ LI1	86	80	-0.632	157.02	0.528
BL CEJ UM3	54	52	0.022	103.9	0.983
BL CEJ UM2	87	92	0.127	176.93	0.899
BL CEJ UM1	105	105	-0.476	207.25	0.635
BL CEJ UP4	78	82	-0.982	155.64	0.327
BL CEJ UP3	95	82	0.379	173.94	0.705
BL CEJ UC	89	97	-0.251	182.29	0.802
BL CEJ UI2	79	69	0.891	146.00	0.375
BL CEJ UI1	70	74	1.196	140.05	0.234
BL CEJ LM3	40	43	-0.687	73.84	0.495
BL CEJ LM2	64	71	-0.774	131.78	0.440
BL CEJ LM1	111	102	-0.302	209.12	0.763
BL CEJ LP4	102	100	-1.964	193.95	0.051*
BL CEJ LP3	108	105	0.637	207.34	0.525
BL CEJ LC	119	118	0.051	234.49	0.960
BL CEJ LI2	97	96	0.663	191.00	0.506
BL CEJ LI1	78	69	-0.408	144.85	0.684

* Significant at the 0.05 level.

Normality

Since most parametric statistical tests assume the data to be normally distributed. The Kolmogorov-Smirnov, Shapiro-Wilk, and D'Agostino-Pearson omnibus tests were used to test the metric data for normality. The Kolmogorov-Smirnov test has been more commonly used in the past, but is now considered to be less accurate (D'Agostino and Stephens, 1986). The Shapiro-Wilk test is considered more useful, but struggles when there are several repeated values (Thompson, 2013). The D'Agostino-Pearson omnibus test evaluates normality based upon whether a variable's skewness and kurtosis values differ from expected values of a Gaussian distribution (DeCarlo, 1997; Thompson, 2013).

The metric data sets were first reduced to include only the adults and older adolescents (those showing clear sexually dimorphic traits), and then the data were separated by sex. The R packages *nortest* and *stats* were used to test for a normal distribution of the metric traits (Gross and Ligges, 2015; R Core Team, 2017). The results of the normality tests are presented in Table

6-7 and Table 6-8. Variables were selected for removal if they had a significant p-value for the D'Agostino-Pearson Omnibus test and at least one other normality test. Only one sex needed to meet the criterion for removal to eliminate the variable from the dataset. Fifteen dental metric variables (Table 6-7), and five cranial metric variables (Table 6-8) were removed.

Table 6 - 8: Dental normality test results.

	Sex	n	Wilks (W)	*p*-value	Kolmogorov (D)	*p*-value	D'Agostino-Pearson (P)	*p*-value
MD Crown UI1	F	16	0.906	0.101	0.154	0.390	5.875	0.209
	M	12	0.983	0.993	0.140	0.741	3.000	0.392
	Total	55	0.990	0.935	0.054	0.952	1.182	0.991
MD Crown UI2	F	27	0.969	0.582	0.104	0.643	4.704	0.453
	M	20	0.965	0.657	0.158	0.213	3.800	0.434
	Total	62	0.972	0.177	0.090	0.240	5.774	0.673
MD Crown UC	F	35	0.981	0.803	0.089	0.689	4.343	0.630
	M	37	0.977	0.626	0.103	0.412	3.135	0.792
	Total	89	0.982	0.256	0.064	0.491	14.562	0.149
MD Crown UP3	F	42	0.990	0.968	0.075	0.801	4.286	0.638
	M	32	0.914	0.015	0.130	0.181	6.000	0.306
	Total	89	0.963	0.012	0.075	0.248	5.798	0.832
MD Crown UP4	F	39	0.956	0.128	0.139	0.055	12.000	0.062
	M	35	0.963	0.283	0.129	0.144	4.857	0.562
	Total	85	0.981	0.238	0.065	0.495	6.906	0.647
MD Crown UM1	F	40	0.956	0.120	0.093	0.511	3.650	0.724
	M	29	0.960	0.332	0.101	0.629	4.379	0.496
	Total	124	0.987	0.302	0.050	0.641	6.742	0.820
MD Crown UM2	F	50	0.976	0.398	0.079	0.613	3.600	0.825
	M	40	0.975	0.524	0.098	0.425	5.000	0.544
	Total	111	0.981	0.127	0.064	0.328	10.459	0.490
MD Crown UM3	F	34	0.926	0.024	0.103	0.474	11.000	0.088
	M	35	0.976	0.639	0.087	0.719	8.971	0.175
	Total	75	0.971	0.085	0.074	0.383	11.880	0.220
MD Crown LI1	F	22	0.965	0.597	0.132	0.411	4.727	0.316
	M	21	0.988	0.992	0.112	0.707	1.333	0.856
	Total	72	0.978	0.242	0.089	0.176	12.000	0.213
MD Crown LI2	F	34	0.963	0.304	0.099	0.538	1.471	0.961
	M	29	0.830	0.000	0.182	0.015	8.793	0.118
	Total	94	0.943	0.000	0.078	0.165	13.596	0.192
MD Crown LC	F	52	0.969	0.194	0.092	0.339	9.538	0.216
	M	48	0.965	0.164	0.135	0.029	19.083	0.008
	Total	125	0.992	0.658	0.052	0.555	12.648	0.317
MD Crown LP3	F	52	0.969	0.188	0.125	0.041	8.385	0.300
	M	50	0.976	0.396	0.095	0.320	12.400	0.088
	Total	118	0.988	0.369	0.062	0.319	9.661	0.561
MD Crown LP4	F	52	0.985	0.742	0.071	0.735	10.692	0.153
	M	48	0.936	0.012	0.148	0.010	12.000	0.101
	Total	115	0.983	0.162	0.073	0.137	13.922	0.237

Table 6 – 8 Cont'd: Dental normality test results.

	Sex	n	Wilks (W)	*p*-value	Kolmogorov (D)	*p*-value	D'Agostino-Pearson (P)	*p*-value
MD Crown LM1	F	39	0.945	0.056	0.108	0.300	7.385	0.287
	M	32	0.951	0.150	0.122	0.262	7.000	0.221
	Total	119	0.992	0.755	0.054	0.535	9.588	0.568
MD Crown LM2	F	43	0.966	0.235	0.120	0.125	19.093	0.008
	M	38	0.976	0.585	0.078	0.817	5.579	0.472
	Total	99	0.988	0.539	0.073	0.221	9.596	0.477
MD Crown LM3	F	37	0.957	0.165	0.104	0.401	13.351	0.038
	M	31	0.975	0.672	0.091	0.743	6.419	0.268
	Total	71	0.972	0.117	0.100	0.073	6.915	0.646
BL Crown UI1	F	22	0.898	0.027	0.158	0.161	7.273	0.122
	M	19	0.979	0.924	0.095	0.921	5.684	0.224
	Total	69	0.857	0.000	0.155	0.000	23.623	0.003
BL Crown UI2	F	37	0.963	0.245	0.100	0.462	4.108	0.662
	M	31	0.970	0.509	0.076	0.923	1.258	0.939
	Total	82	0.979	0.200	0.086	0.142	7.854	0.549
BL Crown UC	F	36	0.930	0.025	0.116	0.255	7.500	0.277
	M	38	0.982	0.779	0.104	0.381	9.368	0.154
	Total	91	0.982	0.259	0.085	0.108	21.143	0.020
BL Crown UP3	F	43	0.981	0.668	0.060	0.960	6.070	0.532
	M	36	0.979	0.699	0.074	0.886	3.000	0.809
	Total	94	0.992	0.831	0.049	0.846	5.021	0.890
BL Crown UP4	F	39	0.835	0.000	0.133	0.079	11.077	0.086
	M	36	0.952	0.124	0.114	0.278	9.000	0.174
	Total	86	0.955	0.004	0.070	0.372	8.884	0.448
BL Crown UM1	F	40	0.972	0.408	0.094	0.499	4.550	0.603
	M	30	0.967	0.473	0.097	0.663	2.000	0.849
	Total	125	0.980	0.060	0.066	0.206	8.840	0.637
BL Crown UM2	F	49	0.976	0.409	0.118	0.087	10.388	0.168
	M	40	0.974	0.466	0.077	0.804	2.300	0.890
	Total	109	0.978	0.063	0.076	0.126	15.716	0.152
BL Crown UM3	F	34	0.974	0.566	0.104	0.464	6.765	0.343
	M	35	0.965	0.321	0.106	0.408	3.314	0.768
	Total	75	0.993	0.952	0.058	0.767	4.840	0.848
BL Crown LI1	F	31	0.960	0.296	0.106	0.500	3.323	0.650
	M	25	0.897	0.016	0.136	0.274	9.880	0.079
	Total	82	0.982	0.286	0.082	0.192	7.854	0.549
BL Crown LI2	F	46	0.973	0.363	0.082	0.610	8.783	0.269
	M	39	0.987	0.914	0.066	0.942	6.000	0.423
	Total	114	0.993	0.819	0.050	0.681	16.421	0.126
BL Crown LC	F	51	0.983	0.675	0.083	0.519	7.627	0.367
	M	49	0.956	0.065	0.108	0.167	6.714	0.459
	Total	124	0.979	0.051	0.060	0.340	14.419	0.211
BL Crown LP3	F	51	0.956	0.056	0.112	0.115	9.196	0.239
	M	51	0.986	0.788	0.069	0.789	3.314	0.855
	Total	119	0.989	0.435	0.074	0.115	5.588	0.899
BL Crown LP4	F	51	0.946	0.021	0.124	0.048	8.020	0.331
	M	48	0.972	0.311	0.100	0.265	9.083	0.247
	Total	113	0.990	0.593	0.048	0.742	11.761	0.382
BL Crown LM1	F	38	0.974	0.515	0.115	0.231	14.579	0.024
	M	32	0.955	0.201	0.130	0.184	8.500	0.131
	Total	118	0.938	0.000	0.126	0.000	31.017	0.001

Table 6 – 8 Cont'd: Dental normality test results.

	Sex	n	Wilks (W)	*p*-value	Kolmogorov (D)	*p*-value	D'Agostino-Pearson (P)	*p*-value
BL Crown LM2	F	41	0.975	0.494	0.109	0.254	4.439	0.617
	M	38	0.974	0.520	0.068	0.931	3.211	0.782
	Total	98	0.988	0.536	0.078	0.148	21.388	0.019
BL Crown LM3	F	37	0.968	0.351	0.084	0.733	6.541	0.365
	M	33	0.970	0.494	0.107	0.446	6.000	0.423
	Total	73	0.985	0.556	0.044	0.980	1.466	0.997
MD CEJ UI1	F	34	0.984	0.885	0.089	0.707	3.588	0.732
	M	35	0.976	0.617	0.087	0.718	4.343	0.630
	Total	93	0.971	0.038	0.077	0.185	5.828	0.830
MD CEJ UI2	F	41	0.959	0.141	0.114	0.199	7.512	0.276
	M	44	0.938	0.020	0.163	0.005	18.727	0.009
	Total	100	0.975	0.052	0.090	0.043	17.000	0.074
MD CEJ UC	F	47	0.791	0.000	0.171	0.001	18.745	0.009
	M	51	0.974	0.326	0.085	0.476	5.275	0.627
	Total	116	0.962	0.002	0.095	0.011	11.690	0.387
MD CEJ UP3	F	48	0.684	0.000	0.215	0.000	31.167	0.000
	M	50	0.989	0.908	0.080	0.581	8.000	0.333
	Total	112	0.891	0.000	0.087	0.038	14.250	0.219
MD CEJ UP4	F	48	0.822	0.000	0.136	0.027	17.000	0.017
	M	51	0.782	0.000	0.151	0.005	13.510	0.061
	Total	110	0.811	0.000	0.115	0.001	31.273	0.001
MD CEJ UM1	F	48	0.658	0.000	0.239	0.000	26.167	0.000
	M	49	0.985	0.775	0.055	0.970	3.449	0.841
	Total	133	0.882	0.000	0.074	0.071	15.534	0.214
MD CEJ UM2	F	49	0.931	0.007	0.128	0.044	10.388	0.168
	M	50	0.950	0.033	0.116	0.088	11.600	0.115
	Total	115	0.957	0.001	0.102	0.005	29.991	0.002
MD CEJ UM3	F	31	0.962	0.338	0.092	0.718	5.387	0.370
	M	38	0.976	0.578	0.088	0.651	11.263	0.081
	Total	72	0.982	0.416	0.070	0.506	17.000	0.049
MD CEJ LI1	F	43	0.965	0.219	0.115	0.160	11.186	0.131
	M	37	0.655	0.000	0.245	0.000	33.297	0.000
	Total	105	0.669	0.000	0.182	0.000	41.467	0.000
MD CEJ LI2	F	53	0.973	0.281	0.085	0.439	4.547	0.715
	M	50	0.940	0.013	0.114	0.106	13.200	0.067
	Total	130	0.946	0.000	0.086	0.019	11.000	0.529
MD CEJ LC	F	61	0.977	0.291	0.084	0.350	9.148	0.330
	M	56	0.960	0.062	0.089	0.336	7.250	0.510
	Total	140	0.991	0.472	0.061	0.229	9.143	0.691
MD CEJ LP3	F	61	0.970	0.143	0.077	0.494	4.098	0.848
	M	57	0.954	0.031	0.097	0.202	9.965	0.267
	Total	133	0.944	0.000	0.077	0.051	24.782	0.016
MD CEJ LP4	F	58	0.969	0.147	0.090	0.285	4.207	0.838
	M	57	0.874	0.000	0.119	0.043	10.351	0.241
	Total	129	0.885	0.000	0.090	0.012	15.233	0.172
MD CEJ LM1	F	48	0.971	0.275	0.127	0.050	12.417	0.088
	M	50	0.970	0.222	0.098	0.265	14.400	0.045
	Total	135	0.989	0.351	0.059	0.310	15.333	0.224
MD CEJ LM2	F	46	0.969	0.248	0.104	0.239	8.783	0.269
	M	46	0.979	0.565	0.059	0.957	6.609	0.471
	Total	110	0.979	0.082	0.090	0.029	29.491	0.002

Table 6 – 8 Cont'd: Dental normality test results.

	Sex	n	Wilks (W)	*p*-value	Kolmogorov (D)	*p*-value	D'Agostino-Pearson (P)	*p*-value
MD CEJ LM3	F	37	0.970	0.406	0.128	0.129	7.027	0.318
	M	35	0.956	0.176	0.146	0.058	12.057	0.061
	Total	75	0.974	0.122	0.087	0.170	13.160	0.155
BL CEJ UI1	F	35	0.958	0.194	0.132	0.125	1.771	0.939
	M	35	0.960	0.221	0.126	0.170	4.857	0.562
	Total	94	0.990	0.713	0.070	0.304	10.553	0.393
BL CEJ UI2	F	42	0.979	0.630	0.066	0.917	2.143	0.906
	M	44	0.983	0.768	0.083	0.622	2.364	0.937
	Total	101	0.994	0.935	0.041	0.944	4.416	0.927
BL CEJ UC	F	45	0.977	0.490	0.085	0.574	16.111	0.024
	M	52	0.990	0.928	0.083	0.494	3.769	0.806
	Total	114	0.991	0.635	0.055	0.531	9.789	0.549
BL CEJ UP3	F	47	0.744	0.000	0.146	0.014	11.511	0.118
	M	50	0.978	0.464	0.074	0.713	8.800	0.267
	Total	111	0.920	0.000	0.064	0.309	12.730	0.311
BL CEJ UP4	F	45	0.980	0.613	0.092	0.436	5.889	0.553
	M	48	0.969	0.239	0.099	0.283	9.500	0.219
	Total	104	0.971	0.022	0.081	0.087	16.750	0.080
BL CEJ UM1	F	48	0.943	0.021	0.107	0.181	8.250	0.311
	M	48	0.985	0.793	0.068	0.841	5.750	0.569
	Total	132	0.989	0.413	0.045	0.751	9.364	0.672
BL CEJ UM2	F	50	0.987	0.857	0.053	0.978	4.400	0.733
	M	50	0.975	0.353	0.093	0.342	8.400	0.299
	Total	116	0.977	0.042	0.068	0.210	9.759	0.552
BL CEJ UM3	F	32	0.939	0.069	0.157	0.043	13.000	0.023
	M	39	0.964	0.250	0.089	0.617	2.308	0.889
	Total	74	0.974	0.123	0.093	0.121	15.838	0.070
BL CEJ LI1	F	39	0.979	0.652	0.076	0.826	2.769	0.837
	M	31	0.870	0.001	0.155	0.056	6.935	0.225
	Total	95	0.906	0.000	0.091	0.051	13.789	0.183
BL CEJ LI2	F	50	0.992	0.977	0.041	1.000	2.800	0.903
	M	44	0.868	0.000	0.140	0.029	5.091	0.649
	Total	121	0.921	0.000	0.073	0.120	14.950	0.185
BL CEJ LC	F	62	0.941	0.005	0.068	0.681	9.677	0.288
	M	55	0.847	0.000	0.182	0.000	24.091	0.001
	Total	139	0.949	0.000	0.067	0.132	19.309	0.081
BL CEJ LP3	F	59	0.971	0.180	0.065	0.777	5.322	0.723
	M	56	0.926	0.002	0.110	0.090	11.571	0.171
	Total	130	0.957	0.000	0.065	0.196	22.769	0.030
BL CEJ LP4	F	46	0.964	0.159	0.091	0.448	10.087	0.184
	M	44	0.970	0.301	0.103	0.285	6.000	0.540
	Total	102	0.975	0.047	0.089	0.047	10.157	0.427
BL CEJ LM1	F	44	0.953	0.073	0.123	0.094	7.818	0.349
	M	45	0.957	0.093	0.123	0.083	9.444	0.222
	Total	126	0.966	0.003	0.091	0.012	8.889	0.632
BL CEJ LM2	F	34	0.970	0.463	0.085	0.769	6.235	0.397
	M	36	0.969	0.405	0.105	0.405	6.000	0.423
	Total	86	0.985	0.402	0.061	0.585	7.209	0.615
BL CEJ LM3	F	29	0.969	0.536	0.088	0.817	7.138	0.211
	M	30	0.931	0.053	0.153	0.070	8.400	0.136
	Total	61	0.976	0.275	0.083	0.362	13.475	0.097

Table 6 - 9: Cranial normality test results.

	Sex	n	Wilks (W)	*p*-value	Kolmogorov (D)	*p*-value	D'Agostino-Pearson (P)	*p*-value
Maximum Length (g-op)	F	60	0.973	0.199	0.135	0.008	15.167	0.056
	M	53	0.984	0.697	0.081	0.520	8.321	0.305
	Total	113	0.994	0.919	0.059	0.440	15.478	0.162
Maximum Breadth (eu-eu)	F	58	0.977	0.353	0.071	0.658	6.862	0.552
	M	55	0.967	0.135	0.116	0.061	18.273	0.011
	Total	113	0.990	0.598	0.065	0.277	8.044	0.709
Bizygomatic Breadth (zy-zy)	F	32	0.990	0.990	0.078	0.895	3.000	0.700
	M	39	0.967	0.292	0.106	0.326	7.385	0.287
	Total	71	0.971	0.100	0.101	0.068	7.930	0.541
Basion-Bregma (ba-b)	F	57	0.978	0.380	0.085	0.384	6.491	0.592
	M	49	0.966	0.160	0.096	0.316	8.347	0.303
	Total	106	0.991	0.675	0.056	0.571	18.849	0.042
Cranial Base Length (ba-n)	F	56	0.980	0.492	0.086	0.375	21.000	0.007
	M	48	0.973	0.324	0.137	0.026	11.583	0.115
	Total	104	0.981	0.141	0.114	0.002	20.500	0.025
Basion-Prosthion Length (ba-pr)	F	49	0.961	0.109	0.080	0.601	3.449	0.841
	M	43	0.966	0.223	0.122	0.112	9.326	0.230
	Total	92	0.980	0.162	0.087	0.082	9.739	0.464
Maximum Alveolar Breadth (ecm-ecm)	F *	56	0.956	0.041	0.147	0.004	19.429	0.013
	M	56	0.965	0.105	0.079	0.515	6.464	0.595
	Total	112	0.989	0.518	0.059	0.438	8.000	0.713
Maximum Alveolar Length (pr-alv)	F	58	0.962	0.063	0.089	0.305	8.379	0.397
	M	58	0.962	0.064	0.102	0.135	13.310	0.102
	Total	116	0.988	0.424	0.059	0.404	4.690	0.945
Biauricular Breadth	F	58	0.990	0.929	0.088	0.326	8.759	0.363
	M	54	0.971	0.214	0.103	0.163	8.222	0.313
	Total	112	0.988	0.389	0.059	0.437	10.750	0.464
Upper Facial Height (n-pr)	F	51	0.965	0.135	0.087	0.445	7.235	0.405
	M*	51	0.948	0.027	0.165	0.001	18.608	0.010
	Total	102	0.979	0.099	0.074	0.179	13.980	0.174
Minimum Frontal Breadth (ft-ft)	F	65	0.974	0.183	0.099	0.116	11.323	0.184
	M	64	0.986	0.683	0.075	0.491	7.156	0.520
	Total	129	0.987	0.279	0.073	0.091	18.488	0.071
Upper Facial Breadth (fmt-fmt)	F	66	0.986	0.683	0.068	0.626	3.333	0.912
	M	64	0.988	0.779	0.081	0.375	6.813	0.557
	Total	130	0.989	0.358	0.058	0.353	17.462	0.133
Nasal Height (n-ns)	F	51	0.970	0.230	0.119	0.069	12.725	0.079
	M	52	0.915	0.001	0.113	0.092	6.846	0.445
	Total	103	0.926	0.000	0.074	0.182	7.942	0.635
Nasal Breadth (al-al)	F	53	0.989	0.895	0.072	0.712	11.340	0.124
	M	52	0.957	0.055	0.112	0.106	6.077	0.531
	Total	105	0.984	0.247	0.060	0.466	8.533	0.577
Orbital Breadth (mf-ec)	F	57	0.980	0.461	0.072	0.648	8.035	0.430
	M	55	0.943	0.011	0.087	0.379	7.364	0.392
	Total	112	0.971	0.017	0.045	0.830	8.500	0.668
Orbital Height	F	56	0.985	0.705	0.088	0.347	9.214	0.325
	M	55	0.980	0.473	0.072	0.688	8.091	0.325
	Total	111	0.985	0.230	0.065	0.292	11.216	0.425
Biorbital Breadth (ec-ec)	F	47	0.966	0.179	0.082	0.587	8.532	0.288
	M	46	0.977	0.477	0.096	0.364	6.174	0.520
	Total	93	0.991	0.752	0.053	0.751	10.301	0.414

Table 6 – 9 Cont'd: Cranial normality test results.

	Sex	n	Wilks (W)	*p*-value	Kolmogorov (D)	*p*-value	D'Agostino-Pearson (P)	*p*-value
Interorbital Breadth (mf-mf)	F	64	0.964	0.062	0.070	0.610	2.688	0.952
	M	59	0.986	0.706	0.063	0.815	6.068	0.640
	Total	123	0.980	0.061	0.049	0.653	11.423	0.409
Frontal Chord (n-b)	F	67	0.384	0.000	0.266	0.000	62.866	0.000
	M	63	0.973	0.189	0.120	0.025	15.048	0.058
	Total	130	0.515	0.000	0.183	0.000	66.615	0.000
Parietal Chord (b-l)	F	68	0.979	0.295	0.062	0.740	4.794	0.779
	M	62	0.977	0.300	0.071	0.605	9.323	0.316
	Total	130	0.984	0.128	0.053	0.495	14.923	0.246
Occipital Chord (l-o)	F	66	0.986	0.692	0.048	0.968	4.333	0.826
	M	57	0.985	0.722	0.063	0.836	5.719	0.679
	Total	123	0.984	0.162	0.054	0.500	5.959	0.876
Foramen Magnum Length (ba-o)	F	59	0.984	0.629	0.078	0.508	8.678	0.370
	M	51	0.971	0.252	0.087	0.427	1.353	0.987
	Total	110	0.991	0.677	0.062	0.382	11.418	0.409
Foramen Magnum Breadth	F	60	0.989	0.869	0.083	0.383	7.100	0.526
	M	48	0.969	0.233	0.109	0.160	7.417	0.387
	Total	108	0.988	0.431	0.080	0.087	15.407	0.165
Mastoid Length	F	72	0.983	0.441	0.072	0.462	6.000	0.740
	M	68	0.984	0.547	0.058	0.833	6.088	0.637
	Total	140	0.993	0.753	0.039	0.858	10.429	0.578
Chin Height (gn-id)	F	71	0.945	0.004	0.112	0.027	15.704	0.073
	M	59	0.986	0.727	0.085	0.367	11.288	0.186
	Total	130	0.988	0.328	0.064	0.210	17.462	0.133
Body Height at Mental Foramen	F	74	0.900	0.000	0.144	0.001	18.432	0.030
	M	66	0.962	0.042	0.081	0.355	14.000	0.082
	Total	140	0.967	0.002	0.089	0.009	20.071	0.066
Body Thickness at Mental Foramen	F	75	0.977	0.201	0.075	0.372	16.680	0.054
	M	69	0.985	0.573	0.092	0.159	12.783	0.120
	Total	144	0.986	0.150	0.062	0.200	16.833	0.156
Bigonial Diameter (go-go)	F	59	0.984	0.627	0.055	0.929	3.085	0.929
	M	52	0.974	0.307	0.077	0.618	8.000	0.333
	Total	111	0.972	0.021	0.069	0.226	8.694	0.650
Bicondylar Breadth (cdl-cdl)	F	44	0.986	0.864	0.066	0.901	2.364	0.937
	M	36	0.968	0.377	0.098	0.519	3.000	0.809
	Total	80	0.993	0.947	0.053	0.837	5.500	0.789
Minimum Ramus Breadth	F	71	0.984	0.525	0.088	0.190	6.915	0.646
	M	61	0.989	0.873	0.053	0.938	6.262	0.618
	Total	132	0.987	0.223	0.056	0.406	6.182	0.907
Maximum Ramus Breadth	F	67	0.891	0.000	0.086	0.258	7.373	0.497
	M	56	0.945	0.013	0.072	0.657	4.107	0.847
	Total	123	0.980	0.064	0.042	0.850	7.553	0.753
Mandibular Length	F	52	0.960	0.078	0.095	0.282	11.077	0.135
	M	52	0.965	0.132	0.084	0.472	5.692	0.576
	Total	104	0.960	0.003	0.071	0.223	13.000	0.224
Ramus Height	F	27	0.949	0.201	0.169	0.046	14.185	0.014
	M	17	0.919	0.143	0.175	0.179	7.294	0.121
	Total	44	0.972	0.355	0.073	0.799	9.636	0.210

Age and sex correlations

Dental metrics are easily affected by age-related dental wear (Hillson, 1996a; Hillson, et al. 2005) and have been shown to exhibit sexual dimorphic size differences (Kieser, 1990; Moorrees, 1959; Seipel, 1946). Although teeth with moderate to high dental wear were omitted from this study, it is still important to verify that wear does not significantly affect any single measurement. Dental non-metric traits are reported to show minimal trait sexual dimorphism (Bermudez de Castro, 1989; Hanihara, 1992, 2008; Irish, 1993; Scott 1973, 1980; Scott and Turner II, 1997; Smith and Shegev, 1988; Turner II, et al. 1991), therefore pooling of the sexes for nonmetric dental traits is considered standard (Irish, 1997). However, certain traits are more commonly expressed in males or females (Nichol, 1990; Harris, 2007; Garn, et al. 1966a, 1966b). Cranial nonmetrics do not correlate with age, but produce mixed results for correlations with sex (Corruccini, 1974; Perizonius, 1979). All variables were tested for correlation with age and sex using linear and logistic regression analysis for the metric data and chi-square tests for non-metric data. Variables with significant p-values were removed prior to the multivariate analysis.

Since the dental metrics include only the permanent dentition, there was no need to remove subadults from the dental data. The cranial metric data were first reduced to adults and older adolescents, due to age-related growth differences between adults and subadults. Linear regression was then utilized to test for correlation with age, for each metric variable. Due to the compounding influence of sexual dimorphism, linear regression analyses were run separately for each sex and for the total sample. The midpoint of the age-estimate range was used for the linear regression comparisons. The linear regression function *lm*(), from the R package *stats* was used

to run the age comparisons (R Core Team, 2017). The results of the dental and cranial metric correlations with age are presented in Table 6-10 and Table 6-11.

Linear regression analysis was also used to test the dental non-metric traits for correlation with age. Sexual dimorphism has a much smaller influence on non-metric traits and therefore for the non-metric data, the datasets were not separated by sex prior to the linear regression analysis. As with the metric data, each non-metric trait was compared to the age midpoints, using the linear model function (*lm*()) from the *stats* package of R (R Core Team, 2017). Traits that correlated significantly with age were removed from the final multivariate statistical analysis. The linear regression for age-correlation was run on the non-dichotomized and the dichotomized datasets. The results are presented in Table 6-12 and Table 6-13.

To test for correlation with sex the non-metric variables were compared using the chi-square test, *chisq.test*(), and the Fisher's Odds Ratio statistic, *fisher.test*(), from the *stats* package in R (R Core Team, 2017). The Fisher's test was included as it is reported to handle small sample sizes better. The chi-square test comparisons were run on both the non-dichotomized and dichotomized data sets. Any variables that significantly correlated with sex were selected for removal from the final analysis. The results are presented in Table 6-14 and Table 6-15. Rather than remove metric variables due to correlation with sex, the metric data were standardized for sex after variable exclusion but prior to the multivariate analyses (see below).

Table 6 - 10: Dental metric linear regression and age results.

	Sex	n	Adjusted R^2	F	*p*-value
MD Crown UI1	F	16	0.171	4.093	0.063
	M	12	0.174	3.320	0.098
	Total	55	0.043	3.417	0.070
MD Crown UI2	F	27	-0.004	0.904	0.351
	M	20	-0.048	0.132	0.721
	Total	62	0.021	2.277	0.137
MD Crown UC	F	35	0.047	2.681	0.111
	M	37	-0.005	0.807	0.375
	Total	89	-0.002	0.832	0.364
MD Crown UP3	F	42	0.071	4.132	0.049
	M	32	-0.032	0.042	0.839
	Total	89	-0.001	0.943	0.334
MD Crown UP4	F	39	0.091	4.813	0.035
	M	35	-0.009	0.697	0.410
	Total	85	0.057	6.043	0.016
MD Crown UM1	F	40	0.007	1.255	0.270
	M	29	0.113	4.559	0.042
	Total	124	0.040	6.182	0.014
MD Crown UM2	F	50	-0.021	0.001	0.971
	M	40	-0.026	0.018	0.895
	Total	111	-0.008	0.152	0.697
MD Crown UM3	F	34	-0.031	0.001	0.975
	M	35	0.128	5.980	0.020
	Total	75	-0.006	0.551	0.460
MD Crown LI1	F	22	0.009	1.190	0.288
	M	21	0.186	5.555	0.029
	Total	72	0.027	2.959	0.090
MD Crown LI2	F	34	-0.019	0.380	0.542
	M	29	-0.001	0.978	0.332
	Total	94	-0.006	0.400	0.529
MD Crown LC	F	52	0.004	1.212	0.276
	M	48	0.019	1.922	0.172
	Total	125	0.000	1.008	0.317
MD Crown LP3	F	52	0.112	7.459	0.009
	M	50	0.042	3.147	0.082
	Total	118	0.047	5.724	0.018
MD Crown LP4	F	52	0.000	0.983	0.326
	M	48	0.107	6.622	0.013
	Total	115	0.017	2.959	0.088
MD Crown LM1	F	39	0.006	1.217	0.277
	M	32	-0.022	0.320	0.576
	Total	119	-0.008	0.037	0.848
MD Crown LM2	F	43	-0.016	0.350	0.557
	M	38	-0.012	0.571	0.455
	Total	99	0.015	2.507	0.117
MD Crown LM3	F	37	-0.017	0.406	0.528
	M	31	0.023	1.707	0.202
	Total	71	-0.010	0.327	0.569
BL Crown UI1	F	22	0.140	4.429	0.048
	M	19	0.157	4.343	0.053
	Total	69	0.234	21.810	0.000
BL Crown UI2	F	37	-0.023	0.198	0.659

Table 6 – 10 Cont'd: Dental metric linear regression and age results.

	Sex	n	Adjusted R^2	F	*p*-value
	M	31	-0.017	0.497	0.486
	Total	82	0.014	2.139	0.148
BL Crown UC	F	36	-0.027	0.075	0.787
	M	38	-0.027	0.044	0.834
	Total	91	0.018	2.689	0.105
BL Crown UP3	F	43	-0.024	0.014	0.905
	M	36	-0.026	0.115	0.737
	Total	94	-0.006	0.403	0.527
BL Crown UP4	F	39	-0.015	0.421	0.521
	M	36	0.024	1.860	0.182
	Total	86	-0.012	0.001	0.972
BL Crown UM1	F	40	-0.022	0.162	0.690
	M	30	-0.018	0.475	0.496
	Total	125	0.040	6.208	0.014
BL Crown UM2	F	49	0.003	1.148	0.290
	M	40	-0.001	0.959	0.334
	Total	109	-0.004	0.599	0.441
BL Crown UM3	F	34	0.168	7.649	0.009
	M	35	0.127	5.924	0.021
	Total	75	-0.009	0.341	0.561
BL Crown LI1	F	31	0.003	1.088	0.306
	M	25	-0.006	0.860	0.363
	Total	82	0.068	6.956	0.010
BL Crown LI2	F	46	0.020	1.935	0.171
	M	39	-0.026	0.032	0.859
	Total	114	0.024	3.835	0.053
BL Crown LC	F	51	-0.020	0.005	0.946
	M	49	-0.014	0.358	0.553
	Total	124	0.017	3.113	0.080
BL Crown LP3	F	51	-0.016	0.227	0.636
	M	51	-0.020	0.029	0.866
	Total	119	0.002	1.244	0.267
BL Crown LP4	F	51	0.008	1.416	0.240
	M	48	-0.011	0.483	0.491
	Total	113	-0.008	0.094	0.760
BL Crown LM1	F	38	-0.003	0.873	0.356
	M	32	-0.032	0.051	0.823
	Total	118	0.098	13.700	0.000
BL Crown LM2	F	41	-0.023	0.087	0.769
	M	38	-0.001	0.958	0.334
	Total	98	-0.010	0.024	0.878
BL Crown LM3	F	37	-0.022	0.232	0.633
	M	33	-0.018	0.425	0.519
	Total	73	-0.008	0.445	0.507
MD CEJ UI1	F	34	-0.014	0.537	0.469
	M	35	-0.011	0.630	0.433
	Total	93	0.001	1.117	0.293
MD CEJ UI2	F	41	0.029	2.175	0.148
	M	44	0.024	2.058	0.159
	Total	100	-0.007	0.290	0.592
MD CEJ UC	F	47	-0.017	0.212	0.648
	M	51	-0.015	0.260	0.612

Table 6 – 10 Cont'd: Dental metric linear regression and age results.

	Sex	n	Adjusted R^2	F	*p*-value
	Total	116	0.003	1.292	0.258
MD CEJ UP3	F	48	-0.006	0.699	0.408
	M	50	-0.018	0.133	0.717
	Total	112	-0.001	0.851	0.358
MD CEJ UP4	F	48	-0.014	0.360	0.552
	M	51	-0.015	0.248	0.620
	Total	110	-0.006	0.404	0.527
MD CEJ UM1	F	48	0.002	1.081	0.304
	M	49	0.021	2.039	0.160
	Total	133	0.002	1.325	0.252
MD CEJ UM2	F	49	-0.021	0.010	0.922
	M	50	0.005	1.225	0.274
	Total	115	-0.008	0.044	0.834
MD CEJ UM3	F	31	-0.013	0.614	0.440
	M	38	-0.027	0.011	0.918
	Total	72	-0.008	0.430	0.514
MD CEJ LI1	F	43	-0.017	0.304	0.584
	M	37	-0.010	0.643	0.428
	Total	105	0.000	1.039	0.311
MD CEJ LI2	F	53	-0.006	0.695	0.408
	M	50	-0.018	0.145	0.705
	Total	130	-0.007	0.075	0.785
MD CEJ LC	F	61	0.007	1.432	0.236
	M	56	-0.016	0.127	0.723
	Total	140	0.011	2.603	0.109
MD CEJ LP3	F	61	-0.011	0.341	0.562
	M	57	0.003	1.147	0.289
	Total	133	-0.007	0.059	0.809
MD CEJ LP4	F	58	-0.003	0.851	0.360
	M	57	0.029	2.666	0.108
	Total	129	-0.007	0.113	0.737
MD CEJ LM1	F	48	-0.005	0.785	0.380
	M	50	-0.007	0.640	0.428
	Total	135	0.011	2.519	0.115
MD CEJ LM2	F	46	0.000	1.001	0.323
	M	46	-0.016	0.312	0.579
	Total	110	-0.007	0.241	0.624
MD CEJ LM3	F	37	-0.014	0.496	0.486
	M	35	-0.025	0.170	0.683
	Total	75	0.005	1.350	0.249
BL CEJ UI1	F	35	-0.028	0.075	0.787
	M	35	0.022	1.748	0.195
	Total	94	0.099	11.270	0.001
BL CEJ UI2	F	42	-0.024	0.028	0.869
	M	44	-0.015	0.359	0.553
	Total	101	0.001	1.053	0.307
BL CEJ UC	F	45	-0.007	0.680	0.414
	M	52	-0.016	0.207	0.651
	Total	114	0.030	4.449	0.037
BL CEJ UP3	F	47	-0.004	0.803	0.375
	M	50	-0.007	0.680	0.414
	Total	111	-0.008	0.104	0.748

Table 6 – 10 Cont'd: Dental metric linear regression and age results.

	Sex	n	Adjusted R^2	F	*p*-value
BL CEJ UP4	F	45	-0.016	0.291	0.592
	M	48	-0.001	0.930	0.340
	Total	104	-0.009	0.114	0.737
BL CEJ UM1	F	48	0.078	4.971	0.031
	M	48	0.029	2.399	0.128
	Total	132	-0.006	0.264	0.608
BL CEJ UM2	F	50	-0.021	0.008	0.929
	M	50	0.005	1.227	0.274
	Total	116	-0.008	0.072	0.789
BL CEJ UM3	F	32	-0.003	0.897	0.351
	M	39	0.002	1.071	0.307
	Total	74	-0.014	0.002	0.968
BL CEJ LI1	F	39	0.004	1.159	0.289
	M	31	-0.034	0.024	0.877
	Total	95	-0.005	0.549	0.461
BL CEJ LI2	F	50	-0.006	0.706	0.405
	M	44	-0.022	0.079	0.781
	Total	121	-0.008	0.000	0.987
BL CEJ LC	F	62	-0.011	0.323	0.572
	M	55	-0.012	0.346	0.559
	Total	139	0.002	1.341	0.249
BL CEJ LP3	F	59	-0.017	0.037	0.848
	M	56	-0.007	0.607	0.439
	Total	130	-0.007	0.056	0.813
BL CEJ LP4	F	46	-0.019	0.172	0.680
	M	44	-0.020	0.162	0.690
	Total	102	-0.005	0.477	0.491
BL CEJ LM1	F	44	-0.011	0.537	0.468
	M	45	-0.022	0.039	0.845
	Total	126	-0.002	0.696	0.406
BL CEJ LM2	F	34	-0.030	0.038	0.847
	M	36	-0.020	0.309	0.582
	Total	86	-0.008	0.330	0.567
BL CEJ LM3	F	29	0.003	1.071	0.310
	M	30	-0.031	0.126	0.725
	Total	61	-0.015	0.101	0.752

Table 6 - 11: Cranial metric linear regression and age results.

	Sex	n	Adjusted R^2	F	*p*-value
Maximum Length (g-op)	F	60	0.178	13.730	0.000
	M	53	0.044	3.365	0.072
	Total	113	0.082	11.060	0.001
Maximum Breadth (eu-eu)	F	58	-0.015	0.180	0.673
	M	55	-0.003	0.646	0.425
	Total	113	-0.006	0.308	0.580
Bizygomatic Breadth (zy-zy)	F	32	-0.033	0.008	0.930
	M	39	0.041	2.639	0.113
	Total	71	-0.001	0.900	0.346
Basion-Bregma (ba-b)	F	57	-0.017	0.060	0.808
	M	49	-0.016	0.228	0.635
	Total	106	-0.010	0.005	0.946
Cranial Base Length (ba-n)	F	56	-0.008	0.583	0.449
	M	48	-0.022	0.011	0.918
	Total	104	-0.007	0.252	0.617
Basion-Prosthion Length (ba-pr)	F	49	-0.006	0.722	0.400
	M	43	-0.001	0.974	0.329
	Total	92	-0.011	0.003	0.954
Maximum Alveolar Breadth (ecm-ecm)	F	56	0.207	15.350	0.000
	M	56	0.074	5.373	0.024
	Total	112	0.083	11.060	0.001
Maximum Alveolar Length (pr-alv)	F	58	-0.014	0.216	0.644
	M	58	-0.012	0.306	0.582
	Total	116	-0.008	0.088	0.767
Biauricular Breadth	F	58	-0.011	0.390	0.535
	M	54	-0.016	0.171	0.681
	Total	112	-0.009	0.023	0.880
Upper Facial Height (n-pr)	F	51	0.001	1.050	0.311
	M	51	-0.010	0.497	0.484
	Total	102	-0.010	0.027	0.869
Minimum Frontal Breadth (ft-ft)	F	65	-0.012	0.251	0.618
	M	64	-0.008	0.524	0.472
	Total	129	-0.002	0.701	0.404
Upper Facial Breadth (fmt-fmt)	F	66	0.016	2.067	0.155
	M	64	0.013	1.824	0.182
	Total	130	0.018	3.308	0.071
Nasal Height (n-ns)	F	51	-0.020	0.004	0.948
	M	52	-0.012	0.380	0.541
	Total	103	-0.005	0.511	0.476
Nasal Breadth (al-al)	F	53	0.081	5.604	0.022
	M	52	0.043	3.317	0.075
	Total	105	0.082	10.320	0.002
Orbital Breadth (mf-ec)	F	57	-0.016	0.120	0.731
	M	55	-0.017	0.080	0.778
	Total	112	-0.008	0.144	0.705
Orbital Height	F	56	0.000	1.022	0.316
	M	55	-0.014	0.261	0.612
	Total	111	-0.008	0.087	0.769
Biorbital Breadth (ec-ec)	F	47	0.035	2.679	0.109
	M	46	-0.023	0.004	0.950
	Total	93	0.002	1.199	0.277

Table 6 – 11 Cont'd: Cranial metric linear regression and age results.

	Sex	n	Adjusted R^2	F	*p*-value
Interorbital Breadth (mf-mf)	F	64	-0.013	0.205	0.653
	M	59	-0.015	0.122	0.728
	Total	123	-0.005	0.343	0.559
Frontal Chord (n-b)	F	67	-0.013	0.130	0.720
	M	63	-0.010	0.376	0.542
	Total	130	-0.004	0.517	0.473
Parietal Chord (b-l)	F	68	0.014	1.922	0.170
	M	62	-0.014	0.187	0.667
	Total	130	0.006	1.802	0.182
Occipital Chord (l-o)	F	66	-0.015	0.028	0.868
	M	57	-0.017	0.065	0.799
	Total	123	-0.008	0.024	0.876
Foramen Magnum Length (ba-o)	F	59	0.083	6.276	0.015
	M	51	0.014	1.729	0.195
	Total	110	-0.003	0.661	0.418
Foramen Magnum Breadth	F	60	0.043	3.670	0.060
	M	48	-0.001	0.961	0.332
	Total	108	-0.003	0.631	0.429
Mastoid Length	F	72	-0.011	0.205	0.652
	M	68	-0.013	0.115	0.736
	Total	140	-0.006	0.206	0.651
Chin Height (gn-id)	F	71	0.058	5.272	0.025
	M	59	0.002	1.109	0.297
	Total	130	0.031	5.172	0.025
Body Height at Mental Foramen	F	74	0.064	5.985	0.017
	M	66	-0.009	0.423	0.518
	Total	140	0.019	3.763	0.054
Body Thickness at Mental Foramen	F	75	-0.014	0.005	0.943
	M	69	-0.012	0.179	0.673
	Total	144	-0.006	0.143	0.706
Bigonial Diameter (go-go)	F	59	0.268	22.250	0.000
	M	52	0.020	2.045	0.159
	Total	111	0.072	9.508	0.003
Bicondylar Breadth (cdl-cdl)	F	44	0.070	4.243	0.046
	M	36	0.114	5.498	0.025
	Total	80	0.071	7.060	0.010
Minimum Ramus Breadth	F	71	0.000	1.018	0.316
	M	61	-0.014	0.143	0.707
	Total	132	-0.004	0.487	0.486
Maximum Ramus Breadth	F	67	-0.013	0.154	0.696
	M	56	0.038	3.177	0.080
	Total	123	0.011	2.410	0.123
Mandibular Length	F	52	-0.020	0.003	0.957
	M	52	-0.010	0.492	0.487
	Total	104	-0.009	0.083	0.774
Ramus Height	F	27	0.102	3.952	0.058
	M	17	-0.055	0.163	0.692
	Total	44	0.013	1.562	0.218

Table 6 - 12: Dental non-metric linear regression and age results.

	n	Non-Dichotomized			Dichotomized		
		Adj R^2	F	*p*-value	Adj R^2	F	*p*-value
UI1 Shoveling	85	0.179	4.652	0.001	0.039	4.410	0.039
UI2 Shoveling	91	0.088	2.440	0.032	0.074	8.231	0.005
UC Shoveling	102	0.043	3.259	0.043	0.043	5.582	0.020
LI1 Shoveling	112	0.121	16.260	0.000	0.121	16.260	0.000
LI2 Shoveling	130	0.103	15.800	0.000	0.103	15.800	0.000
LC Shoveling	138	0.023	2.594	0.078	0.024	4.416	0.037
UI1 Double Shoveling	96	-0.015	0.533	0.661	-0.007	0.351	0.555
UI2 Double Shoveling	101	0.008	1.272	0.289	0.023	3.351	0.070
UC Double Shoveling	111	0.108	4.334	0.003	-0.002	0.737	0.392
UI1 Labial Curvature	86	0.044	1.987	0.104	0.040	4.503	0.037
UI2 Labial Curvature	91	-0.029	0.373	0.827	0.000	1.008	0.318
UI1 Tuberculum Dentale	85	0.119	3.833	0.007	0.063	6.622	0.012
UI2 Tuberculum Dentale	99	0.005	1.091	0.371	-0.010	0.009	0.924
UC Tuberculum Dentale	101	0.067	2.205	0.049	0.085	10.330	0.002
LI1 Tuberculum Dentale	NA	NA	NA	NA	NA	NA	NA
LI2 Tuberculum Dentale	NA	NA	NA	NA	NA	NA	NA
LC Tuberculum Dentale	140	0.013	1.912	0.152	-0.006	0.217	0.642
UI1 Interruption Grooves	86	-0.034	0.073	0.974	-0.012	0.009	0.925
UI2 Interruption Grooves	99	-0.030	0.297	0.880	-0.001	0.910	0.343
UC Interruption Grooves	103	-0.006	0.840	0.503	0.013	2.337	0.130
LI1 Interruption Grooves	NA	NA	NA	NA	NA	NA	NA
LI2 Interruption Grooves	NA	NA	NA	NA	NA	NA	NA
LC Interruption Grooves	140	-0.001	0.816	0.368	-0.001	0.816	0.368
UI1 Winging	81	0.008	1.312	0.275	-0.002	0.861	0.356
UI2 Variants	107	0.003	1.168	0.315	0.013	2.339	0.129
UI2 Peg Shaped	107	0.012	2.339	0.129	0.012	2.339	0.129
LI2 Peg Shaped	NA	NA	NA	NA	NA	NA	NA
UC Mesial Ridge	67	0.019	2.277	0.136	0.019	2.277	0.136
UC Distal Accessory Ridge	61	0.044	1.694	0.164	0.068	5.474	0.023
LC Distal Accessory Ridge	90	0.089	3.167	0.018	0.116	12.670	0.001
LC Double Root	145	0.013	1.647	0.181	-0.003	0.561	0.455
UI2 Congenital Absence	158	0.004	1.688	0.196	0.004	1.688	0.196
LI1 Congenital Absence	NA	NA	NA	NA	NA	NA	NA
UI1 Root #	NA	NA	NA	NA	NA	NA	NA
UI2 Root #	NA	NA	NA	NA	NA	NA	NA
UC Root #	NA	NA	NA	NA	NA	NA	NA
LI1 Root #	NA	NA	NA	NA	NA	NA	NA
LI2 Root #	NA	NA	NA	NA	NA	NA	NA
LC Root #	145	0.011	2.606	0.109	0.011	2.606	0.109
UI1 Radical #	112	-0.006	0.313	0.577	-0.006	0.313	0.577
UI2 Radical #	113	0.008	1.458	0.237	-0.008	0.116	0.734
UC Radical #	122	-0.008	0.005	0.946	-0.008	0.005	0.946
LI1 Radical #	144	0.004	1.594	0.209	0.004	1.594	0.209
LI2 Radical #	155	0.008	2.286	0.133	0.008	2.286	0.133
LC Radical #	NA	NA	NA	NA	NA	NA	NA
UP3 Accessory Ridge - Mesial	72	0.050	4.698	0.034	0.050	4.698	0.034
UP4 Accessory Ridge - Mesial	65	0.069	5.759	0.019	0.069	5.759	0.019
LP3 Accessory Ridge - Mesial	86	0.013	2.079	0.153	0.013	2.079	0.153
LP4 Accessory Ridge - Mesial	76	-0.005	0.654	0.421	-0.005	0.654	0.421
UP3 Accessory Ridge - Distal	72	0.072	6.501	0.013	0.072	6.501	0.013
UP4 Accessory Ridge - Distal	65	0.000	1.027	0.315	0.000	1.027	0.315
LP3 Accessory Ridge - Distal	86	0.158	16.960	0.000	0.158	16.960	0.000

Table 6 – 12 Cont'd: Dental non-metric linear regression and age results.

		Non-Dichotomized			Dichotomized		
	n	Adj R^2	F	*p*-value	Adj R^2	F	*p*-value
LP4 Accessory Ridge – Distal	76	0.161	15.440	0.000	0.161	15.440	0.000
UP3 Accessory Marginal Tubercles	99	-0.007	0.677	0.511	0.003	1.332	0.251
UP4 Accessory Marginal Tubercles	87	0.009	1.249	0.297	0.010	1.877	0.174
UP3 Odontomes	NA	NA	NA	NA	NA	NA	NA
UP4 Odontomes	NA	NA	NA	NA	NA	NA	NA
LP3 Odontomes	108	-0.009	0.073	0.787	-0.009	0.073	0.787
LP4 Odontomes	NA	NA	NA	NA	NA	NA	NA
UP4 Distosagittal Ridge	NA	NA	NA	NA	NA	NA	NA
LP3 Multiple Lingual Cusps	124	0.009	1.160	0.331	-0.008	0.059	0.808
LP4 Multiple Lingual Cusps	117	-0.035	0.505	0.850	-0.009	0.008	0.928
UP3 Tricuspid	NA	NA	NA	NA	NA	NA	NA
UP4 Tricuspid	96	0.004	1.362	0.246	0.004	1.362	0.246
UP3 Enamel Extension/Pearl	113	0.006	1.645	0.202	0.006	1.645	0.202
UP4 Enamel Extension/Pearl	NA	NA	NA	NA	NA	NA	NA
LP3 Tome's Root	122	0.012	1.477	0.224	-0.008	0.055	0.816
UP4 Congenital Absence	NA	NA	NA	NA	NA	NA	NA
LP4 Congenital Absence	NA	NA	NA	NA	NA	NA	NA
UP3 Root #	103	-0.006	0.702	0.498	-0.005	0.467	0.496
UP4 Root #	99	-0.010	0.022	0.881	-0.010	0.022	0.881
UP3 Radical #	99	-0.002	0.922	0.433	0.001	1.146	0.287
UP4 Radical #	93	-0.007	0.696	0.506	-0.010	0.049	0.825
UM1 Carabelli's Cusp	139	0.311	9.879	0.000	0.224	40.820	0.000
UM2 Carabelli's Cusp	113	0.055	2.303	0.050	0.083	11.120	0.001
UM3 Carabelli's Cusp	75	0.058	1.905	0.105	0.020	2.506	0.118
UM1 Metacone (Cusp 3)	174	-0.008	0.526	0.665	-0.006	0.002	0.961
UM2 Metacone (Cusp 3)	131	0.000	1.014	0.389	0.006	1.839	0.178
UM3 Metacone (Cusp 3)	86	-0.024	0.349	0.790	-0.010	0.118	0.732
UM1 Mesial Paracone Tubercle	83	-0.003	0.718	0.399	-0.003	0.718	0.399
UM2 Mesial Paracone Tubercle	59	-0.003	0.810	0.372	-0.003	0.810	0.372
UM3 Mesial Paracone Tubercle	56	-0.017	0.102	0.751	-0.017	0.102	0.751
UM1 Protoconule Tubercle	83	0.106	10.760	0.002	0.106	10.760	0.002
UM2 Protoconule Tubercle	60	0.004	1.226	0.273	0.004	1.226	0.273
UM3 Protoconule Tubercle	57	-0.014	0.203	0.654	-0.014	0.203	0.654
UM1 Mesial Accessory Tubercle	85	0.027	3.308	0.073	0.027	3.308	0.073
UM2 Mesial Accessory Tubercle	58	0.082	6.120	0.016	0.082	6.120	0.016
UM3 Mesial Accessory Tubercle	58	0.018	2.048	0.158	0.018	2.048	0.158
UM1 Lingual Paracone Tubercle	81	0.206	21.730	0.000	0.206	21.730	0.000
UM2 Lingual Paracone Tubercle	59	0.067	5.158	0.027	0.067	5.158	0.027
UM3 Lingual Paracone Tubercle	58	-0.015	0.161	0.690	-0.015	0.161	0.690
UM1 Parastyle	163	-0.009	0.249	0.780	-0.006	0.013	0.911
UM2 Parastyle	126	-0.004	0.837	0.476	0.004	1.555	0.215
UM3 Parastyle	83	0.014	1.575	0.213	0.011	1.880	0.174
UM1 Enamel Extension/Pearl	133	-0.014	0.103	0.902	-0.006	0.197	0.658
UM2 Enamel Extension/Pearl	116	-0.010	0.716	0.583	-0.009	0.011	0.917
UM3 Enamel Extension/Pearl	75	-0.049	0.132	0.970	-0.010	0.302	0.585
UM3 Peg Shaped	89	-0.006	0.445	0.507	-0.006	0.445	0.507
UM3 Congenital Absence	111	-0.006	0.324	0.570	-0.006	0.324	0.570
LM3 Congenital Absence	127	-0.008	0.011	0.918	-0.008	0.011	0.918
UM1 Hypocone (Cusp 4)	171	0.026	2.488	0.062	0.034	7.063	0.009
UM2 Hypocone (Cusp 4)	122	0.050	2.065	0.063	0.033	5.082	0.026
UM3 Hypocone (Cusp 4)	81	-0.050	0.390	0.884	-0.008	0.333	0.566
UM1 Metaconule (Cusp 5)	118	0.027	1.655	0.151	0.043	6.233	0.014

Table 6 – 12 Cont'd: Dental non-metric linear regression and age results.

		Non-Dichotomized			Dichotomized		
	n	Adj R^2	F	*p*-value	Adj R^2	F	*p*-value
UM2 Metaconule (Cusp 5)	89	0.064	2.207	0.061	0.089	9.580	0.003
UM3 Metaconule (Cusp 5)	74	-0.002	0.972	0.442	-0.014	0.010	0.921
LM1 Hypoconulid (Cusp 5)	119	-0.003	0.923	0.469	0.008	1.942	0.166
LM2 Hypoconulid (Cusp 5)	79	0.091	2.567	0.034	0.026	3.059	0.084
LM3 Hypoconulid (Cusp 5)	69	0.027	1.376	0.245	-0.013	0.095	0.759
UM1 Root #	74	0.054	2.386	0.076	0.075	6.893	0.011
UM2 Root #	75	0.024	1.600	0.197	0.003	1.213	0.274
UM3 Root #	52	-0.014	0.770	0.517	-0.016	0.191	0.664
LM1 Root #	NA	NA	NA	NA	NA	NA	NA
LM2 Root #	80	0.040	2.660	0.076	0.007	1.561	0.215
LM3 Root #	68	0.016	1.530	0.224	0.007	1.490	0.227
UM1 Radical #	49	0.022	1.266	0.298	-0.018	0.131	0.720
UM2 Radical #	51	-0.021	0.745	0.566	-0.013	0.380	0.540
UM3 Radical #	42	-0.031	0.390	0.680	-0.018	0.275	0.603
LM1 Radical #	47	0.051	2.248	0.118	0.032	2.525	0.119
LM2 Radical #	58	0.013	1.246	0.302	-0.008	0.549	0.462
LM3 Radical #	50	-0.032	0.248	0.782	-0.012	0.412	0.524
UM1 Cusp #	157	0.087	8.388	0.000	0.092	16.860	0.000
UM2 Cusp #	115	0.092	6.756	0.002	-0.009	0.006	0.941
UM3 Cusp #	82	0.012	1.336	0.269	-0.009	0.285	0.595
LM1 Cusp #	136	0.158	13.680	0.000	0.030	5.128	0.025
LM2 Cusp #	96	-0.004	0.791	0.457	-0.007	0.355	0.553
LM3 Cusp #	73	-0.001	0.986	0.405	-0.014	0.000	0.998
LM1 Entoconulid (Cusp 6)	74	-0.038	0.255	0.936	-0.009	0.055	0.815
LM2 Entoconulid (Cusp 6)	69	-0.018	0.383	0.683	-0.005	0.637	0.428
LM3 Entoconulid (Cusp 6)	56	-0.032	0.573	0.683	-0.018	0.030	0.864
LM1 Metaconulid (Cusp 7)	113	0.052	2.028	0.068	0.051	6.957	0.010
LM2 Metaconulid (Cusp 7)	75	-0.009	0.829	0.512	0.017	2.263	0.137
LM3 Metaconulid (Cusp 7)	59	-0.023	0.678	0.610	0.001	1.058	0.308
LM1 Groove Pattern	114	0.015	1.878	0.158	0.024	3.777	0.054
LM2 Groove Pattern	95	0.003	1.161	0.318	0.009	1.828	0.180
LM3 Groove Pattern	69	-0.025	0.156	0.856	-0.015	0.008	0.931
LM1 Protostylid Buccal Pit	140	0.009	2.253	0.136	0.009	2.253	0.136
LM2 Protostylid Buccal Pit	113	0.026	4.017	0.047	0.026	4.017	0.047
LM3 Protostylid Buccal Pit	79	-0.003	0.805	0.372	-0.003	0.805	0.372
LM1 Protostylid	NA	NA	NA	NA	NA	NA	NA
LM2 Protostylid	113	-0.018	0.010	0.990	-0.009	0.009	0.925
LM3 Protostylid	79	-0.005	0.823	0.443	0.008	1.636	0.205
LM1 Deflecting Wrinkle	73	0.095	3.519	0.019	0.118	10.610	0.002
LM2 Deflecting Wrinkle	51	-0.039	0.375	0.772	-0.012	0.427	0.517
LM3 Deflecting Wrinkle	43	-0.013	0.726	0.490	-0.022	0.107	0.746
LM1 Anterior Fovea	79	0.064	2.331	0.064	0.032	3.613	0.061
LM2 Anterior Fovea	59	0.159	3.746	0.009	-0.017	0.028	0.868
LM3 Anterior Fovea	49	-0.031	0.644	0.634	-0.017	0.218	0.643
LM1 Distal Trigonid Crest	92	-0.009	0.213	0.645	-0.009	0.213	0.645
LM2 Distal Trigonid Crest	57	-0.018	0.000	0.984	-0.018	0.000	0.984
LM3 Distal Trigonid Crest	47	-0.022	0.039	0.844	-0.022	0.039	0.844

* NA – all observations for this trait were "A"

Table 6 - 13: Cranial non-metric linear regression and age results

		Non-Dichotomized			Dichotomized		
	n	Adj R^2	F	*p*-value	Adj R^2	F	*p*-value
Metopic Suture	211	-0.005	0.001	0.982	-0.005	0.001	0.982
Metopic Fissure	217	NA	NA	NA	NA	NA	NA
Supranasal Suture	212	0.002	1.363	0.244	0.002	1.363	0.244
Frontal Grooves	228	-0.002	0.878	0.454	-0.004	0.005	0.945
Supratrochlear Notch	226	0.024	2.845	0.039	0.024	6.606	0.011
Medial Supraorbital Notch	237	0.055	7.917	0.000	0.057	15.380	0.000
Lateral Supraorbital Notch	242	0.018	3.225	0.041	0.000	1.084	0.299
Nutrient Foramen in Notch	236	0.017	4.955	0.027	0.017	4.955	0.027
Superior Trochlear Foramen	223	0.086	6.205	0.000	0.029	7.542	0.007
Medial Supraorbital Foramen	237	0.041	4.329	0.005	0.001	1.188	0.277
Lateral Supraorbital Foramen	244	0.000	1.015	0.387	-0.004	0.109	0.742
Anterior Ethmoid Foramen	73	0.124	4.410	0.007	0.094	8.472	0.005
Posterior Ethmoid Foramen	108	-0.021	0.269	0.848	-0.009	0.001	0.980
Trochlear Spine Spur	163	0.017	3.861	0.051	0.017	3.861	0.051
Nasal Foramen	112	0.069	3.730	0.014	0.001	1.080	0.300
Infraorbital Suture	202	0.117	27.580	0.000	0.117	27.580	0.000
Accessory Infraorbital Foramen	207	-0.002	0.885	0.450	0.003	1.591	0.209
Zygomaxillary Tubercle	207	0.007	1.483	0.220	-0.004	0.267	0.606
Zygomatico-Facial Foramen	224	0.105	7.541	0.000	0.023	6.262	0.013
Marginal Tubercle	221	0.083	7.661	0.000	0.045	11.270	0.001
Bipartite Zygomatic	225	NA	NA	NA	NA	NA	NA
Parietal Foramen	212	0.011	2.156	0.118	-0.001	0.886	0.348
Symmetrically Thin Parietals	215	-0.004	0.138	0.711	-0.004	0.138	0.711
Coronal Ossicle	187	-0.010	0.070	0.932	-0.005	0.097	0.756
Sagittal Ossicle	188	-0.005	0.104	0.748	-0.005	0.104	0.748
Ossicle at Bregma	183	-0.003	0.507	0.477	-0.003	0.507	0.477
Lambdoid Ossicle	194	0.037	3.472	0.017	0.027	6.404	0.012
Ossicle at Lambda	189	-0.011	0.018	0.982	-0.005	0.003	0.953
Inca Bone	200	-0.005	0.018	0.893	-0.005	0.018	0.893
Occipito-Mastoid Ossicle	175	-0.006	0.036	0.849	-0.006	0.036	0.849
Occipital Foramen	209	-0.002	0.876	0.455	-0.001	0.858	0.356
Ossicle at Asterion	173	-0.006	0.006	0.938	-0.006	0.006	0.938
Condylar Canal	216	-0.006	0.574	0.633	-0.001	0.751	0.387
Double Condylar Facet	183	-0.003	0.484	0.488	-0.003	0.484	0.488
Hypoglossal Canal Bridge	220	0.050	6.764	0.001	0.040	10.110	0.002
Inter-Condylar Canal Bridge	214	0.118	15.260	0.000	0.094	23.030	0.000
Jugular Foramen Bridge	175	0.105	11.240	0.000	0.020	4.563	0.034
Precondylar Tubercle	202	0.052	3.773	0.006	0.058	7.136	0.001
Pharyngeal Tubercle	202	0.290	17.440	0.000	0.255	69.600	0.000
Pharyngeal Fovea	193	0.001	1.067	0.364	-0.005	0.135	0.713
Median Basilar Canal Foramen	170	-0.002	0.895	0.445	-0.004	0.386	0.536
Craniopharyngeal Canal	177	0.000	1.061	0.304	0.000	1.061	0.304
Tympanic Dehiscence	218	0.161	42.590	0.000	0.161	42.590	0.000
Postglenoid Foramen	234	0.012	3.868	0.050	0.012	3.868	0.050
Oval Foramen Incomplete	203	0.019	5.006	0.026	0.019	5.006	0.026
Foramen of Vesalius	206	-0.009	0.531	0.713	-0.005	0.033	0.856
Spinosum Foramen Open	188	0.026	6.001	0.015	0.026	6.001	0.015
Basilar Sphenoid Bridge	198	0.073	6.205	0.000	0.006	2.120	0.147
Accessory Lesser Palatine Foramen	172	0.083	6.171	0.001	0.070	13.930	0.000
Palatine Bridge	199	0.040	5.091	0.007	0.021	5.331	0.022
Palatine Torus	176	-0.001	0.947	0.438	0.005	1.911	0.169
Maxillary Torus	205	-0.001	0.851	0.429	0.003	1.656	0.200

Table 6 – 13 Cont'd: Cranial non-metric linear regression and age results

		Non-Dichotomized			Dichotomized		
	n	Adj R^2	F	*p*-value	Adj R^2	F	*p*-value
Retromastoid Process	201	0.060	5.795	0.004	0.057	10.110	0.002
Paracondylar Process	155	0.193	13.270	0.000	0.120	22.000	0.000
Sella Bridges	91	0.005	1.420	0.237	0.005	1.420	0.237
Flexure of Superior Sagittal Sulcus	206	0.008	1.532	0.207	-0.003	0.404	0.526
Auditory Torus	252	-0.003	0.219	0.641	-0.003	0.219	0.641
Suprameatal Spine	252	0.207	22.840	0.000	0.212	68.410	0.000
Suprameatal Depression	252	0.152	23.490	0.000	0.155	47.040	0.000
Inferior Squamous Foramen	231	0.013	2.001	0.115	0.020	5.642	0.018
Superior Squamous Foramen	206	-0.005	0.640	0.590	-0.005	0.003	0.959
Inferior Parietal Foramen	220	0.018	2.329	0.075	0.013	3.876	0.050
Bipartite Parietal	231	NA	NA	NA	NA	NA	NA
Bipartite Temporal Squama	227	NA	NA	NA	NA	NA	NA
Biasterionic Suture	188	0.002	1.112	0.346	-0.004	0.206	0.650
Mastoid Foramen Extrasutural	206	0.011	1.789	0.151	-0.004	0.127	0.722
Accessory Mastoid Foramen	236	0.048	3.980	0.004	0.059	15.830	0.000
Squamomastoid Suture	243	0.035	2.762	0.019	0.037	10.180	0.002
Parietal Notch Bone	186	0.000	1.150	0.319	-0.001	0.852	0.357
Epipteric Bone	152	-0.003	0.803	0.450	-0.006	0.172	0.679
Frontotemporal Articulation	169	0.000	0.995	0.320	0.000	0.995	0.320
Squamous Ossicle	160	0.012	1.656	0.179	0.014	3.305	0.071
Mandibular Torus	251	0.159	24.610	0.000	0.161	48.880	0.000
Accessory Mental Foramen	251	0.002	1.126	0.339	0.002	1.528	0.218
Mylohyoid Bridge	233	0.004	1.493	0.227	0.009	2.997	0.085
Mental Spines	241	0.350	26.860	0.00	0.207	63.530	0.000
Median Pit	241	0.029	2.775	0.028	0.015	2.859	0.059
Retromolar Foramen	195	-0.014	0.115	0.951	-0.005	0.050	0.823
Molar Foramen	230	-0.012	0.331	0.857	-0.004	0.031	0.860
Canal de Serres Foramen	226	-0.004	0.070	0.792	-0.004	0.070	0.792
Canal of Robinson	229	-0.010	0.222	0.881	-0.004	0.009	0.925
Rocker Mandible	182	0.115	24.520	0.000	0.115	24.520	0.000
Atlas Bridge	193	0.004	1.693	0.195	0.004	1.693	0.195
Double Articular Facet of C1	190	0.023	5.476	0.020	0.023	5.476	0.020
Septal Aperture	238	0.036	9.752	0.002	0.036	9.752	0.002

* NA – all observations for this trait were "A"

Table 6 - 14: Dental non-metric sex correlation results.

	n	Non-Dichotomized		Dichotomized			
		X^2	*p*-value	X^2	*p*-value	Fishers	*p*-value
UI1 Shoveling	53	4.110	0.392	0.526	0.468	0.456	0.318
UI2 Shoveling	73	1.960	0.924	0.087	0.769	0.753	0.615
UC Shoveling	82	1.570	0.457	0.004	0.951	1.141	0.821
LI1 Shoveling	79	0.008	0.929	0.008	0.929	Inf	0.456
LI2 Shoveling	98	0.000	1.000	0.000	1.000	1.042	1.000
LC Shoveling	113	4.690	0.096	0.533	0.465	1.448	0.424
UI1 Double Shoveling	63	3.650	0.161	2.225	0.136	0.234	0.082
UI2 Double Shoveling	80	2.740	0.254	1.423	0.233	0.286	0.150
UC Double Shoveling	90	1.700	0.636	0.000	1.000	1.941	1.000
UI1 Labial Curvature	57	2.330	0.676	0.156	0.693	0.709	0.600
UI2 Labial Curvature	72	2.880	0.579	0.069	0.793	0.792	0.644
UI1 Tuberculum Dentale	57	1.060	0.587	0.000	1.000	0.000	1.000
UI2 Tuberculum Dentale	81	3.450	0.486	0.144	0.704	1.623	0.519
UC Tuberculum Dentale	83	6.490	0.371	2.640	0.104	2.510	0.090
LI1 Tuberculum Dentale	82	NA	NA	NA	NA	NA	NA
LI2 Tuberculum Dentale	100	NA	NA	NA	NA	NA	NA
LC Tuberculum Dentale	114	0.000	1.000	0.000	1.000	1.152	1.000
UI1 Interruption Grooves	59	2.000	0.572	0.000	1.000	1.036	1.000
UI2 Interruption Grooves	82	8.630	0.071	0.315	0.575	0.559	0.520
UC Interruption Grooves	85	3.700	0.296	0.479	0.489	2.475	0.435
LI1 Interruption Grooves	80	NA	NA	NA	NA	NA	NA
LI2 Interruption Grooves	99	NA	NA	NA	NA	NA	NA
LC Interruption Grooves	115	0.000	1.000	0.000	1.000	0.000	1.000
UI1 Winging	63	2.320	0.314	0.000	1.000	1.490	1.000
UI2 Variants	87	2.950	0.229	0.001	0.972	0.000	0.483
UI2 Peg Shaped	87	0.001	0.972	0.001	0.972	0.000	0.483
LI2 Peg Shaped	107	NA	NA	NA	NA	NA	NA
UC Mesial Ridge	48	0.000	1.000	0.000	1.000	Inf	1.000
UC Distal Accessory Ridge	44	1.520	0.824	0.237	0.627	1.647	0.534
LC Distal Accessory Ridge	64	3.670	0.160	2.103	0.147	6.428	0.090
LC Double Root	126	2.440	0.487	0.832	0.362	0.359	0.281
UI2 Congenital Absence	127	0.000	1.000	0.000	1.000	0.867	1.000
LI1 Congenital Absence	135	NA	NA	NA	NA	NA	NA
UI1 Root #	121	NA	NA	NA	NA	NA	NA
UI2 Root #	117	NA	NA	NA	NA	NA	NA
UC Root #	119	NA	NA	NA	NA	NA	NA
LI1 Root #	126	NA	NA	NA	NA	NA	NA
LI2 Root #	129	NA	NA	NA	NA	NA	NA
LC Root #	126	1.210	0.272	1.205	0.272	0.216	0.213
UI1 Radical #	87	3.340	0.068	3.339	0.068	0.410	0.052
UI2 Radical #	94	9.370	0.009	6.965	0.008	0.131	0.004
UC Radical #	103	0.457	0.499	0.457	0.499	0.298	0.377
LI1 Radical #	114	1.100	0.294	1.102	0.294	0.000	0.247
LI2 Radical #	126	0.000	1.000	0.000	1.000	0.000	1.000
LC Radical #	122	NA	NA	NA	NA	NA	NA
UP3 Accessory Ridge - Mesial	55	0.011	0.918	0.011	0.918	0.619	0.686
UP4 Accessory Ridge - Mesial	53	0.298	0.585	0.298	0.585	0.443	0.436
LP3 Accessory Ridge - Mesial	70	1.830	0.176	1.835	0.176	0.169	0.102
LP4 Accessory Ridge - Mesial	61	0.092	0.762	0.092	0.762	1.909	0.674
UP3 Accessory Ridge - Distal	55	1.550	0.213	1.554	0.213	5.817	0.156
UP4 Accessory Ridge - Distal	53	0.457	0.499	0.457	0.499	2.245	0.444

Table 6 – 14 Cont'd: Dental non-metric sex correlation results.

	n	Non-Dichotomized		Dichotomized			
		X^2	*p*-value	X^2	*p*-value	Fishers	*p*-value
LP3 Accessory Ridge – Distal	70	0.000	1.000	0.000	1.000	1.082	1.000
LP4 Accessory Ridge – Distal	61	0.000	1.000	0.000	1.000	1.155	1.000
UP3 Accessory Marginal Tubercles	82	1.620	0.444	0.812	0.368	0.356	0.275
UP4 Accessory Marginal Tubercles	75	4.790	0.188	0.237	0.627	0.329	0.615
UP3 Odontomes	74	NA	NA	NA	NA	NA	NA
UP4 Odontomes	66	NA	NA	NA	NA	NA	NA
LP3 Odontomes	91	0.000	1.000	0.000	1.000	0.000	1.000
LP4 Odontomes	86	NA	NA	NA	NA	NA	NA
UP4 Distosagittal Ridge	73	NA	NA	NA	NA	NA	NA
LP3 Multiple Lingual Cusps	107	4.670	0.700	0.032	0.857	1.208	0.817
LP4 Multiple Lingual Cusps	101	12.200	0.143	2.452	0.117	0.488	0.106
UP3 Tricuspid	89	NA	NA	NA	NA	NA	NA
UP4 Tricuspid	84	0.000	1.000	0.000	1.000	Inf	1.000
UP3 Enamel Extension/Pearl	99	0.000	1.000	0.000	1.000	0.000	1.000
UP4 Enamel Extension/Pearl	97	NA	NA	NA	NA	NA	NA
LP3 Tome's Root	108	1.600	0.660	0.000	1.000	1.036	1.000
UP4 Congenital Absence	131	NA	NA	NA	NA	NA	NA
LP4 Congenital Absence	133	NA	NA	NA	NA	NA	NA
UP3 Root #	90	0.229	0.892	0.006	0.940	0.886	0.833
UP4 Root #	87	1.410	0.235	1.413	0.235	2.652	0.192
UP3 Radical #	85	5.170	0.160	0.000	1.000	0.000	1.000
UP4 Radical #	80	2.780	0.250	0.023	0.879	0.000	0.425
UM1 Carabelli's Cusp	80	6.520	0.368	0.000	1.000	1.058	1.000
UM2 Carabelli's Cusp	93	4.590	0.468	0.051	0.821	0.686	0.741
UM3 Carabelli's Cusp	69	4.000	0.549	0.000	1.000	0.969	1.000
UM1 Metacone (Cusp 3)	104	2.000	0.572	0.000	1.000	1.000	1.000
UM2 Metacone (Cusp 3)	107	1.110	0.775	0.241	0.623	2.192	0.429
UM3 Metacone (Cusp 3)	73	3.000	0.392	0.051	0.822	0.804	0.812
UM1 Mesial Paracone Tubercle	18	0.000	1.000	0.000	1.000	1.466	1.000
UM2 Mesial Paracone Tubercle	37	0.000	1.000	0.000	1.000	0.981	1.000
UM3 Mesial Paracone Tubercle	45	0.033	0.855	0.033	0.855	0.640	0.705
UM1 Protoconule Tubercle	18	0.000	1.000	0.000	1.000	0.000	1.000
UM2 Protoconule Tubercle	38	0.000	1.000	0.000	1.000	1.415	1.000
UM3 Protoconule Tubercle	46	0.000	1.000	0.000	1.000	1.217	1.000
UM1 Mesial Accessory Tubercle	20	0.804	0.370	0.804	0.370	0.216	0.325
UM2 Mesial Accessory Tubercle	37	0.007	0.932	0.007	0.932	0.615	0.680
UM3 Mesial Accessory Tubercle	47	0.704	0.402	0.704	0.402	0.358	0.269
UM1 Lingual Paracone Tubercle	17	0.000	1.000	0.000	1.000	0.000	1.000
UM2 Lingual Paracone Tubercle	37	0.287	0.592	0.287	0.592	0.000	0.495
UM3 Lingual Paracone Tubercle	47	0.522	0.470	0.522	0.470	2.351	0.437
UM1 Parastyle	101	1.530	0.464	0.445	0.505	0.482	0.487
UM2 Parastyle	103	0.919	0.631	0.000	1.000	1.836	1.000
UM3 Parastyle	74	2.290	0.318	0.003	0.957	0.000	0.473
UM1 Enamel Extension/Pearl	98	2.970	0.226	0.000	1.000	1.945	1.000
UM2 Enamel Extension/Pearl	99	7.670	0.053	1.547	0.214	2.891	0.200
UM3 Enamel Extension/Pearl	71	7.400	0.116	2.523	0.112	6.634	0.065
UM3 Peg Shaped	76	0.006	0.936	0.006	0.936	0.000	0.461
UM3 Congenital Absence	96	0.261	0.610	0.261	0.610	3.099	0.617
LM3 Congenital Absence	112	0.914	0.339	0.914	0.339	0.230	0.202
UM1 Hypocone (Cusp 4)	101	1.040	0.791	0.000	1.000	0.929	1.000
UM2 Hypocone (Cusp 4)	98	6.140	0.408	0.265	0.607	1.340	0.540
UM3 Hypocone (Cusp 4)	70	7.860	0.249	0.000	1.000	0.937	1.000

Table 6 – 14 Cont'd: Dental non-metric sex correlation results.

	n	Non-Dichotomized		Dichotomized			
		X^2	*p*-value	X^2	*p*-value	Fishers	*p*-value
UM1 Metaconule (Cusp 5)	53	1.860	0.762	0.023	0.879	0.703	0.732
UM2 Metaconule (Cusp 5)	66	2.360	0.669	0.000	1.000	1.064	1.000
UM3 Metaconule (Cusp 5)	64	9.170	0.102	0.065	0.799	0.775	0.799
LM1 Hypoconulid (Cusp 5)	55	2.240	0.814	0.013	0.909	1.232	0.787
LM2 Hypoconulid (Cusp 5)	55	4.030	0.402	0.514	0.474	0.536	0.377
LM3 Hypoconulid (Cusp 5)	64	8.470	0.132	3.882	0.049	3.264	0.039
UM1 Root #	61	1.930	0.381	0.173	0.677	0.351	0.614
UM2 Root #	67	2.220	0.528	0.000	1.000	1.098	1.000
UM3 Root #	52	1.800	0.614	0.172	0.679	1.531	0.558
LM1 Root #	61	NA	NA	NA	NA	NA	NA
LM2 Root #	65	0.443	0.801	0.054	0.817	1.791	0.678
LM3 Root #	66	0.570	0.752	0.087	0.768	0.630	0.721
UM1 Radical #	37	5.230	0.265	0.000	1.000	0.000	1.000
UM2 Radical #	44	6.110	0.191	0.000	1.000	1.229	1.000
UM3 Radical #	42	0.101	0.951	0.000	1.000	0.822	1.000
LM1 Radical #	33	1.480	0.478	0.000	1.000	0.730	1.000
LM2 Radical #	43	7.190	0.066	0.000	1.000	1.325	1.000
LM3 Radical #	48	3.100	0.212	0.828	0.363	0.000	0.186
UM1 Cusp #	87	1.330	0.515	0.000	1.000	0.927	1.000
UM2 Cusp #	91	2.210	0.331	1.044	0.307	4.384	0.217
UM3 Cusp #	71	2.730	0.434	0.246	0.620	0.683	0.608
LM1 Cusp #	69	3.700	0.157	1.440	0.230	0.291	0.161
LM2 Cusp #	73	1.740	0.418	0.000	1.000	0.000	1.000
LM3 Cusp #	69	7.100	0.069	5.554	0.018	3.658	0.015
LM1 Entoconulid (Cusp 6)	40	2.840	0.417	0.835	0.361	0.384	0.281
LM2 Entoconulid (Cusp 6)	46	0.000	1.000	0.000	1.000	0.000	1.000
LM3 Entoconulid (Cusp 6)	52	1.800	0.772	0.016	0.899	1.427	0.722
LM1 Metaconulid (Cusp 7)	49	4.040	0.544	0.000	1.000	1.147	1.000
LM2 Metaconulid (Cusp 7)	52	2.950	0.400	0.000	1.000	0.527	1.000
LM3 Metaconulid (Cusp 7)	55	4.720	0.317	0.371	0.543	0.496	0.486
LM1 Groove Pattern	49	1.880	0.391	0.575	0.448	2.696	0.417
LM2 Groove Pattern	71	1.240	0.538	0.040	0.842	1.300	0.782
LM3 Groove Pattern	65	1.350	0.509	0.742	0.389	0.579	0.324
LM1 Protostylid Buccal Pit	91	0.557	0.456	0.557	0.456	1.586	0.357
LM2 Protostylid Buccal Pit	93	1.150	0.284	1.148	0.284	0.427	0.235
LM3 Protostylid Buccal Pit	75	0.330	0.565	0.330	0.565	2.036	0.461
LM1 Protostylid	91	NA	NA	NA	NA	NA	NA
LM2 Protostylid	93	1.080	0.582	0.001	0.974	Inf	0.484
LM3 Protostylid	75	1.170	0.557	0.014	0.906	2.337	0.596
LM1 Deflecting Wrinkle	13	0.000	1.000	0.000	1.000	1.673	1.000
LM2 Deflecting Wrinkle	27	0.000	1.000	0.000	1.000	0.000	1.000
LM3 Deflecting Wrinkle	39	0.046	0.977	0.000	1.000	0.916	1.000
LM1 Ant. Fovea	18	2.970	0.564	0.000	1.000	0.728	1.000
LM2 Ant. Fovea	35	8.840	0.065	0.153	0.696	0.602	0.503
LM3 Ant. Fovea	44	6.190	0.186	0.448	0.503	0.553	0.373
LM1 Distal Trigonid Crest	28	0.022	0.883	0.022	0.883	Inf	0.429
LM2 Distal Trigonid Crest	34	0.000	1.000	0.000	1.000	0.000	1.000
LM3 Distal Trigonid Crest	42	0.000	1.000	0.000	1.000	1.343	1.000

* NA – all observations for this trait were "A"

Table 6 - 15: Cranial non-metrics and sex correlation results.

	n	Non-Dichotomized X^2	Non-Dichotomized p-value	Dichotomized X^2	Dichotomized p-value	Dichotomized Fishers'	Dichotomized p-value
Metopic Suture	140	0.820	0.365	0.820	0.365	0.472	0.366
Metopic Fissure	137	NA	NA	NA	NA	NA	NA
Supranasal Suture	134	1.608	0.205	1.608	0.205	1.653	0.166
Frontal Grooves	137	4.357	0.225	0.378	0.539	1.574	0.443
Supratrochlear Notch	133	0.441	0.932	0.029	0.864	0.885	0.860
Medial Supraorbital Notch	137	0.518	0.772	0.291	0.590	0.783	0.494
Lateral Supraorbital Notch	138	1.487	0.475	0.321	0.571	3.255	0.355
Nutrient Foramen in Notch	138	1.472	0.225	1.472	0.225	0.434	0.175
Supratrochlear Foramen	136	12.454	0.014	6.121	0.013	2.640	0.012
Medial Supraorbital Foramen	137	1.563	0.668	0.084	0.772	0.841	0.714
Lateral Supraorbital Foramen	139	6.538	0.088	3.647	0.056	2.097	0.051
Anterior Ethmoid Foramen	55	0.517	0.915	0.145	0.704	1.542	0.547
Posterior Ethmoid Foramen	83	2.873	0.412	1.287	0.257	0.421	0.223
Trochlear Spine/Spur	113	0.008	0.927	0.008	0.927	0.829	0.796
Nasal Foramen	90	0.855	0.836	NA	NA	NA	NA
Infraorbital Suture	122	2.070	0.150	2.070	0.150	0.555	0.146
Accessory Infraorbital Foramen	123	6.749	0.080	3.551	0.060	2.153	0.045
Zygomaxillary Tubercle	132	13.496	0.004	2.662	0.103	2.140	0.072
Zygomatico Facial Foramen	138	12.359	0.015	1.845	0.174	1.914	0.153
Marginal Tubercle	136	10.863	0.012	3.462	0.063	2.072	0.052
Bipartite Zygomatic	136	NA	NA	NA	NA	NA	NA
Parietal Foramen	138	1.430	0.489	0.471	0.493	0.707	0.431
Symmetrically Thin Parietals	138	0.001	0.974	0.001	0.974	1.564	0.678
Coronal Ossicle	124	1.578	0.454	0.479	0.489	0.477	0.491
Sagittal Ossicle	122	2.130	0.144	2.130	0.144	0.000	0.120
Ossicle Bregma	126	0.000	1.000	0.000	1.000	0.511	1.000
Lambdoid Ossicle	128	2.035	0.565	0.000	1.000	1.017	1.000
Ossicle at Lambda	129	4.980	0.083	3.748	0.053	0.343	0.038
Inca Bone	135	2.869	0.090	2.869	0.090	Inf	0.042
Occipital Mastoid Ossicle	125	0.000	1.000	0.000	1.000	1.136	1.000
Occipital Foramen	127	0.174	0.982	0.001	0.970	1.129	0.824
Ossicle at Asterion	126	0.008	0.928	0.008	0.928	1.132	0.835
Parietal Notch Bone	130	0.362	0.835	0.155	0.694	1.278	0.680
Epipteric Bone	113	2.635	0.105	2.635	0.105	0.386	0.089
Frontotemporal Articulation	121	0.000	1.000	0.000	1.000	1.126	1.000
Squamous Ossicle	114	8.246	0.041	6.358	0.012	0.241	0.009
Condylar Canal	124	3.834	0.280	0.004	0.949	0.769	0.752
Double Condylar Facet	120	0.512	0.474	0.512	0.474	3.783	0.326
Hypoglossal Canal Bridge	128	5.425	0.066	4.557	0.033	0.429	0.030
Intermediate Condylar Canal Bridge	122	0.725	0.696	0.010	0.921	0.903	0.856
Jugular Foramen Bridge	114	4.810	0.090	0.017	0.897	1.189	0.813
Precondylar Tubercle	123	0.381	0.944	0.029	0.866	1.165	0.837
Pharyngeal Tubercle	123	8.204	0.145	0.003	0.954	1.214	0.783
Pharyngeal Fovea	118	3.139	0.371	0.000	1.000	0.951	1.000
Median Basilar Canal Foramen	115	1.288	0.525	0.520	0.471	1.441	0.426
Craniopharyngeal Canal	110	1.443	0.230	1.443	0.230	0.517	0.171
Tympanic Dehiscence	141	1.783	0.182	1.783	0.182	0.419	0.127
Postglenoid Foramen	141	0.825	0.364	0.825	0.364	0.691	0.307
Oval Foramen Incomplete	120	0.564	0.453	0.564	0.453	3.917	0.320
Foramen of Vesalius	122	4.019	0.403	0.075	0.784	1.308	0.617
Spinosum Foramen Open	121	1.227	0.268	1.227	0.268	0.620	0.266
Basilar Sphenoid Bridge	114	3.856	0.277	0.127	0.721	0.709	0.596

Table 6 – 15 Cont'd: Cranial non-metrics and sex correlation results.

	n	Non-Dichotomized X^2	Non-Dichotomized p-value	Dichotomized X^2	Dichotomized p-value	Dichotomized Fishers'	Dichotomized p-value
Accessory. Lesser Palatine Foramen	111	11.672	0.009	3.152	0.076	3.299	0.058
Palatine Bridge	123	0.446	0.800	0.000	1.000	1.011	1.000
Palatine Torus	117	4.664	0.323	0.012	0.912	1.138	0.838
Maxillary Torus	123	0.149	0.928	0.037	0.848	1.156	0.707
Retromastoid Process	114	1.529	0.466	0.835	0.361	1.685	0.355
Paracondylar Process	100	3.486	0.323	1.729	0.189	1.872	0.149
Sella Bridges	31	NA	NA	NA	NA	NA	NA
Flexure of Superior Sagittal Sulcus	123	1.563	0.668	0.705	0.401	0.664	0.325
Auditory Torus	143	0.405	0.525	0.405	0.525	3.487	0.341
Suprameatal Spine	143	2.890	0.409	1.593	0.207	1.613	0.181
Suprameatal Depression	143	15.345	0.000	7.870	0.005	2.756	0.004
Inferior Squamous Foramen	141	0.856	0.836	0.000	1.000	1.052	1.000
Superior Squamous Foramen	132	2.116	0.549	0.221	0.638	0.776	0.568
Inferior Parietal Foramen	138	0.722	0.868	0.076	0.783	1.214	0.686
Bipartite Parietal	140	NA	NA	NA	NA	NA	NA
Bipartite Temporal Squama	141	NA	NA	NA	NA	NA	NA
Biasterionic Suture	133	4.078	0.253	0.838	0.360	1.624	0.285
Mastoid Foramen Extrasutural	139	3.717	0.294	0.663	0.415	1.398	0.394
Accessory Mastoid Foramen	142	9.972	0.041	0.523	0.470	1.488	0.402
Squamomastoid Suture	143	3.277	0.657	0.339	0.561	1.283	0.505
Mandibular Torus	142	2.002	0.368	0.374	0.541	1.308	0.492
Accessory Mental Foramen	143	3.878	0.275	2.358	0.125	1.794	0.123
Mylohyoid Bridge	136	1.535	0.464	0.893	0.345	0.469	0.254
Mental Spines	143	16.580	0.005	0.000	1.000	1.163	1.000
Median Pit	143	6.372	0.173	4.135	0.042	0.000	0.028
Retromolar Foramen	135	2.731	0.435	0.893	0.345	1.493	0.286
Molar Foramen	133	3.457	0.484	1.084	0.298	1.530	0.293
Canal de Serres Foramen	132	1.063	0.303	1.063	0.303	1.726	0.281
Canal of Robinson	133	3.102	0.376	0.683	0.408	0.260	0.367
Rocker Mandible	119	1.716	0.190	1.716	0.190	0.574	0.144
Atlas Bridge	121	0.000	1.000	0.000	1.000	1.136	1.000
Double Articular Facet C1	119	0.704	0.401	0.704	0.401	2.094	0.345
Septal Aperture	147	11.323	0.001	11.323	0.001	0.130	0.000

* NA – all observations for this trait were "A"

Non-metric trait dichotomization

Most multivariate statistical analyses require dichotomized data. The majority of traits from the ASUDAS are scored on an ordinal scale. In addition, most of the cranial non-metric traits follow a ranked scale (Hauser and De Stefano, 1989) (see Table 6-4). Dichotomization is the process of setting a threshold point at which a score at or above that point is considered positive (present) and a score below that point is considered negative (absent). The threshold level is referred to as the breakpoint. While more detailed information is lost by dichotomization,

there are some benefits. The main benefit is that by converting observations to a presence/absence scale sample-sizes for each category tend in increase and there tends to be a reduction in observer error. Even with reference plaques, high-quality digital images, thorough trait descriptions and experience, observer error remains a concern because judgments must often be made on a case-by-case (or tooth-by-tooth) basis.

Turner (1986) is one of the most commonly cited sources for defining breakpoints for dichotomization of traits. While this scheme is appropriate when looking at population differences across broad geographic space or time, and is more limited when assessing the variability within a confined time or space (Nichol, 1990; Scherer, 2004; Thompson, 2013). Nichol (1990) developed a method for dichotomizing traits that is study specific and more applicable to smaller scaled projects. The first step is to calculate the frequency of each grade for each trait for each sample (site). Next, the sample with the highest frequency at each grade is subtracted from the sample with the lowest frequency. This process is then applied to all grades of all traits. Within each trait, the grade-level with the largest frequency difference is used as the breakpoint for that trait.

For an example, with a hypothetical trait with only three categories (0-2), and a comparison between three groups (Table 6-16), following Nichol (1990) for category zero we would subtract the highest group frequency (Group B = 0.96), from the lowest group frequency (Group A = 0.94), to get the difference of -0.02. For Category 1, we would subtract 0.05 from 0.00 and get the difference of -0.05. For Category 2, we would subtract 0.04 from 0.01 and get the difference of -0.03. Category 1 would have the greatest difference and would therefore become the breakpoint for the trait.

Table 6 - 16: Example dichotomization following Nichol (1990).

	Group A	Group B	Group C	Nichol 1990
Category 2	0.01	0.04	0.03	-0.03
Category 1	0.05	0.00	0.02	-0.05
Category 0	0.94	0.96	0.95	-0.02
Breakpoint				0/1-2

However, Thompson (2013:144) identified a downside to the Nichol (1990) method: "By subtracting the highest and lowest frequencies at only each specific grade, information of trait distribution above and below those grades is lost." Thompson modified the Nichol method to factor in the cumulative frequency at each grade within each sample. The Thompson method begins by calculating the frequency of each grade for each sample (just as with Nichol, 1990). Next, the frequencies within each sample are added cumulatively from the most extreme expression to zero expression of the trait. Therefore, the zero expression always accounts for 100 percent of the sample. Lastly, the maximum and minimum values of each grade are subtracted between sites (just as with Nichol, 1990). Whichever grade has the largest difference becomes the breakpoint.

Using the same hypothetical example as above, the Thompson method would take the frequencies presented in Table 6-16, and for each group cumulatively add the frequencies before calculating the differences, see Table 6-17. In this example, the breakpoint actually remained the same, but this is not always the case. Thompson (2013) and Zejdlik Passalacqua (2015) have found that the breakpoints using Thompson's method generally do not differ from those calculated using the Nichol (1990) method, but in some cases the cumulative approach did identify differences that would have otherwise been unnoticed.

Table 6 - 17: Example dichotomization following Thompson (2013)

	Group A	Group B	Group C	Thompson 2013
Category 2	0.01	0.04	0.03	-0.03
Category 1	0.06	0.04	0.02	-0.04
Category 0	1.00	1.00	1.00	0.00
Breakpoint				0/1-2

For the purposes of this study, only the Šibenik-Sv. Lovre and Koprivno-Križ II sites were used in the dichotomization process, because the sample sizes of Koprivno-Križ Phase I and Drinovci-Greblje were too small. Table 6-18 presents the breakpoints determined using the Thompson (2013) method, as well as the Nichol (1990) method. In most cases, they are in agreement. This study followed the Thompson (2013) method for trait dichotomization because it calculates the breakpoints based off of the exact P/A frequencies, at each potential breakpoint, for each sample.

Recently, Scott and Irish (2017) published a guidebook for the identification and scoring of dental non-metric traits, *Human Tooth Crown and Root Morphology: The Arizona State University Dental Anthropology System*. This book presents detailed trait descriptions, classifications and photographs to aid in trait recordation. Although published after the data collection for this study had already taken place, the book also presents and summarizes much of Turner, Nichol, Scott and Irish's lifetime work using the ASUDAS. Scott and Irish (2017) include suggested breakpoints that largely follow those of Turner (1986) and are included in Table 6-18, for reference purposes.

The literature is lacking in examples of methods of dichotomization of cranial non-metric traits. In addition, there is a general lack of recent studies that utilize cranial non-metrics. Most studies that use cranial non-metrics seem to simply include anything that is not absent as present, or only record data in a present/absent format to begin with. However, as with dental non-metric traits, most cranial non-metric traits also follow an ordinal scale of development (Hauser and De

Stefano, 1989). Therefore, the dichotomization process for the cranial non-metric traits used here followed the Thompson (2013) and Nichol (1990) methods (Table 6-19). Only the two larger sites, Koprivno-Križ II and Šibenik-Sv. Lovre, were used to calculate the breakpoints. As with the dental non-metrics there was not much difference between the breakpoints calculated using either Thompson or Nichol. The Thompson method was followed for this study.

Table 6 - 18: Dichotomization breakpoints of dental non-metric variables.

	Grade Scale	Thompson, 2013	Nichol, 1990	Scott and Irish, 2017
UI1 Shoveling	8 (0-7)	A-1/2-7	A/1-7	A-1/2-5 or A-3/4-5
UI2 Shoveling	8 (0-7)	A/1-7	A-1/2-7	A-1/2-5 or A-3/4-5
UC Shoveling	8 (0-7)	A/1-7	A/1-7	A-1/2-5 or A-3/4-5
LI1 Shoveling	8 (0-7)	A/1-7	A/1-7	A-1/2-5 or A-3/4-5
LI2 Shoveling	8 (0-7)	A/1-7	A/1-7	A-1/2-5 or A-3/4-5
LC Shoveling	8 (0-7)	A/1-7	A/1-7	A-1/2-5 or A-3/4-5
UI1 Double Shoveling	7 (0-6)	A/1-6	A/1-6	A-1/2-6
UI2 Double Shoveling	7 (0-6)	A/1-6	A/1-6	A-1/2-7
UC Double Shoveling	7 (0-6)	A-1/2-6	A-1/2-6	A-1/2-8
UI1 Labial Curvature	5 (0-4)	A/1-4	A/1-4	A-1/2-4
UI2 Labial Curvature	5 (0-4)	A/1-4	A/1-4	A-1/2-4
UI1 Tuberculum Dentale	8 (0-7)	A-1/2-7	A/1-7	A-1/2+
UI2 Tuberculum Dentale	8 (0-7)	A/1-7	A/1-7	A-1/2+
UC Tuberculum Dentale	8 (0-7)	A/1-7	A/1-7	A-1/2+
LI1 Tuberculum Dentale	8 (0-7)	NA	NA	A-1/2+
LI2 Tuberculum Dentale	8 (0-7)	NA	NA	A-1/2+
LC Tuberculum Dentale	8 (0-7)	A/1-7	A/1-7	A-1/2+
UI1 Interruption Grooves	5 (0-4)	A/1-4	A/1-4	A/1+
UI2 Interruption Grooves	5 (0-4)	A-3/4	A-3/4	A/1+
UC Interruption Grooves	5 (0-4)	A/1-4	A/1-4	A/1+
LI1 Interruption Grooves	5 (0-4)	NA	NA	A/1+
LI2 Interruption Grooves	5 (0-4)	NA	NA	A/1+
LC Interruption Grooves	5 (0-4)	A-3/4	A-3/4	A/1+
UI1 Winging	5 (1-5)	1/2-5	1/2-5	A/1-2
UI2 Variants	6 (0-5)	A-1/2-5	A/1-5	A/1+
UI2 Peg Shaped	3 (0-2)	A-1/2	A-1/2	A/1+
LI2 Peg Shaped	3 (0-2)	NA	NA	A/1+
UC Mesial Ridge	4 (0-3)	A/1-3	A/1-3	A/1+
UC Distal Accessory Ridge	6 (0-5)	A/1-5	A/1-5	A-1/2+
LC Distal Accessory Ridge	6 (0-5)	A/1-5	A/1-5	A-1/2+
LC Double Root	4 (0-3)	A/1-3	A/1-3	A/1+
UI2 Congenital Absence	3 (0-2)	A-1/2	A-1/2	
LI1 Congenital Absence	3 (0-2)	NA	NA	
UI1 Root #	4 (1-4)	NA	NA	
UI2 Root #	4 (1-4)	NA	NA	
UC Root #	4 (1-4)	NA	NA	
LI1 Root #	4 (1-4)	NA	NA	
LI2 Root #	4 (1-4)	NA	NA	

Table 6 – 18 Cont'd: Dichotomization breakpoints of dental non-metric variables.

	Grade Scale	Thompson, 2013	Nichol, 1990	Scott and Irish, 2017
LC Root #	4 (1-4)	1/2-4	1/2-4	
UI1 Radical #	8 (1-8)	1/2-8	1/2-8	
UI2 Radical #	8 (1-8)	1/2-8	1/2-8	
UC Radical #	8 (1-8)	1/2-8	1/2-8	
LI1 Radical #	8 (1-8)	1/2-8	1/2-8	
LI2 Radical #	8 (1-8)	1/2-8	1/2-8	
LC Radical #	8 (1-8)	NA	NA	
UP3 Accessory Ridge - Mesial	2 (0-1)	A/1	A/1	
UP4 Accessory Ridge - Mesial	2 (0-1)	A/1	A/1	
LP3 Accessory Ridge - Mesial	2 (0-1)	A/1	A/1	
LP4 Accessory Ridge - Mesial	2 (0-1)	A/1	A/1	
UP3 Accessory Ridge - Distal	2 (0-1)	A/1	A/1	
UP4 Accessory Ridge - Distal	2 (0-1)	A/1	A/1	
LP3 Accessory Ridge - Distal	2 (0-1)	A/1	A/1	
LP4 Accessory Ridge - Distal	2 (0-1)	A/1	A/1	
UP3 Accessory Marginal Tubercles	4 (0-3)	A/1-3	A/1-3	A/1+
UP4 Accessory Marginal Tubercles	4 (0-3)	A-1/2-3	A/1-3	A/1+
UP3 Odontomes	2 (0-1)	NA	NA	A/1+
UP4 Odontomes	2 (0-1)	A/1	A/1	A/1+
LP3 Odontomes	2 (0-1)	A/1	A/1	A/1+
LP4 Odontomes	2 (0-1)	NA	NA	A/1+
UP4 Distosagittal Ridge	2 (0-1)	NA	NA	A/1+
LP3 Multiple Lingual Cusps	11 (0-10)	1/2-11	1/2-11	1/2+
LP4 Multiple Lingual Cusps	11 (0-10)	1/2-11	1/2-11	1/2+
UP3 Tricuspid	2 (0-1)	NA	NA	
UP4 Tricuspid	2 (0-1)	A/1	A/1	
UP3 Enamel Extension/Pearl	6 (0-5)	A/1-5	A/1-5	
UP4 Enamel Extension/Pearl	6 (0-5)	NA	NA	
LP3 Tome's Root	6 (0-5)	A/1-6	A/1-6	A-3/4+
UP4 Congenital Absence	2 (0-1)	A/1	A/1	
LP4 Congenital Absence	2 (0-1)	A/1	A/1	
UP3 Root #	4 (1-4)	1/2-4	1/2-4	1/2+
UP4 Root #	4 (1-4)	1/2-4	1/2-4	1/2+
UP3 Radical #	8 (1-8)	1-4/5-8	1-3/4-8	
UP4 Radical #	8 (1-8)	1/2-8	1/2-8	
UM1 Carabelli's	8 (0-7)	A-2/3-7	A-2/3-7	A-1/2+
UM2 Carabelli's Cusp	8 (0-7)	A/1-7	A/1-7	A-1/2+
UM3 Carabelli's Cusp	8 (0-7)	A/1-7	A-1/2-7	A-1/2+
UM1 Metacone (Cusp 3)	7 (0-6)	A-4/5-7	A-3/4-7	0-3/4+
UM2 Metacone (Cusp 3)	7 (0-6)	A-3/4-7	A-4/5-7	0-3/4+
UM3 Metacone (Cusp 3)	7 (0-6)	A-4/5-7	A-3/4-7	0-3/4+
UM1 Mesial Paracone Tubercle	2 (0-1)	A/1	A/1	A/1
UM2 Mesial Paracone Tubercle	2 (0-1)	A/1	A/1	A/1
UM3 Mesial Paracone Tubercle	2 (0-1)	A/1	A/1	A/1
UM1 Protoconule Tubercle	2 (0-1)	A/1	A/1	A/1
UM2 Protoconule Tubercle	2 (0-1)	A/1	A/1	A/1
UM3 Protoconule Tubercle	2 (0-1)	A/1	A/1	A/1
UM1 Mesial Accessory Tubercle	2 (0-1)	A/1	A/1	A/1
UM2 Mesial Accessory Tubercle	2 (0-1)	A/1	A/1	A/1
UM3 Mesial Accessory Tubercle	2 (0-1)	A/1	A/1	A/1
UM1 Lingual Paracone Tubercle	2 (0-1)	A/1	A/1	A/1
UM2 Lingual Paracone Tubercle	2 (0-1)	A/1	A/1	A/1

Table 6 – 18 Cont'd: Dichotomization breakpoints of dental non-metric variables.

	Grade Scale	Thompson, 2013	Nichol, 1990	Scott and Irish, 2017
UM3 Lingual Paracone Tubercle	2 (0-1)	A/1	A/1	A/1
UM1 Parastyle	7 (0-6)	A/1-6	A/1-6	A-1/2+
UM2 Parastyle	7 (0-6)	A/1-6	A/1-6	A-1/2+
UM3 Parastyle	7 (0-6)	A-1/2-6	A-1/2-6	A-1/2+
UM1 Enamel Extension/Pearl	6 (0-5)	A/1-5	A/1-5	A-1/2+
UM2 Enamel Extension/Pearl	6 (0-5)	A/1-5	A/1-5	A-1/2+
UM3 Enamel Extension/Pearl	6 (0-5)	A/1-5	A/1-5	A-1/2+
UM3 Peg Shaped	3 (0-2)	A/1-2	A/1-2	0/1+
UM3 Congenital Absence	2 (0-1)	A/1-2	A/1-2	0/1+
LM3 Congenital Absence	2 (0-1)	A/1-2	A/1-2	0/1+
UM1 Hypocone (Cusp 4)	7 (0-6)	A-5/6	A-5/6	0-1/2+
UM2 Hypocone (Cusp 4)	7 (0-6)	A-4/5-6	A-4/5-6	0-1/2+
UM3 Hypocone (Cusp 4)	7 (0-6)	A-2/3-6	A/1-6	0-1/2+
UM1 Metaconule (Cusp 5)	6 (0-5)	A/1-5	A/1-5	A/1+
UM2 Metaconule (Cusp 5)	6 (0-5)	A/1-5	A/1-5	A/1+
UM3 Metaconule (Cusp 5)	6 (0-5)	A/1-5	A/1-5	A/1+
LM1 Hypoconulid (Cusp 5)	6 (0-5)	A-4/5	A-3/4-5	A/1+
LM2 Hypoconulid (Cusp 5)	6 (0-5)	A-1/2-5	A-3/4-5	A/1+
LM3 Hypoconulid (Cusp 5)	6 (0-5)	A-1/2-5	A-3/4-5	A/1+
UM1 Root #	4 (1-4)	1-2/3-4	½-4	1-2/3+
UM2 Root #	4 (1-4)	1-2/3-4	1-2/3-4	1-2/3+
UM3 Root #	4 (1-4)	1-2/3-4	½-4	1-2/3+
LM1 Root #	4 (1-4)	NA	NA	1-2/3+
LM2 Root #	4 (1-4)	½-4	½-4	1-2/3+
LM3 Root #	4 (1-4)	½-4	½-4	1-2/3+
UM1 Radical #	8 (1-8)	1-6/7-8	1-6/7-8	
UM2 Radical #	8 (1-8)	1-3/4-8	1-2/3-8	
UM3 Radical #	8 (1-8)	1-4/5-8	1-3/4-8	
LM1 Radical #	8 (1-8)	1-3/4-8	1-2/3-8	
LM2 Radical #	8 (1-8)	1-2/3-8	1-4/5-8	
LM3 Radical #	8 (1-8)	1-2/3-8	1-2/3-8	
UM1 Cusp #	3 (4-6)	4/5-6	4/5-6	
UM2 Cusp #	3 (4-6)	¾-6	¾-6	
UM3 Cusp #	3 (4-6)	3-4/5-6	3-4/5-6	
LM1 Cusp #	3 (4-6)	4-5/6	4-5/6	
LM2 Cusp #	3 (4-6)	4-5/6	4-5/6	
LM3 Cusp #	3 (4-6)	3-4/5-6	3-4/5-6	
LM1 Entoconulid (Cusp 6)	6 (0-5)	A/1-5	A/1-5	A/1+
LM2 Entoconulid (Cusp 6)	6 (0-5)	A-1/2-5	A/1-5	A/1+
LM3 Entoconulid (Cusp 6)	6 (0-5)	A/1-5	A/1-5	A/1+
LM1 Metaconulid (Cusp 7)	7 (0-6)	A/1-6	A/1-6	A/1+
LM2 Metaconulid (Cusp 7)	7 (0-6)	A/1-6	A/1-6	A/1+
LM3 Metaconulid (Cusp 7)	7 (0-6)	A/1-6	A/1-6	A/1+
LM1 Groove Pattern	4 (1-4)	½-4	½-4	Y/+-X
LM2 Groove Pattern	4 (1-4)	½-4	½-4	Y/+-X
LM3 Groove Pattern	4 (1-4)	1-2/3-4	1-2/3-4	Y/+-X
LM1 Protostylid Buccal Pit	2 (0-1)	A/1	A/1	
LM2 Protostylid Buccal Pit	2 (0-1)	A/1	A/1	
LM3 Protostylid Buccal Pit	2 (0-1)	A/1	A/1	
LM1 Protostylid	7 (0-6)	A/1	A/1	A-1/2+
LM2 Protostylid	7 (0-6)	A-5/6	A-5/6	A-1/2+
LM3 Protostylid	7 (0-6)	A-3/4-6	A-3/4-6	A-1/2+

Table 6 – 18 Cont'd: Dichotomization breakpoints of dental non-metric variables.

	Grade Scale	Thompson, 2013	Nichol, 1990	Scott and Irish, 2017
LM1 Deflecting Wrinkle	4 (0-3)	A/1-3	A/1-3	A-1/2+
LM2 Deflecting Wrinkle	4 (0-3)	A/1-3	A/1-3	A-1/2+
LM3 Deflecting Wrinkle	4 (0-3)	A/1-3	A/1-3	A-1/2+
LM1 Anterior Fovea	5 (0-4)	A-1/2-4	A-3/4	A-2/3+
LM2 Anterior Fovea	5 (0-4)	A-1/2-4	A-2/3-4	A-2/3+
LM3 Anterior Fovea	5 (0-4)	A-1/2-4	A/1-4	A-2/3+
LM1 Distal Trigonid Crest	2 (0-1)	A/1	A/1	A/1+
LM2 Distal Trigonid Crest	2 (0-1)	A/1	A/1	A/1+
LM3 Distal Trigonid Crest	2 (0-1)	A/1	A/1	A/1+

* The numeric values reflect the ASUDAS scoring system levels.

Table 6 - 19: Dichotomization breakpoints for cranial non-metric variables.

	Grade Scale*	Thompson 2013	Nichol 1990
Metopic Suture	2 (0-1)	A/1	A/1
Metopic Fissure	2 (0-1)	NA	NA
Supranasal Suture	2 (0-1)	A/1	A/1
Frontal Grooves	4 (0-3)	A-1/2-3	A-2/3
Supratrochlear Notch	4 (0-3)	A/1-3	A/1-3
Medial Supraorbital Notch	3 (0-2)	A-1/2	A/1-2
Lateral Supraorbital Notch	3 (0-2)	A/1-2	A/1-2
Nutrient Foramen in Notch	2 (0-1)	A/1	A/1
Supratrochlear Foramen	5 (0-4)	A/1-4	A/1-4
Medial Supraorbital Foramen	4 (0-3)	A/1-3	A/1-3
Lateral Supraorbital Foramen	4 (0-3)	A/1-3	A/1-3
Anterior Ethmoid Foramen	4 (0-3)	A/1-3	A/1-3
Posterior Ethmoid Foramen	4 (0-3)	A-1/2-3	A/1-3
Trochlear Spine (Spur)	2 (0-1)	A/1	A/1
Nasal Foramen	4 (0-3)	A-2/3	A-1/2-3
Infraorbital Suture	2 (0-1)	A/1	A/1
Accessory Infraorbital Foramen	4 (0-3)	A/1-3	A/1-3
Zygomaxillary Tubercle	4 (0-3)	A/1-3	A-1/2-3
Zygomatico-Facial Foramen	5 (0-4)	A-2/3-4	A-1/2-4
Marginal Tubercle	4 (0-3)	A-1/2-3	A-2/3
Parietal Foramen	3 (0-2)	A/1-2	A/1-2
Symmetrically Thin Parietals	2 (0-1)	A/1	A/1
Coronal Ossicle	3 (0-2)	A/1-2	A/1-2
Sagittal Ossicle	2 (0-1)	A/1	A/1
Ossicle at Bregma	2 (0-1)	A/1	A/1
Lambdoid Ossicle	4 (0-3)	A-2/3	A-2/3
Ossicle at Lambda	3 (0-2)	A/1-2	A/1-2
Inca Bone	3 (0-2)	A/1-2	A/1-2
Occipital-Mastoid Ossicle	2 (0-1)	A/1	A/1
Occipital Foramen	4 (0-3)	A-1/2-3	A/1-3
Ossicle at Asterion	2 (0-1)	A/1	A/1
Condylar Canal	4 (0-3)	A-1/2-3	A-1/2-3
Double Condylar Facet	2 (0-1)	A/1	A/1
Hypoglossal Canal Bridge	3 (0-2)	A/1-2	A/1-2
Intermediate Condylar Canal Bridge	3 (0-2)	A-1/2	A-1/2
Jugular Foramen Bridge	3 (0-2)	A-1/2	A-1/2
Precondylar Tubercle	5 (0-4)	A-1/2	A-2/3-4

Table 6 - 19 Cont'd: Dichotomization breakpoints for cranial non-metric variables.

	Grade Scale*	Thompson 2013	Nichol 1990
Pharyngeal Tubercle	6 (0-5)	A-1/2-5	A-2/3-5
Pharyngeal Fovea	4 (0-3)	A/1-3	A/1-3
Median Basilar Canal Foramen	4 (0-3)	A/1-3	A/1-3
Craniopharyngeal Canal	2 (0-1)	A/1	A/1
Tympanic Dehiscence	2 (0-1)	A/1	A/1
Postglenoid Foramen	2 (0-1)	A/1	A/1
Oval Foramen Incomplete	2 (0-1)	A/1	A/1
Foramen of Vesalius	5 (0-4)	A-1/2-4	A/1-4
Spinosum Foramen Open	2 (0-1)	A/1	A/1
Basilar-Sphenoid Bridge	4 (0-3)	A-1/2-3	A/1-3
Accessory Lesser Palatine Foramen	4 (0-3)	A/1-3	A/1-3
Palatine Bridge	3 (0-2)	A/1-2	A/1-2
Palatine Torus	5 (0-4)	A-1/2-4	A/1-4
Maxillary Torus	3 (0-2)	A/1-2	A/1-2
Retromastoid Process	3 (0-2)	A/1-2	A/1-2
Paracondylar Process	4 (0-3)	A-1/2-3	A/1-3
Sella Bridges	2 (0-1)	A/1	A/1
Flexure of Superior Sagittal Sulcus	4 (1-4)	1/2-4	1/2-4
Auditory Torus	2 (0-1)	A/1	A/1
Suprameatal Spine	4 (0-3)	A/1-3	A/1-3
Suprameatal Depression	3 (0-2)	A/1-2	A/1-2
Inferior Squamous Foramen	4 (0-3)	A-2/3	A-2/3
Superior Squamous Foramen	4 (0-3)	A/1-3	A/1-3
Inferior Parietal Foramen	4 (0-3)	A/1-3	A/1-3
Bipartite Parietal	2 (0-1)	A/1	A/1
Bipartite Temporal Squama	2 (0-1)	A/1	A/1
Bipartite Zygomatic	2 (0-1)	A/1	A/1
Biasterionic Suture	4 (0-3)	A/1-3	A/1-3
Mastoid Foramen Extrasutural	4 (1-4)	1/2-4	1/2-4
Accessory Mastoid Foramen	5 (0-4)	A-2/3-4	A/1-4
Squamomastoid Suture	6 (0-5)	A-3/4-5	A-3/4-5
Parietal Notch Bone	3 (0-2)	A/1-2	A/1-2
Epipteric Bone	3 (0-2)	A/1-2	A/1-2
Frontotemporal Articulation	2 (0-1)	A/1	A/1
Squamous Ossicle	4 (0-3)	A/1-3	A/1-3
Mandibular Torus	3 (0-2)	A/1-2	A/1-2
Accessory Mental Foramen	4 (0-3)	A/1-3	A/1-3
Mylohyoid Bridge	3 (0-2)	A-1/2	A/1-2
Mental Spines	6 (0-5)	A/1-5	A/1-5
Median Pit	5 (0-4)	A-1/2-4	A/1-4
Retromolar Foramen	4 (0-3)	A/1-3	A/1-3
Molar Foramen	5 (0-4)	A-1/2-4	A-1/2-4
Canal de Serres Foramen	2 (0-1)	A/1	A/1
Canal of Robinson	4 (0-3)	A-1/2-3	A/1-3
Rocker Mandible	2 (0-1)	A/1	A/1
Atlas Bridging	2 (0-1)	A/1	A/1
Double Articular Facet of C1	2 (0-1)	A/1	A/1
Septal Aperture	2 (0-1)	A/1	A/1

* See Table 6-4 for a breakdown of the grade-scale categories of cranial non-metric traits

Intraobserver error

Measurement error can come from a variety of sources, including experience, fatigue, and gradual shifts in measurement technique. To test for intraobserver error of the metric data, 28 individuals from the Koprivno-Križ I (n=5), Koprivno-Križ II (n=15) and Drinovci-Greblje (n=8) site samples were reanalyzed. For the metric data the following descriptive statistics were calculated to assess intraobserver error: mean difference, standard error difference, the mean absolute difference, and the absolute standard difference. A student's t-test and technical error measurement (TEM) were also utilized to identify any systematic differences between the measurement sessions; following the procedures outlined by A. A. Dahlberg (1945), G. Dahlberg (1940), Knapp (1992) and Harris (2008), and utilized by two recent PhD dissertations by Thompson (2013) and Zejdlik Passalacqua (2015). The results are presented in Table 6-20 and Table 6-21.

The first column of Table 6-20 and Table 6-21, mean difference, is simply the average difference in the recorded measurement between sessions.

$$Mean\ Diff = \frac{\sum(X_i^1 - X_i^2)}{n}$$

where X^1 is the *i*th measurement from the first session and X^2 is the *i*th measurement from the second session, and *n* is the number of teeth. The mean difference takes into account whether or not one observation session resulted in consistently higher or lower measurements and thus varies from negative to positive. The dental metric data ranged from -0.178 to 0.381 mm, with an average of -0.009 mm. Hillson and colleagues (2005) report a range from -0.742 to 0.541mm, and suggest a critical value of +/- 0.1 mm for this statistic. Five measurements from this study exceed +/- 0.1 mm, and are highlighted in gray in Table 6-20. For the cranial metrics, the mean difference ranges from -6.5 to 2.992 mm, with an average mean difference of 0.219 mm. Most

cranial metric studies consider +/- 1.0 mm difference acceptable. There are only seven measures that exceed this level, and they are highlighted in gray in Table 6-21.

The second column, mean absolute difference, is calculated by averaging the absolute value of the difference between sessions.

$$Mean\ ABS\ Diff = \frac{\sum \left| X_i^1 - X_i^2 \right|}{n}$$

where X^1 is the *i*th measurement from the first session and X^2 is the *i*th measurement from the second session, and *n* is the number of teeth. The mean absolute difference does not take into account whether or not one observation session resulted in consistently larger (or smaller) measurements than the other; rather it represents the overall level of difference and always gives a positive value. The dental metric absolute mean differences range from 0.048 to 0.396 mm, with an average of 0.199 mm. Hillson and colleagues (2005) report a range from 0.036 to 0.310 mm, with most falling below 0.15 mm. Highlighted in gray in Table 6-20 are values that exceed 0.2 mm (the average value for this measure). For the cranial metric data, absolute mean difference values range from 0.211 to 6.5 mm, with an average of 1.231 mm. Values that exceed the 1.231 mm average are highlighted in gray in Table 6-21.

The third column is the standard error of the mean absolute difference, which is an expression of the spread of measurements around the mean difference between observation sessions. The standard error of the mean absolute difference is simply the standard deviation of the mean absolute difference. For the dental metric data the standard errors of the absolute mean difference range from 0.012 to 0.166 mm, with an average of 0.06 mm. Hillson and colleagues (2005) report a range from 0.006 to 0.185 mm, with most below 0.02 mm. Values that exceed .15 mm are highlighted in gray in Table 6-20. For the cranial metric data, the standard error of

the absolute mean difference ranges from 0.030 to 0.715 mm, with an average of 0.188 mm. Values that exceed 0.5 mm are highlighted in gray in Table 6-21.

A paired student's *t*-test was performed to evaluate any systematic differences between measurement sessions. The *p*-value of this test is provided in the fifth column of Table 6-20 and Table 6-21; traits with significantly different measurements between sessions are highlighted in gray.

Finally, the technical error of measurement (TEM) (Dahlberg 1940; Knapp 1992) was calculated. TEM is a type of mean difference between observations that is not influenced by systematically larger or smaller values (Hillson, et al. 2005; Kieser, 1990). The formula for TEM is

$$TEM = \sqrt{\sum_{i-1-n} \frac{(X_i^1 - X_i^2)^2}{2n}}$$

where X^1 is the *i*th measurement from the first session and X^2 is the *i*th measurement from the second session, and *n* is the number of teeth. For the dental metric data, TEM values range from 0.054 to 0.535 mm, with an average of 0.235 mm. Hillson and colleagues (2005) report a range for TEM from 0.037 to 0.948 mm, with most falling around 0.1 mm. Values higher than 0.25 mm for TEM are highlighted in gray in Table 6-20. For cranial metric data, TEM values range from 0.185 to 4.596 mm, with an average of 1.135 mm. Most of the measurements with TEM values above 1.0 mm are "metrically determined" measurements, such as Maximum Breadth (eu-eu), and either have none or only one measurement point at a known landmark. Therefore, it is not surprising that these measurements have a greater measurement error value. Values exceeding 1.0 mm have been highlighted in gray in Table 6-21.

Two dental metric variables were selected for removal from the dataset: BL Crown LP4, and MD CEJ UP3. These variables were removed because they not only have a significant *p*-value, but also have high values for mean difference, mean absolute difference and TEM. Seven cranial metric variables were selected for removal from the dataset: maximum length (g-op), maximum breath (eu-eu), bizygomatic breath (zy-zy), basion-bregma length (ba-b), cranial base length (ba-n), mandibular length and ramus height. These variables were removed because not only do they all have a significant *p*-value, but they also have high values for mean difference, mean absolute difference and TEM. The interorbital breadth (mf-mf) and chin height (gn-id) were kept in spite of their significant *p*-values because the mean difference, mean absolute difference, and TEM values for these two measures were not particularly high and fell mostly in line with the other kept measurements.

Table 6 - 20: Dental metric intraobserver error.

	n	Mean Diff	Mean ABS Diff	Std Err Abs Diff	paired student's t-test *p*-value	TEM
MD Crown UI1	16	0.020	0.048	0.015	0.311	0.054
MD Crown UI2	18	0.007	0.091	0.021	0.814	0.088
MD Crown UC	19	-0.022	0.117	0.045	0.687	0.159
MD Crown UP3	22	-0.050	0.115	0.030	0.203	0.127
MD Crown UP4	19	-0.097	0.107	0.032	0.010	0.123
MD Crown UM1	23	0.070	0.325	0.060	0.446	0.303
MD Crown UM2	23	-0.058	0.274	0.040	0.413	0.235
MD Crown UM3	16	-0.072	0.258	0.054	0.404	0.235
MD Crown LI1	19	-0.139	0.281	0.166	0.438	0.535
MD Crown LI2	22	-0.022	0.090	0.038	0.614	0.139
MD Crown LC	24	-0.005	0.183	0.064	0.943	0.254
MD Crown LP3	24	0.001	0.129	0.034	0.977	0.147
MD Crown LP4	27	0.118	0.184	0.056	0.070	0.240
MD Crown LM1	23	-0.020	0.155	0.049	0.737	0.195
MD Crown LM2	24	-0.085	0.332	0.075	0.404	0.346
MD Crown LM3	18	0.093	0.286	0.145	0.569	0.470
BL Crown UI1	20	-0.004	0.089	0.012	0.869	0.074
BL Crown UI2	21	-0.035	0.160	0.047	0.554	0.187
BL Crown UC	19	-0.147	0.176	0.056	0.025	0.208
BL Crown UP3	23	-0.018	0.078	0.017	0.462	0.080
BL Crown UP4	19	-0.045	0.064	0.016	0.029	0.065
BL Crown UM1	23	-0.056	0.130	0.031	0.176	0.139
BL Crown UM2	23	-0.019	0.307	0.076	0.854	0.333

Table 6 – 20 Cont'd: Dental metric intraobserver error.

	n	Mean Diff	Mean ABS Diff	Std Err Abs Diff	paired student's t-test *p*-value	TEM
BL Crown UM3	16	-0.053	0.164	0.027	0.295	0.138
BL Crown LI1	20	0.002	0.184	0.036	0.972	0.172
BL Crown LI2	20	-0.060	0.125	0.036	0.184	0.141
BL Crown LC	24	-0.121	0.189	0.061	0.086	0.245
BL Crown LP3	24	-0.052	0.189	0.040	0.357	0.191
BL Crown LP4	27	-0.178	0.206	0.061	0.010	0.263
BL Crown LM1	23	0.043	0.158	0.024	0.294	0.136
BL Crown LM2	23	0.123	0.207	0.050	0.057	0.221
BL Crown LM3	18	0.008	0.132	0.035	0.871	0.138
MD CEJ UI1	21	-0.072	0.208	0.045	0.267	0.206
MD CEJ UI2	22	-0.094	0.153	0.027	0.021	0.138
MD CEJ UC	21	0.101	0.287	0.098	0.387	0.369
MD CEJ UP3	25	0.381	0.396	0.120	0.005	0.502
MD CEJ UP4	22	0.158	0.247	0.077	0.086	0.305
MD CEJ UM1	26	0.133	0.255	0.047	0.048	0.245
MD CEJ UM2	24	0.067	0.178	0.034	0.184	0.172
MD CEJ UM3	15	0.059	0.178	0.026	0.273	0.144
MD CEJ LI1	21	-0.161	0.373	0.123	0.277	0.470
MD CEJ LI2	21	-0.036	0.236	0.066	0.675	0.267
MD CEJ LC	25	-0.056	0.319	0.115	0.675	0.458
MD CEJ LP3	24	0.048	0.221	0.069	0.564	0.282
MD CEJ LP4	26	0.093	0.350	0.126	0.518	0.508
MD CEJ LM1	24	0.174	0.184	0.028	0.000	0.162
MD CEJ LM2	24	0.121	0.274	0.035	0.063	0.227
MD CEJ LM3	17	-0.058	0.270	0.048	0.486	0.234
BL CEJ UI1	21	0.037	0.111	0.034	0.376	0.132
BL CEJ UI2	22	-0.048	0.076	0.021	0.063	0.086
BL CEJ UC	19	0.067	0.129	0.063	0.338	0.209
BL CEJ UP3	24	-0.057	0.276	0.130	0.694	0.483
BL CEJ UP4	19	0.037	0.109	0.030	0.352	0.119
BL CEJ UM1	26	-0.020	0.187	0.037	0.713	0.187
BL CEJ UM2	23	0.004	0.280	0.068	0.962	0.301
BL CEJ UM3	15	-0.075	0.283	0.077	0.489	0.285
BL CEJ LI1	19	-0.101	0.212	0.109	0.402	0.361
BL CEJ LI2	20	-0.122	0.182	0.110	0.301	0.364
BL CEJ LC	25	-0.108	0.200	0.113	0.370	0.415
BL CEJ LP3	24	-0.033	0.237	0.068	0.695	0.286
BL CEJ LP4	20	0.027	0.120	0.025	0.475	0.114
BL CEJ LM1	22	0.030	0.189	0.019	0.511	0.147
BL CEJ LM2	18	-0.047	0.234	0.039	0.496	0.201
BL CEJ LM3	12	-0.127	0.282	0.076	0.264	0.268

Table 6 - 21: Cranial metric intraobserver error.

	n	Mean Diff	Mean ABS Diff	Std Err Abs Diff	paired student's t-test *p*-value	TEM
Maximum Length (g-op)	26	1.865	2.288	0.219	0.000	1.793
Maximum Breadth (eu-eu)	27	1.593	2.148	0.198	0.000	1.678
Bizygomatic Breadth (zy-zy)	16	2.500	2.500	0.320	0.000	1.972
Basion-Bregma (ba-b)	26	2.154	2.654	0.216	0.000	2.026
Cranial Base Length (ba-n)	26	2.642	2.927	0.332	0.000	2.379
Basion-Prosthion Length (ba-pr)	24	-0.088	0.721	0.170	0.702	0.769
Maximum Alveolar Breadth (ecm-ecm)	26	0.181	0.581	0.161	0.362	0.701
Maximum Alveolar Length (pr-alv)	27	0.111	1.126	0.221	0.724	1.127
Biauricular Breadth	27	0.193	0.363	0.103	0.118	0.450
Upper Facial Height (n-pr)	25	0.124	0.732	0.213	0.637	0.902
Minimum Frontal Breadth (ft-ft)	28	-0.104	0.396	0.076	0.337	0.396
Upper Facial Breadth (fmt-fmt)	28	0.139	0.332	0.053	0.087	0.304
Nasal Height (n-ns)	25	-0.220	1.708	0.715	0.784	2.756
Nasal Breadth (al-al)	26	-0.185	0.408	0.069	0.078	0.379
Orbital Breadth (mf-ec)	27	0.111	1.000	0.165	0.667	0.924
Orbital Height	27	0.104	0.437	0.089	0.404	0.447
Biorbital Breadth (ec-ec)	24	-0.150	0.983	0.148	0.556	0.858
Interorbital Breadth (mf-mf)	27	0.656	1.167	0.221	0.033	1.148
Frontal Chord (n-b)	28	0.057	0.514	0.096	0.681	0.506
Parietal Chord (b-l)	28	0.532	0.896	0.220	0.051	1.028
Occipital Chord (l-o)	27	-0.252	0.726	0.181	0.274	0.832
Foramen Magnum Length (ba-o)	27	0.007	0.304	0.063	0.933	0.313
Foramen Magnum Breadth	25	-0.340	0.452	0.191	0.102	0.734
Mastoid Length	28	-0.093	1.136	0.152	0.730	0.979
Chin Height (gn-id)	25	-0.312	0.424	0.099	0.012	0.455
Body Height at Mental Foramen	28	-0.425	0.718	0.195	0.069	0.877
Body Thickness at Mental Foramen	28	0.014	0.350	0.069	0.883	0.354
Bicondylar Breadth (cdl-cdl)	21	-0.005	0.243	0.083	0.962	0.314
Bigonial Diameter (go-go)	26	0.188	0.604	0.110	0.247	0.578
Minimum Ramus Breadth	27	0.004	0.211	0.030	0.943	0.185
Maximum Ramus Breadth	27	-0.278	0.833	0.191	0.268	0.906
Mandibular Length	26	2.992	4.231	0.656	0.002	3.786
Ramus Height	1	-6.500	6.500	NA	NA	4.596

The procedures for error testing of non-metric data outlined by Nichol and Turner II (1986) were followed here. The same 28 individuals that were used in the intraobserver error for the metric data were used in the non-metric analyses (Table 6-6). The results of the intraobserver error analysis are presented in Table 6-22 and Table 6-23.

The first column, n pairs, is the number of times the trait was observable in at least one session. The second column, %-one-only, represents the frequency of traits that were scored in only one session. All calculations of %-one-only were based on a sample size of 56 (28

individuals, with each trait being scored in both sessions). This was done to include cases where the trait was not observed in either session, which would not be considered if the frequency were based on the number of pairs (n pairs). Results for the dental non-metric data show a range of 0-70% difference, with an average of 15.2% of the traits being scored in one session but not the other. For the cranial non-metric data, results show a range of 0-15%, with an average of 2.4% of the traits being scored in one session but not the other. A trait may not have been recorded for various reasons including: not being found, pathology, damage etc. The %-one-only calculation does not indicate variability in the actual scoring of traits. Other sources of error not directly related to the decision to record a trait as observable or not observable could falsely inflate this calculation (e.g., misidentification of a loose tooth, post-mortem tooth loss between recording sessions, or simply missing a loose tooth in a box of fragments).

The third column, % variant score, considers any variation in the observed score between recording sessions. Values for this statistic ranged from 0-83.3% for the dental non-metrics, with an average of 17.8% of the variables being scored one or more grades differently between sessions. This average value is less than that reported by Nichol and Turner (1986) of 27.2% between three scoring sessions. The highest values in this study for the dental non-metric data tend to be traits that are more affected by dental attrition, such as the distal trigonid crest or anterior fovea. For the cranial non-metrics, this statistic ranged from 0-76.9%, with an average of 27.1% of the variables being scored one or more grades differently between sessions. There are little to no cranial non-metric intraobserver error studies to compare the cranial data to. However, the average cranial variant score seems reasonable compared to the dental data. The highest values in this study for the cranial non-metric data tend to be traits with a wider range of expression, making it more difficult to judge between grades, such as accessory lesser palatine

foramen or median basilar canal, where deciding if a foramen is a true canal or foramen or just a porosity can be challenging.

The fourth column, %>1 grade variant score, presents the results of a statistic looking at the frequency of traits with scores greater than 1 grade different between the observation sessions. This statistic is more telling of true error because most differences of only one grade are negligible once the data are dichotomized. For the dental non-metric data the %>1-grade-variant score ranged from 0-33.3%, with an average of 8.2%. This value is only somewhat larger than the 6.4% reported in Nichol and Turner (1986), and below their suggested critical value of 10% or more for this statistic. For the cranial non-metric data, the grade score error ranged from 0-46.4%, with an average of 11.6%. Note that when the value for %>1-grade-variant-score is "NA", then Nichol and Turner (1986) substitute the value of %-variant-score, when determining if the value exceeds the critical level. Grade variant scores that exceed the critical level of 10% are highlighted in gray in Table 6-22 and Table 6-23.

The fifth column, AMGD, is the Absolute Mean Grade Difference. This measure is an index that provides an average difference (expressed as a percent), between scoring sessions. It is similar to the mean absolute difference used in the metric intraobserver error analysis, in that it removes the directionality of error. The formula for AMGD is

$$AMGD = \frac{\sum(|x_2 - x_1|)}{n} \times 100$$

where x_1 is the first scoring session, x_2 is the second scoring session and n is the number of individuals that could be scored for both sessions (n pairs). For the dental non-metric data the results range from 0-166.7%, with an average of 24.8%. This indicates that a discrepancy of one-fourth of a grade is being made on the average individual for the average trait. This value is

lower than that reported by Nichol and Turner (1986) of 35.5%. For the cranial non-metric data the results range from 0-167.9%, with an average of 36.1%.

The sixth column, NMGD, is the Net Mean Grade Difference. This measure is the same as the AMGD, but that the directionality of scoring difference is taken into consideration. The formula for NMGD is

$$NMGD = \frac{\sum(x_2 - x_1)}{n} \times 100$$

where x_1 is the first scoring session, x_2 is the second scoring session and n is the number of individuals that could be scored for both sessions (n pairs). For the dental non-metric data, the results range from -54.6-166.7%, with an average of 6.4%. The following traits seem to be heavily affecting this measurement: LM1 anterior fovea, and UM1 Carabelli's cusp. For the cranial non-metric data, the results range from -65.2-167.7%, with an average of 9.9%. The following traits seem to be heavily affecting this measurement: supratrochlear foramen, accessory infraorbital foramen, and canal of Robinson. Nichol and Turner (1986) suggest a critical value of 0.05 times the maximum grade for the trait minus the lowest grade. For the trait shoveling, the maximum grade level is seven and the lowest grade is zero (see Table 6-2), so the critical value for shoveling would be 0.05 x (7-0) = 0.35, or 35%. But for the trait winging, the maximum grade level is five and the lowest grade level is one (see Table 6-2), so the critical value is calculated as 0.05 x (5-1) = 0.2, or 20%. Values that exceed their critical level are highlighted in gray in Table 6-22 and Table 6-23.

Column seven presents the *p*-value of a paired student's *t*-test. The traditional alpha level of 0.05 is recommended as the critical value by Nichol and Turner (1986), and is followed here. Traits that are significantly different in their scoring are highlighted in gray in Table 6-22 and Table 6-23.

All of the statistics from columns 1-7 were calculated on the non-dichotomized data set. The remaining columns are calculated using dichotomized data (see above for dichotomization process). Dichotomization should reduce error by collapsing categories into a present/absent scale. Column eight of Table 6-22 and Table 6.23, % P/A variant score, assesses the variation between scoring sessions once the traits were dichotomized. This statistic is a more realistic indicator of the influence of intraobserver error in this study since traits are dichotomized prior to the multivariate biodistance analysis. Results for the dental non-metric data ranged from 0-73.1%, with an average of 11.8%, which is slightly higher than the mean of 10.7% reported by Nichol and Turner (1986). Results for the cranial non-metric data ranged from 0-64.3%, with an average of 17.2%. Nichol and Turner (1986) do not provide a critical level value for this statistic. Values that exceeded 15% are highlighted in gray in Table 6-22 and Table 6-23.

The ninth column, phi coefficient, was calculated to assess the amount of agreement between dichotomized recording sessions (Willemsen, 1974; Nichol and Turner, 1986; Molto, 1979). Phi is a measure of the association between two paired samples for a dichotomized trait. In this calculation, values can range from negative one to positive one, with positive one indicating complete agreement between sessions. Phi values for the dental non-metric data of this study, range from -0.32 to 1, with an average of 0.5, which is close to that reported by Nichol and Turner (1986) of 0.57. Phi values for the cranial non-metric data range from -0.06 to 1, with an average of 0.5. Molto (1979) used the Phi coefficient on cranial non-metric traits, and found a range of 0.59-1%. Molto (1979) also provides a critical level of 0.7 or higher to be considered a good agreement. Any phi value above 0.7 is considered a strong association, indicating that on average there was considerable agreement between the two sessions once traits were dichotomized.

The last column of Table 6-22 and Table 6-23, present the McNemar's chi-squared test *p*-value, to test for symmetry of the dichotomized data scoring between sessions. The McNemar's test is basically a paired version of a chi-square test. This statistic was included to assess whether the observed differences of the dichotomized data between sessions were significant. Table 6-22 and Table 6-23 highlight in gray the values that exceed a 0.05 level.

Nichol and Turner (1986) emphasize three critical levels (>10% for >1 grade variant score, >5% multiplied by the number of the highest grade on the observational standard for the NMGD, and a *t*-value exceeding the 0.05 probability level) for assessing trait reliability. I have chosen to follow their recommendation, with the following addition: variables with a McNemar Chi-square test *p*-value exceeding the 0.05 probability level should be removed. Nichol and Turner (1986) recommend only removing variables that exceed the critical level for two out of three of these factors, in order to avoid rejection of variables due to chance factors. For this study, variables were removed if they exceeded the critical values for two factors.

Table 6 - 22: Dental non-metrics intraobserver error.

	n pairs	% one only	% variant score	% >1 grade variant score	% AMGD	% NMGD	Paired Student's *t*-test *p*-value	% P/A variant score	Phi	McNemar X^2 *p*-value
UI1 Shoveling	20	0.00	40.00	5.00	45.00	-5.00	0.77	20.00	0.64	0.13
UI2 Shoveling	22	0.00	45.45	4.55	50.00	4.55	0.79	4.55	0.91	1.00
UC Shoveling	22	9.09	15.00	0.00	15.00	-5.00	0.58	10.00	0.80	1.00
LI1 Shoveling	22	0.00	13.64	NA	13.64	4.55	0.58	13.64	-0.07	1.00
LI2 Shoveling	23	8.70	28.57	4.76	33.33	23.81	0.10	28.57	-0.12	0.22
LC Shoveling	27	3.70	42.31	0.00	42.31	26.92	0.03	34.62	0.40	0.05
UI1 Double Shoveling	21	0.00	14.29	NA	14.29	4.76	0.58	14.29	-0.07	1.00
UI2 Double Shoveling	22	0.00	13.64	0.00	13.64	13.64	0.08	13.64	0.65	0.25
UC Double Shoveling	21	0.00	23.81	NA	23.81	14.29	0.19	0.00	NA	NA
UI1 Labial Curvature	21	14.29	61.11	11.11	72.22	16.67	0.48	33.33	0.27	0.68
UI2 Labial Curvature	22	18.18	83.33	33.33	138.89	-16.67	0.70	61.11	-0.32	1.00
UI1 Tuberculum Dentale	21	4.76	55.00	20.00	80.00	70.00	0.00	40.00	0.41	0.01
UI2 Tuberculum Dentale	22	0.00	22.73	13.64	59.09	4.55	0.89	18.18	0.62	0.13
UC Tuberculum Dentale	20	0.00	40.00	20.00	80.00	10.00	0.77	25.00	0.53	0.37
LI1 Tuberculum Dentale	22	4.55	4.76	NA	4.76	4.76	0.33	30.00	-0.13	0.22
LI2 Tuberculum Dentale	23	8.70	0.00	NA	0.00	0.00	1.00	13.64	0.59	1.00
LC Tuberculum Dentale	27	7.41	16.00	NA	16.00	8.00	0.33	16.00	-0.08	0.62
UI1 Interruption Grooves	21	4.76	10.00	0.00	10.00	0.00	1.00	10.00	0.61	1.00
UI2 Interruption Grooves	22	9.09	40.00	25.00	90.00	30.00	0.42	20.00	0.39	1.00
UC Interruption Grooves	20	5.00	21.05	15.79	47.37	-47.37	0.07	21.05	NA	NA
LI1 Interruption Grooves	22	0.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LI2 Interruption Grooves	23	8.70	4.76	4.76	9.52	9.52	0.33	4.76	NA	NA
LC Interruption Grooves	27	7.41	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UI1 Winging	22	4.55	4.76	4.76	9.52	9.52	0.33	0.00	1.00	NA
UI2 Variants	22	0.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UI2 Peg Shaped	22	0.00	4.55	NA	4.55	4.55	0.33	4.55	NA	NA
LI2 Peg Shaped	24	4.17	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UC Mesial Ridge	19	21.05	6.67	NA	6.67	-6.67	0.33	6.67	NA	NA
UC Distal Accessory Ridge	18	16.67	53.33	13.33	86.67	60.00	0.11	26.67	0.58	0.13
LC Distal Accessory Ridge	23	13.04	55.00	10.00	70.00	60.00	0.01	35.00	0.45	0.02
LC Double Root	28	7.14	3.85	0.00	3.85	3.85	0.33	3.85	0.69	1.00
UI2 Congenital Absence	28	3.57	0.00	NA	0.00	0.00	1.00	0.00	1.00	NA
LI1 Congenital Absence	28	3.57	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UI1 Root #	28	3.57	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UI2 Root #	26	7.69	0.00	NA	0.00	0.00	1.00	0.00	NA	NA

Table 6 – 22 Cont'd: Dental non-metrics intraobserver error.

	n pairs	% one only	% variant score	% >1 grade variant score	% AMGD	% NMGD	Paired Student's *t*-test *p*-value	% P/A variant score	Phi	McNemar X^2 *p*-value
UC Root #	27	7.41	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LI1 Root #	27	3.70	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LI2 Root #	28	3.57	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LC Root #	28	3.57	3.70	NA	3.70	3.70	0.33	3.70	0.69	1.00
UI1 Radical #	24	25.00	27.78	NA	27.78	5.56	0.67	27.78	0.35	1.00
UI2 Radical #	23	13.04	10.00	NA	10.00	0.00	1.00	10.00	0.44	1.00
UC Radical #	26	26.92	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LI1 Radical #	27	11.11	8.33	NA	8.33	0.00	1.00	8.33	-0.04	1.00
LI2 Radical #	28	7.14	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LC Radical #	28	7.14	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UP3 Mesial Accessory Ridge	24	12.50	19.05	NA	19.05	19.05	0.04	19.05	0.51	0.13
UP4 Mesial Accessory Ridge	20	5.00	15.79	NA	15.79	15.79	0.08	15.79	0.70	0.25
LP3 Mesial Accessory Ridge	25	12.00	27.27	NA	27.27	18.18	0.10	27.27	0.16	0.22
LP4 Mesial Accessory Ridge	25	16.00	28.57	NA	28.57	28.57	0.01	28.57	0.41	0.04
UP3 Distal Accessory Ridge	24	8.33	22.73	NA	22.73	22.73	0.02	22.73	0.46	0.07
UP4 Distal Accessory Ridge	20	5.00	21.05	NA	21.05	21.05	0.04	21.05	0.57	0.13
LP3 Distal Accessory Ridge	25	12.00	31.82	NA	31.82	22.73	0.06	31.82	0.41	0.13
LP4 Distal Accessory Ridge	25	16.00	38.10	NA	38.10	9.52	0.49	38.10	0.08	0.72
UP3 Accessory Marginal Tubercle	26	7.69	20.83	12.50	37.50	20.83	0.26	10.83	0.22	0.37
UP4 Accessory Marginal Tubercle	22	4.55	23.81	4.76	33.33	14.29	0.42	4.76	NA	NA
UP3 Odontomes	25	4.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UP4 Odontomes	22	4.55	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LP3 Odontomes	25	8.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LP4 Odontomes	26	7.69	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UP4 Distosagittal Ridge	26	7.69	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LP3 Multiple Lingual Cusps	26	7.69	12.50	8.33	37.50	37.50	0.16	4.17	0.85	1.00
LP4 Multiple Lingual Cusps	27	11.11	54.17	12.50	70.83	37.50	0.08	16.67	0.66	0.62
UP3 Tricuspid	26	0.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UP4 Tricuspid	23	4.35	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UP3 Enamel Extension/Pearl	27	11.11	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UP4 Enamel Extension/Pearl	22	4.55	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LP3 Tome's Root	21	33.33	35.71	NA	35.71	35.71	0.02	35.71	0.41	0.07
UP4 Congenital Absence	27	0.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LP4 Congenital Absence	28	3.57	3.70	NA	3.70	3.70	0.33	3.70	NA	NA
UP3 Root #	23	39.13	0.00	0.00	0.00	0.00	1.00	0.00	1.00	NA

Table 6 – 22 Cont'd: Dental non-metrics intraobserver error.

	n pairs	% one only	% variant score	% >1 grade variant score	% AMGD	% NMGD	Paired Student's *t*-test *p*-value	% P/A variant score	Phi	McNemar X^2 *p*-value
UP4 Root #	23	17.39	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UP3 Radical #	24	16.67	10.00	5.00	15.00	-5.00	0.67	5.00	NA	NA
UP4 Radical #	23	13.04	5.00	0.00	5.00	5.00	0.33	0.00	NA	NA
UM1 Carabelli's Cusp	23	0.00	43.38	21.74	100.00	91.30	0.01	17.39	0.63	0.13
UM2 Carabelli's Cusp	24	8.33	9.09	9.09	50.00	-4.55	0.90	4.55	0.69	1.00
UM3 Carabelli's Cusp	18	11.11	18.75	18.75	100.00	12.50	0.84	6.25	0.79	1.00
UM1 Metacone (Cusp 3)	26	0.00	73.08	0.00	73.08	65.38	0.00	73.08	-0.09	0.00
UM2 Metacone (Cusp 3)	24	0.00	12.50	8.33	25.00	25.00	0.11	8.33	NA	NA
UM3 Metacone (Cusp 3)	19	0.00	26.32	5.26	31.58	21.05	0.16	15.79	NA	NA
UM1 Mesial Paracone Tubercle	12	41.67	42.86	NA	42.86	42.86	0.08	42.86	0.35	0.25
UM2 Mesial Paracone Tubercle	18	27.78	30.77	NA	30.77	15.38	0.34	30.77	0.18	0.62
UM3 Mesial Paracone Tubercle	17	23.53	15.38	NA	15.38	0.00	1.00	15.38	-0.08	1.00
UM1 Protoconule Tubercle	11	45.45	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UM2 Protoconule Tubercle	17	35.29	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UM3 Protoconule Tubercle	16	25.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UM1 Mesial Accessory Tubercle	13	46.15	14.29	NA	14.29	-14.29	0.36	14.29	0.65	1.00
UM2 Mesial Accessory Tubercle	18	33.33	8.33	NA	8.33	-8.33	0.34	8.33	0.77	1.00
UM3 Mesial Accessory Tubercle	17	23.53	7.69	NA	7.69	-7.69	0.34	7.69	0.68	1.00
UM1 Lingual Paracone Tubercle	10	70.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UM2 Lingual Paracone Tubercle	17	41.18	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UM3 Lingual Paracone Tubercle	14	42.86	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UM1 Parastyle	25	0.00	16.00	NA	16.00	-16.00	0.04	16.00	NA	NA
UM2 Parastyle	24	4.17	4.35	NA	4.35	-4.35	0.33	4.35	NA	NA
UM3 Parastyle	17	11.76	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UM1 Enamel Extension/Pearl	26	0.00	11.54	0.00	11.54	11.54	0.08	11.54	0.59	0.25
UM2 Enamel Extension/Pearl	24	0.00	45.83	4.17	50.00	41.67	0.00	37.50	0.33	0.01
UM3 Enamel Extension/Pearl	17	11.76	13.33	13.33	26.67	0.00	1.00	13.33	-0.07	1.00
UM3 Peg Shaped	19	0.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UM3 Congenital Absence	26	7.69	0.00	NA	0.00	0.00	1.00	0.00	1.00	NA
LM3 Congenital Absence	27	11.11	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
UM1 Hypocone (Cusp 4)	26	0.00	69.23	0.00	69.23	46.15	0.00	61.54	-0.13	0.02
UM2 Hypocone (Cusp 4)	23	8.70	38.10	14.29	57.14	-9.52	0.68	19.05	0.49	1.00
UM3 Hypocone (Cusp 4)	16	31.25	54.55	18.18	81.82	-27.27	0.49	36.36	0.57	0.62
UM1 Metaconule (Cusp 5)	24	25.00	11.11	5.56	16.67	-16.67	0.19	11.11	NA	NA
UM2 Metaconule (Cusp 5)	24	25.00	22.22	11.11	44.44	-33.33	0.19	16.67	0.32	1.00

Table 6 – 22 Cont'd: Dental non-metrics intraobserver error.

	n pairs	% one only	% variant score	% >1 grade variant score	% AMGD	% NMGD	Paired Student's *t*-test *p*-value	% P/A variant score	Phi	McNemar X^2 *p*-value
UM3 Metaconule (Cusp 5)	19	26.32	14.29	7.14	21.43	7.14	0.67	14.29	0.42	1.00
LM1 Hypoconulid (Cusp 5)	22	13.64	47.37	21.05	68.42	36.84	0.13	31.58	0.34	0.68
LM2 Hypoconulid (Cusp 5)	26	19.23	23.81	14.29	57.14	57.14	0.04	14.29	0.46	0.25
LM3 Hypoconulid (Cusp 5)	21	19.05	35.29	23.53	76.47	64.71	0.08	5.88	0.88	1.00
UM1 Root #	12	33.33	12.50	0.00	12.50	12.50	0.35	12.50	0.65	1.00
UM2 Root #	17	41.18	20.00	0.00	20.00	0.00	1.00	0.00	1.00	NA
UM3 Root #	14	28.57	10.00	0.00	10.00	10.00	0.34	0.00	1.00	NA
LM1 Root #	19	63.16	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LM2 Root #	26	42.31	6.67	0.00	6.67	6.67	0.33	0.00	1.00	NA
LM3 Root #	18	50.00	0.00	0.00	0.00	0.00	1.00	0.00	NA	NA
UM1 Radical #	11	36.36	57.14	0.00	57.14	-28.57	0.36	0.00	NA	NA
UM2 Radical #	14	28.57	30.00	0.00	30.00	30.00	0.08	20.00	0.65	0.48
UM3 Radical #	12	33.33	75.00	NA	75.00	-50.00	0.10	0.00	NA	NA
LM1 Radical #	7	42.86	25.00	0.00	25.00	-25.00	0.39	0.00	NA	NA
LM2 Radical #	25	60.00	10.00	0.00	10.00	-10.00	0.34	0.00	NA	NA
LM3 Radical #	15	46.67	25.00	0.00	25.00	-25.00	0.17	0.00	NA	NA
UM1 Cusp #	26	7.69	8.33	4.17	12.50	-22.22	0.19	8.33	NA	NA
UM2 Cusp #	24	0.00	16.67	0.00	16.67	8.33	0.33	4.17	0.85	1.00
UM3 Cusp #	19	5.26	27.78	5.56	33.33	-22.22	0.16	16.67	0.48	1.00
LM1 Cusp #	23	4.35	18.18	0.00	18.18	-9.09	0.33	9.09	0.73	0.48
LM2 Cusp #	25	8.00	17.39	4.35	21.74	21.74	0.06	4.35	NA	NA
LM3 Cusp #	21	14.29	22.22	0.00	22.22	22.22	0.04	22.22	0.62	0.13
LM1 Entoconulid (Cusp 6)	22	13.64	10.53	10.53	31.58	-31.58	0.19	10.53	0.72	0.48
LM2 Entoconulid (Cusp 6)	25	12.00	4.55	4.55	22.73	22.73	0.33	4.55	NA	NA
LM3 Entoconulid (Cusp 6)	20	15.00	5.88	0.00	5.88	5.88	0.33	0.00	1.00	NA
LM1 Metaconulid (Cusp 7)	23	17.39	10.53	0.00	10.53	0.00	1.00	0.00	1.00	NA
LM2 Metaconulid (Cusp 7)	24	8.33	9.09	4.55	13.64	-13.64	0.19	4.55	0.80	1.00
LM3 Metaconulid (Cusp 7)	21	19.05	5.88	5.88	11.76	11.76	0.33	5.88	0.79	1.00
LM1 Groove Pattern	20	15.00	5.88	5.88	11.76	-11.76	0.33	5.88	0.68	1.00
LM2 Groove Pattern	24	4.17	47.83	8.70	56.52	-4.35	0.81	21.74	0.16	1.00
LM3 Groove Pattern	21	14.29	38.89	5.56	4.44	-11.11	0.54	33.33	0.30	1.00
LM1 Protostylid Buccal Pit	23	4.35	22.73	NA	22.73	4.55	0.67	22.73	0.55	1.00
LM2 Protostylid Buccal Pit	26	7.69	8.33	NA	8.33	8.33	0.16	0.00	NA	NA
LM3 Protostylid Buccal Pit	18	0.00	11.11	NA	11.11	-11.11	0.16	11.11	0.54	0.48
LM1 Protostylid	23	4.35	0.00	NA	0.00	0.00	1.00	0.00	NA	NA

Table 6 – 22 Cont'd: Dental non-metrics intraobserver error.

	n pairs	% one only	% variant score	% >1 grade variant score	% AMGD	% NMGD	Paired Student's *t*-test *p*-value	% P/A variant score	Phi	McNemar X^2 *p*-value
LM2 Protostylid	26	7.69	4.17	NA	4.17	-4.17	0.33	4.17	NA	NA
LM3 Protostylid	18	0.00	0.00	NA	0.00	0.00	1.00	0.00	NA	NA
LM1 Deflect Wrinkle	11	63.64	25.00	25.00	50.00	-50.00	0.39	25.00	NA	NA
LM2 Deflect Wrinkle	20	25.00	6.67	6.67	20.00	-20.00	0.33	6.67	NA	NA
LM3 Deflect Wrinkle	17	35.29	18.18	18.18	54.55	-54.55	0.17	18.18	NA	NA
LM1 Anterior Fovea	10	70.00	66.67	33.33	166.67	166.67	0.30	33.33	NA	NA
LM2 Anterior Fovea	20	20.00	75.00	18.75	93.75	31.25	0.29	31.25	0.29	0.37
LM3 Anterior Fovea	20	15.00	40.00	26.67	73.33	33.33	0.31	26.67	0.49	0.62
LM1 Distal Trigonid Crest	16	62.50	16.67	NA	16.67	-16.67	0.36	16.67	NA	NA
LM2 Distal Trigonid Crest	19	10.53	5.88	NA	5.88	-5.88	0.33	5.88	NA	NA
LM3 Distal Trigonid Crest	18	16.67	13.33	NA	13.33	-13.33	0.16	13.33	NA	NA

Table 6 - 23: Cranial non-metric intraobserver error.

	n pairs	% one only	% variant score	% >1 grade variant score	% AMGD	% NMGD	Paired Student's *t* *p*-value	% P/A variant score	phi	McNemar X^2 *p*-value
Metopic Suture	28	0	0	NA	0	0	1	0	1	NA
Metopic Fissure	28	7.14	0	NA	0	0	1	0	NA	NA
Supranasal Suture	28	7.14	19.23	NA	19.23	3.85	0.66	19.23	0.57	1
Frontal Grooves	28	3.57	22.22	7.41	29.63	-7.41	0.57	18.52	0.44	1
Supratrochlear Notch	28	3.57	55.56	3.7	59.26	29.63	0.06	37.04	0.38	0.03
Medial Supraorbital Notch	28	0	28.57	10.71	39.29	-10.71	0.48	25	0.47	1
Lateral Supraorbital Notch	28	0	0	NA	0	0	1	0	NA	NA
Nutrient Foramen in Notch	28	0	14.29	NA	14.29	14.29	0.04	14.29	NA	NA
Superior Trochlear Foramen	28	0	57.14	46.43	167.86	167.68	0.00	32.14	0.4	0.01
Medial Supraorbital Foramen	28	3.57	29.63	7.41	37.04	0	1	11.11	0.7	0.25
Lateral Supraorbital Foramen	28	0	NA	0	0	0	1	0	NA	NA
Anterior Ethmoid Foramen	20	15	52.94	0	52.94	5.88	0.75	47.06	-0.03	1
Posterior Ethmoid Foramen	25	8	30.43	0	30.43	13.04	0.27	8.7	NA	NA
Trochlear Spine Spur	28	10.71	4	NA	4	4	0.33	4	0.85	1
Nasal Foramen	24	0	41.67	12.5	54.17	12.5	0.50	29.17	0.32	1
Infraorbital Suture	26	0	19.23	NA	19.23	11.54	0.18	19.23	0.62	0.37
Accessory Infraorbital Foramen	27	3.7	65.38	42.31	119.23	111.54	0.00	46.15	0.18	0.01

Table 6 – 23 Cont'd: Cranial non-metric intraobserver error.

	N pairs	% one only	% variant score	% >1 grade variant score	% AMGD	% NMGD	Paired Student's *t* *p*-value	% P/A variant score	phi	McNemar X^2 *p*-value
Zygomaxillary Tubercle	27	14.81	52.17	13.04	65.22	-65.22	0.00	21.74	0.53	0.07
Zygomatico Facial Foramen	28	0	42.86	14.29	64.29	14.29	0.50	32.14	0.37	0.51
Marginal Tubercle	28	0	28.57	0	28.57	14.29	0.16	7.14	0.85	0.48
Bipartite Zygomatic	28	0	0	NA	0	0	1	0	NA	NA
Parietal Foramen	28	0	14.29	0	14.29	7.14	0.33	3.57	0.89	1
Symmetrically Thin Parietals	28	0	7.14	NA	7.14	-7.14	0.16	7.14	NA	NA
Coronal Ossicle	28	0	7.14	NA	7.14	0	1	7.14	0.46	1
Sagittal Ossicle	27	0	0	NA	0	0	1	0	NA	NA
Ossicle at Bregma	28	0	0	NA	0	0	1	0	NA	NA
Lambdoid Ossicle	28	3.57	22.22	3.7	25.93	18.52	0.10	0	1	NA
Ossicle at Lambda	28	0	0	NA	0	0	1	0	1	NA
Inca Bone	28	0	0	NA	0	0	1	0	NA	NA
Occipital Mastoid Ossicle	27	3.7	0	NA	0	0	1	0	1	NA
Occipital Foramen	27	0	55.56	18.52	74.07	0	1	29.63	0.19	0.29
Ossicle at Asterion	26	0	7.69	NA	7.69	-7.69	0.16	7.69	0.55	0.48
Parietal Notch Bone	28	3.57	3.7	NA	3.7	-3.7	0.33	3.7	0.85	1
Epipteric Bone	27	3.7	19.23	0	19.23	19.23	0.02	15.38	0.64	0.13
Frontotemporal Articulation	28	3.57	3.7	NA	3.7	-3.7	0.33	3.7	NA	NA
Squamous Ossicle	27	3.7	23.08	3.85	26.92	-26.92	0.02	23.08	0.5	0.04
Condylar Canal	28	3.57	18.52	0	18.52	11.11	0.18	14.81	0.53	0.13
Double Condylar Facet	27	7.41	8	NA	8	0	1	8	-0.04	1
Hypoglossal Canal Bridging	28	0	25	7.14	32.14	-3.57	0.79	21.43	0.52	0.68
Inter-Condylar Canal Bridging	27	0	29.63	14.81	44.44	-7.41	0.66	22.22	0.53	0.68
Jugular Foramen Bridging	26	0	46.15	0	46.15	-7.69	0.57	23.08	0.43	0.68
Precondylar Tubercle	27	3.7	19.23	7.69	30.77	15.38	0.33	11.54	0.6	1
Pharyngeal Tubercle	28	0	53.57	17.86	71.43	28.57	0.15	10.71	0.35	1
Pharyngeal Fovea	28	0	57.14	21.43	82.14	25	0.27	25	0.41	1
Median Basilar Canal Foramen	28	3.57	70.37	29.63	100	77.78	0.00	51.85	0.2	0.00
Craniopharyngeal Canal	27	7.41	32	NA	32	-24	0.03	32	0.31	0.08
Tympanic Dehiscence	28	0	10.71	NA	10.71	-3.57	0.57	10.71	0.52	1
Postglenoid Foramen	28	3.57	29.63	NA	29.63	14.81	0.16	29.63	0.43	0.29
Oval Foramen Incomplete	28	3.57	0	NA	0	0	1	0	NA	NA
Foramen of Vesalius	28	0	42.86	17.86	78.57	64.29	0.01	25	0.37	0.13
Spinosum Foramen Open	27	0	25.93	NA	25.93	-18.52	0.06	25.93	0.49	0.13
Basilar Sphenoid Bridge	28	10.71	32	4	36	-20	0.13	12	0.7	0.25

Table 6 – 23 Cont'd: Cranial non-metric intraobserver error.

	N pairs	% one only	% variant score	% >1 grade variant score	% AMGD	% NMGD	Paired Student's *t* *p*-value	% P/A variant score	phi	McNemar X^2 *p*-value
Accessory Lesser Palatine Foramen	26	0	76.92	19.23	100	84.62	0.00	23.08	NA	NA
Palatine Bridging	27	0	7.41	0	7.41	0	1	3.7	0.91	1
Palatine Torus	26	0	38.46	3.85	42.31	-26.92	0.05	15.38	0.53	0.62
Maxillary Torus	27	0	37.04	7.41	48.15	-33.33	0.05	29.63	0.44	0.08
Retromastoid Process	27	7.41	16	4	20	20	0.06	16	0.52	0.13
Paracondylar Process	26	7.69	41.67	8.33	50	33.33	0.04	25	0.49	0.22
Sella Bridges	1	0	NA	NA	NA	NA	NA	NA	NA	NA
Flexure of Superior Sagittal Sulcus	28	14.29	16.67	12.5	29.17	12.5	0.42	12.5	0.75	0.25
Auditory Torus	28	0	0	NA	0	0	1	0	NA	NA
Suprameatal Spine	28	0	50	10.71	60.71	3.57	0.84	32.14	0.44	0.05
Suprameatal Depression	28	0	46.43	10.71	57.14	35.71	0.03	32.14	0.45	0.05
Inferior Squamous Foramen	28	0	50	25	78.57	28.57	0.21	25	0.51	0.45
Superior Squamous Foramen	28	3.57	40.74	14.81	59.26	-14.81	0.46	33.33	0.25	0.50
Inferior Parietal Foramen	28	0	25	10.71	35.71	-21.43	0.14	14.29	0.66	0.61
Bipartite Parietal Bone	28	0	0	NA	0	0	1	0	NA	NA
Bipartite Temporal Squama	28	0	0	NA	0	0	1	0	NA	NA
Biasterionic Suture	28	3.57	14.81	3.7	22.22	-22.22	0.08	11.11	0.77	0.25
Mastoid Foramen Extrasutural	27	3.7	15.38	7.69	23.08	23.08	0.06	15.38	0.72	0.13
Accessory Mastoid Foramen	27	0	55.56	7.41	66.67	14.81	0.44	18.52	0.65	.37
Squamomastoid Suture	28	7.14	34.62	26.92	76.92	23.08	0.42	19.23	-0.01	1
Mandibular Torus	28	0	50	0	50	42.86	0.00	46.43	0.35	0.00
Accessory Mental Foramen	28	0	39.29	7.14	46.43	25	0.09	21.43	0.57	0.22
Mylohyoid Bridge	28	0	10.71	3.57	14.29	-14.29	0.10	3.57	0.8	1
Mental Spines	28	0	46.43	25	85.71	-7.14	0.79	10.71	0.35	1
Median Pit	28	0	21.43	10.71	32.14	-3.57	0.80	10.71	0.35	1
Retromolar Foramen	27	3.7	46.15	7.69	53.85	15.38	0.36	26.92	0.36	0.13
Molar Foramen	28	0	60.71	25	89.29	25	0.29	25	NA	NA
Canal de Serres Foramen	28	0	57.14	NA	57.14	-42.86	0.00	57.14	-0.06	0.01
Canal of Robinson	28	0	75	46.43	121.43	121.43	0.00	64.29	NA	NA
Rocker Mandible	27	7.41	24	NA	24	16	0.10	24	0.56	0.22
Atlas Bridge	25	0	12	12	24	24	0.08	12	0.47	0.25
Double Articular Facet of C1	25	0	8	NA	8	0	1	8	-0.04	1
Septal Aperture	28	0	7.14	NA	7.14	0	1	7.14	0.63	1

* NMGD value exceeds the critical level for the trait.

Redundancy

Dental data were further reduced to observations made on the key-teeth for each dental trait. For the dental metrics the key teeth are the I1, C, P3 and M1 as they are considered to be the most genetically stable within each tooth class and less affected by environmental factors (Butler 1939; Dahlberg 1956). For the dental non-metrics these teeth are defined by Turner II and colleagues (1991), Scott and Turner II (1997) and Scott and Irish (2017), and vary depending on the trait. All non-focal teeth were removed from the final analysis; unless the focal was previously removed, in that case another tooth from the same field was substituted (see Table 6-24 through Table 6-27).

Missing data and low trait variance

Most multivariate statistical analyses used to compare populations and calculate biodistance require complete datasets. Unfortunately, most archaeological samples are incomplete. Therefore, studies must make compromises in order to analyze data. There are four commonly used means to handle missing data. The first is to remove all cases (individuals) with missing data, however this option often results in extremely small and unrepresentative samples. The second option is to replace missing values with the grand mean or group mean for that variable (e.g., Droessler, 1976; Pilloud, 2009). However, this can increase homogeneity (group mean substitution) or reduce intragroup heterogeneity (grand mean substitution) (Droessler, 1979). A third option is to eliminate statistical analyses that require complete datasets (Wrobel, 2004), but this limits the degree to which populations can be compared. The fourth, option is to replace missing data using multivariate statistical approaches, such as multiple regression analysis or multiple imputation analysis.

A combination of removal of individuals with high missing data frequencies, removal of variables with high missing data frequencies, and multiple imputation were used in this study in order to accommodate the need for a complete dataset for the multivariate analysis while also maintaining a sufficiently large and representative sample size.

In order to reduce the number of predicted values in the final dataset, variables and cases (individuals) were removed if the majority of data were missing. The first step was to remove cases (individuals) with more than 70% missing data, from each dataset (dental metric, cranial metric, dental non-metric, and cranial non-metric). The cranial metric dataset was reduced to include only the adults and older adolescents for which sex estimates could be made, in order to control for growth and developmental age-related size differences. Next, the percent missing data (% NA) for each variable was calculated, and variables with more than 30% missing data were selected for removal from each dataset (Cook and Aubry, 2014). In addition, for the non-metric datasets, variables with a shared low (<5%) or high (>95%) expression were selected for removal (Irish, 2010; Irish and Konigsberg, 2007; Zejdlik Passalacqua, 2015), as they will not provide useful differentiating information.

The final criterion for inclusion-exclusion of variables is summarized in Table 6-24 for the dental metric data. The removal of variables resulted in a final dental metric dataset of 139 individuals, 20 dental metric variables, and 2110/2780 (75.9%) observations recorded.

The final criterion for inclusion-exclusion of variables is summarized in Table 6-25 for the cranial metric data. The removal of variables resulted in a final cranial metric dataset of 132 individuals, 17 cranial metric variables, and 1952/2244 (87%) observations recorded.

The final criterion for inclusion-exclusion of variables is summarized in Table 6-26 for the dental non-metric data. The removal of variables resulted in a final dental non-metric dataset

of 140 individuals, 15 dental non-metric variables, and 1375/2100 (65.5%) observations recorded.

The final criterion for inclusion-exclusion of variables is summarized in Table 6-27 for the cranial non-metric data. The removal of variables resulted in a final cranial non-metric dataset of 245 individuals, 19 cranial non-metric variables, and 3897/4655 (83.7%) observations recorded.

Rubin (1996:479-480) considered a modest amount to be less than 30% missing data. Additionally, the rate of missing data in this study is comparable to that reported by Schafer and Olsen (1998), and similar to that reported by Thompson (2013). Appendix A provides the descriptive statistics of the reduced datasets by site name and sex.

Table 6 - 24: Criteria for inclusion/exclusion of dental metric variables.

	Error	Non-Normal	Age	Non-Key	NA > 30%	Excluded	Included
MD Crown UI1					X	X	
MD Crown UI2				X	X	X	
MD Crown UC					X	X	
MD Crown UP3			X		X	X	
MD Crown UP4			X	X	X	X	
MD Crown UM1			X		X	X	
MD Crown UM2				X			X
MD Crown UM3			X	X	X	X	
MD Crown LI1			X		X	X	
MD Crown LI2				X	X	X	
MD Crown LC		X					X
MD Crown LP3			X			X	
MD Crown LP4			X	X		X	
MD Crown LM1							X
MD Crown LM2				X		X	
MD Crown LM3				X	X	X	
BL Crown UI1		X	X		X	X	
BL Crown UI2				X	X	X	
BL Crown UC							X
BL Crown UP3					X	X	
BL Crown UP4				X	X	X	
BL Crown UM1					X	X	
BL Crown UM2				X			X
BL Crown UM3			X	X	X	X	
BL Crown LI1			X		X	X	
BL Crown LI2				X			X

Table 6 – 24 Cont'd: Criteria for inclusion/exclusion of dental metric variables.

	Error	Non-Normal	Age	Non-Key	NA > 30%	Excluded	Included
BL Crown LC							X
BL Crown LP3							X
BL Crown LP4	X			X		X	
BL Crown LM1		X	X		X	X	
BL Crown LM2				X			X
BL Crown LM3				X	X	X	
MD CEJ UI1					X	X	
MD CEJ UI2		X		X		X	
MD CEJ UC		X					X
MD CEJ UP3		X				X	
MD CEJ UP4	X	X		X		X	
MD CEJ UM1		X					X
MD CEJ UM2		X		X		X	
MD CEJ UM3				X	X	X	
MD CEJ LI1		X				X	
MD CEJ LI2				X			X
MD CEJ LC							X
MD CEJ LP3		X				X	
MD CEJ LP4				X			X
MD CEJ LM1							X
MD CEJ LM2		X		X		X	
MD CEJ LM3				X	X	X	
BL CEJ UI1			X		X	X	
BL CEJ UI2				X			X
BL CEJ UC			X			X	
BL CEJ UP3							X
BL CEJ UP4				X	X	X	
BL CEJ UM1			X			X	
BL CEJ UM2				X			X
BL CEJ UM3		X		X	X	X	
BL CEJ LI1					X	X	
BL CEJ LI2				X			X
BL CEJ LC		X				X	
BL CEJ LP3		X				X	
BL CEJ LP4				X	X	X	
BL CEJ LM1							X
BL CEJ LM2				X	X	X	
BL CEJ LM3				X	X	X	

Table 6 - 25: Criteria for inclusion/exclusion of cranial metric variables.

	Error	Non-normal	Age	NA > 30%	Excluded	Included
Maximum Length (g-op)	X		X		X	
Maximum Breadth (eu-eu)	X				X	
Bizygomatic Breadth (zy-zy)	X			X	X	
Basion-Bregma (ba-b)	X				X	
Cranial Base Length (ba-n)	X				X	
Basion-Prosthion Length (ba-pr)						X
Maximum Alveolar Breadth (ecm-ecm)		X	X		X	
Maximum Alveolar Length (pr-alv)						X
Biauricular Breadth						X
Upper Facial Height (n-pr)		X			X	

Table 6 – 25 Cont'd: Criteria for inclusion/exclusion of cranial metric variables.

	Error	Non-normal	Age	NA > 30%	Excluded	Included
Minimum Frontal Breadth (ft-ft)						X
Upper Facial Breadth (fmt-fmt)						X
Nasal Height (n-ns)						X
Nasal Breadth (al-al)			X		X	
Orbital Breadth (mf-ec)						X
Orbital Height						X
Biorbital Breadth (ec-ec)						X
Interorbital Breadth (mf-mf)						X
Frontal Chord (n-b)		X			X	
Parietal Chord (b-l)						X
Occipital Chord (l-o)						X
Foramen Magnum Length (ba-o)			X		X	
Foramen Magnum Breadth						X
Mastoid Length						X
Chin Height (gn-id)			X		X	
Body Height at Mental Foramen		X	X		X	
Body Thickness at Mental Foramen						X
Bigonial Diameter (go-go)			X		X	
Bicondylar Breadth (cdl-cdl)			X	X	X	
Minimum Ramus Breadth						X
Maximum Ramus Breadth						X
Mandibular Length	X				X	
Ramus Height	X	X		X	X	

Table 6 - 26: Criteria for inclusion/exclusion of dental non-metric variables.

	Error	Non-Key	Sex	Age	NA >30%	"P" <5% "P">95%	Excluded	Included
UI1 Shoveling				X	X		X	
UI2 Shoveling		X		X	X		X	
UC Shoveling		X		X	X		X	
LI1 Shoveling		X		X	X	X	X	
LI2 Shoveling		X		X		X	X	
LC Shoveling	X	X		X			X	
UI1 Double Shoveling					X			X
UI2 Double Shoveling		X			X		X	
UC Double Shoveling		X				X	X	
UI1 Labial Curvature				X	X		X	
UI2 Labial Curvature		X			X		X	
UI1 Tuberculum Dentale	X	X		X	X		X	
UI2 Tuberculum Dentale					X		X	
UC Tuberculum Dentale		X		X	X		X	
LI1 Tuberculum Dentale		X			X	X	X	
LI2 Tuberculum Dentale		X				X	X	
LC Tuberculum Dentale		X				X	X	
UI1 Interruption Grooves		X			X	X	X	
UI2 Interruption Grooves	X				X		X	
UC Interruption Grooves	X	X			X		X	
LI1 Interruption Grooves		X			X	X	X	
LI2 Interruption Grooves		X				X	X	
LC Interruption Grooves		X				X	X	

Table 6 – 26 Cont'd: Criteria for inclusion/exclusion of dental non-metric variables.

	Error	Non-Key	Sex	Age	NA >30%	"P" <5% "P">95%	Excluded	Included
UI1 Winging					X		X	
UI2 Variants						X	X	
UI2 Peg Shaped						X	X	
LI2 Peg Shaped						X	X	
UC Mesial Ridge					X	X	X	
UC Distal Accessory Ridge	X			X	X		X	
LC Distal Accessory Ridge	X			X	X		X	
LC Double Root								X
UI2 Congenital Absence						X	X	
LI1 Congenital Absence						X	X	
UI1 Root #						X	X	
UI2 Root #		X				X	X	
UC Root #						X	X	
LI1 Root #						X	X	
LI2 Root #		X				X	X	
LC Root #		X					X	
UI1 Radical #			X					X
UI2 Radical #		X	X				X	
UC Radical #		X				X	X	
LI1 Radical #		X				X	X	
LI2 Radical #		X				X	X	
LC Radical #		X				X	X	
UP3 Mesial Accessory Ridges	X	X		X	X		X	
UP4 Mesial Accessory Ridges	X			X	X		X	
LP3 Mesial Accessory Ridges	X	X			X		X	
LP4 Mesial Accessory Ridges	X	X			X			X
UP3 Distal Accessory Ridges	X	X		X	X		X	
UP4 Distal Accessory Ridges	X	X			X		X	
LP3 Distal Accessory Ridges	X	X		X	X		X	
LP4 Distal Accessory Ridges	X	X		X	X		X	
UP3 Accessory Marginal Tubercles	X				X		X	
UP4 Accessory Marginal Tubercles		X			X	X	X	
UP3 Odontomes					X	X	X	
UP4 Odontomes		X			X	X	X	
LP3 Odontomes						X	X	
LP4 Odontomes		X			X	X	X	
UP4 Distosagittal Ridge					X	X	X	
LP3 Multiple Lingual Cusps		X					X	
LP4 Multiple Lingual Cusps								X
UP3 Tricuspid					X	X	X	
UP4 Tricuspid		X			X	X	X	
UP3 Enamel Extension/Pearl						X	X	
UP4 Enamel Extension/Pearl		X			X	X	X	
LP3 Tome's Root	X				X		X	
UP4 Congenital Absence						X	X	
LP4 Congenital Absence						X	X	
UP3 Root #					X		X	
UP4 Root #		X			X		X	
UP3 Radical #					X	X	X	
UP4 Radical #		X			X	X	X	
UM1 Carabelli's Cusp	X			X			X	
UM2 Carabelli's Cusp		X		X				X

Table 6 – 26 Cont'd: Criteria for inclusion/exclusion of dental non-metric variables.

	Error	Non-Key	Sex	Age	NA >30%	"P" <5% "P">95%	Excluded	Included
UM3 Carabelli's Cusp		X			X		X	
UM1 Metacone (Cusp 3)	X	X					X	
UM2 Metacone (Cusp 3)		X						X
UM3 Metacone (Cusp 3)					X		X	
UM1 Mesial Paracone Tubercle	X				X		X	
UM2 Mesial Paracone Tubercle	X	X			X		X	
UM3 Mesial Paracone Tubercle		X			X			X
UM1 Protoconule Tubercle				X	X		X	
UM2 Protoconule Tubercle		X			X		X	
UM3 Protoconule Tubercle		X			X		X	
UM1 Mesial Accessory Tubercle	X				X		X	
UM2 Mesial Accessory Tubercle		X		X	X		X	
UM3 Mesial Accessory Tubercle		X			X		X	
UM1 Lingual Paracone Tubercle				X	X		X	
UM2 Lingual Paracone Tubercle		X		X	X		X	
UM3 Lingual Paracone Tubercle		X			X		X	
UM1 Parastyle	X						X	
UM2 Parastyle						X		X
UM3 Parastyle		X			X	X	X	
UM1 Enamel Extension/Pearl						X	X	
UM2 Enamel Extension/Pearl	X	X					X	
UM3 Enamel Extension/Pearl		X			X		X	
UM3 Peg Shaped					X	X	X	
UM3 Congenital Absence						X	X	
LM3 Congenital Absence						X		X
UM1 Hypocone (Cusp 4)	X	X		X			X	
UM2 Hypocone (Cusp 4)				X			X	
UM3 Hypocone (Cusp 4)		X			X			X
UM1 Metaconule (Cusp 5)				X	X		X	
UM2 Metaconule (Cusp 5)	X	X		X	X		X	
UM3 Metaconule (Cusp 5)		X			X			X
LM1 Hypoconulid (Cusp 5)	X				X		X	
LM2 Hypoconulid (Cusp 5)	X	X			X		X	
LM3 Hypoconulid (Cusp 5)	X	X	X		X		X	
UM1 Root #		X		X	X	X	X	
UM2 Root #					X			X
UM3 Root #		X			X		X	
LM1 Root #		X			X	X	X	
LM2 Root #					X		X	
LM3 Root #		X			X		X	
UM1 Radical #					X	X	X	
UM2 Radical #		X			X		X	
UM3 Radical #	X	X			X	X	X	
LM1 Radical #					X	X	X	
LM2 Radical #		X			X	X	X	
LM3 Radical #		X			X	X	X	
UM1 Cusp #		X		X	X		X	
UM2 Cusp #								X
UM3 Cusp #		X			X		X	
LM1 Cusp #		X		X	X		X	
LM2 Cusp #					X	X	X	
LM3 Cusp #	X	X	X		X		X	

Table 6 – 26 Cont'd: Criteria for inclusion/exclusion of dental non-metric variables.

	Error	Non-Key	Sex	Age	NA >30%	"P" <5% "P">95%	Excluded	Included
LM1 Entoconulid (Cusp 6)	X				X		X	
LM2 Entoconulid (Cusp 6)		X			X	X	X	
LM3 Entoconulid (Cusp 6)		X			X		X	
LM1 Metaconulid (Cusp 7)				X	X		X	
LM2 Metaconulid (Cusp 7)		X			X		X	
LM3 Metaconulid (Cusp 7)		X			X		X	
LM1 Groove Pattern		X			X		X	
LM2 Groove Pattern					X			X
LM3 Groove Pattern		X			X		X	
LM1 Protostylid-Buccal Pit	X						X	
LM2 Protostylid-Buccal Pit		X		X				X
LM3 Protostylid-Buccal Pit	X	X			X		X	
LM1 Protostylid						X	X	
LM2 Protostylid		X				X	X	
LM3 Protostylid		X			X	X	X	
LM1 Deflecting Wrinkle				X	X		X	
LM2 Deflecting Wrinkle		X			X		X	
LM3 Deflecting Wrinkle	X	X			X		X	
LM1 Anterior Fovea	X				X		X	
LM2 Anterior Fovea	X				X		X	
LM3 Anterior Fovea	X	X			X		X	
LM1 Distal Trigonid Crest	X				X	X	X	
LM2 Distal Trigonid Crest					X	X	X	
LM3 Distal Trigonid Crest	X	X			X	X	X	

Table 6 - 27: Criteria for inclusion/exclusion of cranial non-metric variables.

	Error	Sex	Age	NA >30%	"P" < 5% "P" > 95%	Excluded	Included
Metopic Suture							X
Metopic Fissure					X	X	
Supranasal Suture							X
Frontal Grooves							X
Supratrochlear Notch	X		X			X	
Medial Supraorbital Notch	X		X			X	
Lateral Supraorbital Notch					X	X	
Nutrient Foramen in Notch	X		X			X	
Supratrochlear Foramen	X	X	X			X	
Medial Supraorbital Foramen							X
Lateral Supraorbital Foramen							X
Anterior Ethmoid Foramen			X	X		X	
Posterior Ethmoid Foramen				X		X	
Trochlear Spine (Spur)				X		X	
Nasal Foramen				X	X	X	
Infraorbital Suture	X		X			X	
Accessory Infraorbital Foramen	X	X				X	
Zygomaxillary Tubercle	X					X	
Zygomatico-Facial Foramen	X		X			X	
Marginal Tubercle		X	X			X	
Parietal Foramen							X
Symmetrically Thin Parietals					X	X	

Table 6 – 27 Cont'd: Criteria for inclusion/exclusion of cranial non-metric variables.

	Error	Sex	Age	NA >30%	"P" < 5% "P" > 95%	Excluded	Included
Coronal Ossicle					X	X	
Sagittal Ossicle					X	X	
Ossicle at Bregma					X	X	
Lambdoid Ossicle			X			X	
Ossicle at Lambda		X				X	
Inca Bone		X			X	X	
Occipito-Mastoid Ossicle							X
Occipital Foramen							X
Ossicle at Asterion							X
Condylar Canal							X
Double Condylar Facet					X	X	
Hypoglossal Canal Bridge		X	X			X	
Intermediate Condylar Canal Bridge			X			X	
Jugular Foramen Bridge			X			X	
Precondylar Tubercle			X			X	
Pharyngeal Tubercle	X		X			X	
Pharyngeal Fovea	X					X	
Median Basilar Canal Foramen	X			X		X	
Craniopharyngeal Canal	X					X	
Tympanic Dehiscence			X			X	
Postglenoid Foramen	X					X	
Oval Foramen Incomplete			X			X	
Foramen of Vesalius	X					X	
Spinosum Foramen Open	X		X			X	
Basilar-Sphenoid Bridge							X
Accessory Lesser Palatine Foramen	X		X	X		X	
Palatine Bridge			X			X	
Palatine Torus	X					X	
Maxillary Torus	X					X	
Retromastoid Process			X	X		X	
Paracondylar Process	X		X	X		X	
Sella Bridge				X	X	X	
Flexure of Superior Sagittal Sulcus							X
Auditory Torus					X	X	
Suprameatal Spine	X		X			X	
Suprameatal Depression	X	X	X			X	
Inferior Squamous Foramen	X		X			X	
Superior Squamous Foramen	X					X	
Inferior Parietal Foramen	X					X	
Bipartite Parietal					X	X	
Bipartite Temporal Squama					X	X	
Bipartite Zygomatic					X	X	
Biasterionic Suture							X
Mastoid Foramen Extrasutural							X
Accessory Mastoid Foramen			X			X	
Squamomastoid Suture			X			X	
Parietal Notch Bone							X
Epipteric Bone	X			X		X	
Frontotemporal Articulation				X	X	X	
Squamous Ossicle	X	X		X		X	
Mandibular Torus	X		X			X	
Accessory Mental Foramen							X

Table 6 – 27 Cont'd: Criteria for inclusion/exclusion of cranial non-metric variables.

	Error	Sex	Age	NA >30%	"P" < 5% "P" > 95%	Excluded	Included
Mylohyoid Bridge							X
Mental Spines			X			X	
Median Pit		X				X	
Retromolar Foramen							X
Molar Foramen	X					X	
Canal de Serres Foramen	X					X	
Canal of Robinson	X				X	X	
Rocker Mandible	X		X			X	
Atlas Bridge	X					X	
Double Articular Facet of C1			X		X	X	
Septal Aperture		X	X			X	

Multiple imputation for missing data

The remaining cases of missing data were handled by substituting an estimated measure using multiple imputation (MUIP) regression (Josse and Husson, 2016; Schafer, 1997, 1999; Schafer and Graham, 2002; Schafer and Olsen, 1998; Thompson, 2013; van Buuren and Groothuis-Oudshoorn, 2011; Zejdlik Passalacqua, 2015), as it computes the missing data based on the values of multiple variables, rather than a simple linear regression calculating missing data based only on one other variable. MUIP accounts for the structure of the original dataset as it estimates the values for missing data by taking into account global similarities between individuals and links between variables (Josse and Husson 2016). MUIP for metric data is a sophisticated method that has been widely used (Rubin, 1996) and estimates missing data using a simulated list of multiple imputations (m) where $m>1$. Each m dataset is analyzed by a complete-data method with the observed data. The results are then combined to obtain overall estimates and standard errors (Schafer and Graham 2002). Thompson (2013) and Zejdlik Passalacqua (2015) have successfully used MUIP regression on dental metric data.

Since the goal of this project was to identify potential differences between time periods, the MUIP regression was run using the pooled site sample, for all metric and non-metric

datasets. Using the pooled site sample would have biased the sample against the hypotheses that the time periods differ. Therefore, any differences identified in the final multivariate analyses were not the result of the MUIP regression and are in fact true differences between the samples. Due to sample sizes, the datasets were not separated by sex for the MUIP regression analysis. Since the estimated values are based on an individual's known values in relation to the other individuals in the sample, the estimated values should reflect the sex of the known values. Therefore, not separating the sexes should have little effect on the final outcome.

MUIP for the missing metric data of this project was run using the R package *mice*, the function *mice*() was used with 10 imputations, 50 iterations, and an offset of 500 (van Buuren and Groothuis-Oudshoorn, 2011). The first imputated metric dataset was then kept and compared to the original metric dataset using a student's t-test and F test, in order to test the hypothesis that the imputated dataset was not significantly different from the original. The results of the comparison between the original metric data and the matrix produced through a single imputation are presented in Table 6-28.

Table 6 - 28: Student's *t*-test and F ratio comparisons of pre-MUIP and post-MUIP metric variables.

	t	*p*-value	F	*p*-value
MD Crown UM2	0.442	0.659	1.067	0.721
MD Crown LC	0.113	0.910	0.934	0.707
MD Crown LM1	0.548	0.584	0.938	0.745
BL Crown UC	0.915	0.362	1.218	0.299
BL Crown UM2	0.221	0.825	1.027	0.878
BL Crown LI2	0.004	0.997	1.058	0.756
BL Crown LC	0.282	0.778	1.033	0.853
BL Crown LP3	0.116	0.907	1.038	0.833
BL Crown LM2	0.297	0.767	1.107	0.582
MD CEJ UC	0.285	0.776	1.105	0.578
MD CEJ UM1	-0.781	0.435	0.802	0.225
MD CEJ LI2	0.359	0.720	1.134	0.485
MD CEJ LC	0.270	0.788	1.035	0.842
MD CEJ LP4	-0.130	0.897	1.006	0.968
MD CEJ LM1	0.272	0.786	0.899	0.554
BL CEJ UI2	0.255	0.799	1.131	0.507
CL CEJ UP3	0.601	0.548	0.875	0.477

Table 6 – 28 Cont'd: Student's *t*-test and F ratio comparisons of pre-MUIP and post-MUIP metric variables.

	t	*p*-value	F	*p*-value
BL CEJ UM2	0.722	0.471	1.033	0.855
BL CEJ LI2	-0.287	0.774	1.050	0.786
BL CEJ LM1	0.393	0.695	1.084	0.650
Basion-Prosthion Length	0.182	0.856	1.030	0.870
Maximum Alveolar Length	0.256	0.798	1.073	0.693
Biauricular Breadth	0.412	0.681	0.935	0.717
Minimum Frontal Breadth	0.274	0.784	1.017	0.921
Upper Facial Breadth	0.220	0.826	0.994	0.972
Nasal Height	-0.192	0.848	1.088	0.646
Orbital Breadth	-0.054	0.957	1.074	0.692
Orbital Height	0.102	0.919	1.038	0.836
Biorbital Breadth	-0.075	0.941	1.181	0.380
Interorbital Breadth	0.316	0.752	1.021	0.903
Parietal Chord	0.102	0.919	1.016	0.927
Occipital Chord	0.323	0.747	0.957	0.807
Foramen Magnum Breadth	0.222	0.824	0.980	0.917
Mastoid Length	-0.031	0.975	1.006	0.974
Body Thickness at Mental Foramen	0.119	0.905	0.995	0.977
Minimum Ramus Breadth	0.289	0.773	0.959	0.818
Maximum Ramus Breadth	0.039	0.969	0.989	0.956

In order to have a complete dataset for the multiple correspondence analysis, MUIP for the missing non-metric data was run using the R package *missMDA* (Josse and Husson, 2016). The *missMDA* package imputes the missing values of categorical data using a regularized iterative multiple correspondence analysis algorithm (Josse and Husson, 2016; Josse, et al. 2010). The default setting of the *missMDA* package is to have the missing values initially imputed by the proportion of the category for the categorical variables coded with indicator matrices of dummy variables, rather than using random initialization (Josse and Husson, 2016). It is important to estimate the number of MCA dimensions used when imputing the missing data. This is done in the *missMDA* package using the *estim_ncpMCA*() function, which finds the optimal number of components to use when imputing the missing data. Once the number of components is identified, an imputed dataset can be generated using the function *imputeMCA*(). The resulting complete imputed dataset was then used in the multiple correspondence analysis.

Standardization of metric data

The last step prior to principal component analysis of the metric data was to standardize the data by sex. Analyzing size differences due to sexual dimorphism of the dentition and cranium is a complicated issue from a biodistance perspective. There are three main approaches to controlling for sexual dimorphism of dental and cranial metric traits: 1) ignore sex as a variable and combine male and female datasets, 2) analyze males and females separately, or 3) use statistical methods to reduce the effect of sexual dimorphism. Since the crania and dentitions of the samples used in this study are relatively complete and most adults have a sex estimate, for this study sexual dimorphism was handled using options two and three for the metric datasets. For the non-metric data sexual dimorphism was controlled for by removal of variables that positively correlated with sex (see section above: age and sex correlations). In order to test Hypothesis 2 the sexes were also separated after standardization.

First, the sexes were entered into three separate datasets: male, female, and indeterminate. Next, using the R function *scale*(df, center=TRUE, scale=TRUE*),* for each sex separately, each variable was standardized by converting the measurements to z-scores (R Core Team, 2017). Finally, the scaled-sex datasets were then stitched back together into one cohesive dataset. Once standardized, the metric datasets were ready to be subjected to multivariate analysis.

Statistical evaluations of hypotheses

Once the datasets were reduced, missing data estimated, and metric data standardized, the metric and nonmetric data were subjected to multivariate statistical analyses using the statistical program R (R Core Team, 2017). Multivariate statistics are helpful in answering questions concerning the similarities and differences between individuals, from the point of view of all the

variables, rather than using just a single variable or means of variables (Cook and Aubry, 2014; Hefner, 2013; Hefner, et al. 2012; Husson, et al. 2011; Jantz and Ousley, 2005; Krzanowski, 2002). Multivariate statistical tests were used to test the following hypotheses:

Hypothesis 1: If the Ottoman incursions and presence resulted in a large decline (depopulation from out-migration, warfare, famine and disease) of the Croat population, with a corresponding increase in external immigration by Vlachs due to the Ottoman *sürgün* practices, then the Early Modern (Ottoman) sample (Koprivno Križ Phase II and Drinovci-Greblje) should demonstrate a clear separation in phenotypic trait expression from the Medieval sample (Šibenik-Sv. Lovre and Koprivno-Križ Phase I).

Hypothesis 2: If Croat males were the first to leave the region and Ottoman males (Vlach or Serb laborers and soldiers) the first to repopulate the region, Ottoman-period males could have acquired local females as wives. If this is the case, multivariate statistics may find significant differences between males from the pre-Ottoman and Ottoman periods; but no significant differences between females across the time periods.

Null Hypothesis: If the Vlachs and Croats did not vary in phenotypic traits before the Ottoman incursions and if those incursions had a minimal effect on the population, then there will be no observable differences between the samples and biodistance estimates will be insignificant.

In order to determine if the two samples represent two clearly separate populations (both as a combined population, and separated by sex) a combination of principle components analysis (PCA, for metric data), and multiple correspondence analysis (MCA, for nonmetric data) was used to first explore the data. The component loadings of the PCA and MCA were tested to see if they could be used to distinguish between time periods (and sites), using a MANOVA test.

Significant MANOVA findings were followed up with a descriptive discriminate analysis (DDA). Mean measure of divergence (MMD) and multidimensional scaling (MDS) were also used on the non-metric data. Each test provides multiple lines of evidence to either support or reject the hypotheses above.

Metric data analysis

Principle components analysis (PCA) is a multivariate statistic that is applied to data tables with multiple rows of individuals and multiple columns of quantitative variables (Husson, et al. 2011). PCA is typically used as an exploratory data reduction technique that identifies which variables contribute the most to characterizing the individuals and if any of the variables are linearly correlated (Abdi and Williams, 2010; Husson, et al. 2011), allowing a large number of metric variables to be reduced to a few components that capture most of the variation between the samples. PCA uses secondary variables (e.g., age, sex, population, site) to examine the relationship between secondary variables and either individuals or variables (Husson, et al. 2011). PCA will calculate an Euclidean distance (a measure of dissimilarity) and graphically display the individuals in a cluster diagram. The location on the plot relates to the similarity or difference between items (in this case individuals). Groups that are in close proximity are more similar to each other than groups that are more distant. PCA will be used to test the pooled sample (i.e., combined male, female and indeterminate), as well as to test the male sample and female sample separately. The R packages, *FactorMineR* (Husson, et al. 2010; Husson, et al. 2011) and *stats* (R Core Team, 2017), will be used to run the PCA statistical tests. A clear separation between the Medieval and Early Modern samples would support Hypothesis 1, while a lack of separation would support the null hypothesis. In order for Hypothesis 2 to be supported

the PCA for the female data should show little difference between the Medieval and Early Modern females, but the male data should show significant differences between the Medieval and Early Modern males.

A MANOVA test was used as an omnibus test to identify potential group differences between sites and time periods, using the principal components with eigenvalues greater than 1. Pillai's trace, Wilks lambda, Hotelling-Lawley trace and Roy tests were used to test how well the principal components predict time period. The Wilks lambda criterion is the oldest and most widely used technique for testing the significance of a MANOVA test (Huberty and Olejnik, 2006). The Pillai's' trace test is a robust multivariate test for small sample sizes as well as for unequal sample sizes (Tabachnick and Fidell, 2001), and performs about the same as the Wilks lambda criterion (Huberty and Olejnik, 2006). The Hotelling-Lawley trace criterion provides a p-value that is slightly smaller than that obtained using the Wilks criterion (Huberty and Olejnik, 2006). The Roy criterion provides a more liberal p-value, which means that if the p-value is not significant than it is unlikely that the other tests will be significant (Huberty and Olejnik, 2006). In addition, a significant p-value from a Roy test cannot be given "complete confidence" (Huberty and Olejnik, 2006:51). If all four omnibus tests produce significant results this would be an indication of clear and strong support for a difference between time periods. The *stats* package of R was used to run the MANOVA analysis (R Core Team, 2017).

As a follow-up to significant results of the MANOVA test, a descriptive discriminant analysis was performed. Discriminant analysis is a descriptive and classificatory technique developed by R. A. Fisher in 1936 (Brown and Wicker, 2000). Discriminant analysis comprises two approaches to analyzing group data: descriptive discriminant analysis (DDA) and predictive discriminant analysis (PDA). Both methods use continuous data to analyze the characteristics of

group membership. However, predictive DA uses continuous data to classify cases (or individuals) into pre-existing groups, whereas descriptive DA describes characteristics that are specific to groups (Brown and Wicker, 2000). DDA tries to discover which continuous variables contribute to the separation of groups and by how much. Mathematically, DDA weights and linearly combines information from *p*-dependent variables that forces the *k*-groups to be as distinct as possible. The *candisc* package for R was used to run the DDA using the principal components from the PCA with an Eigenvalue greater than 1 (Friendly and Fox, 2017). The function, *candisc()*, performs a generalized canonical discriminant analysis for one term in a multivariate linear model. It represents a transformation of the original variables into canonical space of maximal differences. The results of DDA using the *candisc*() function, identify not only which canon's can successfully separate individuals into groups, but also how distinctive the groups are from one another and which variables (in this case which principal components) contribute most to group separation.

Non-metric data analysis

Multiple correspondence analysis (MCA) is an exploratory multivariate statistic that is applied to data tables with multiple rows of individuals and multiple columns of categorical variables (Husson, et al. 2011). Like PCA, MCA factors categorical data from a contingency table, and presents the data in reduced space to illustrate association (either between individuals or variables) (Irish, 2010). Studying individuals means examining the similarities (and differences) between individuals based on all the variables (Husson, et al. 2011). The produced plots represent the data as dimensions. The first dimension explains the greatest amount of variation (termed inertia) (Irish, 2010). MCA can also use supplementary variables to aide in

interpretation of the data. The resulting euclidean representations and hierarchical trees may be able to identify key differences between the individuals of the two time periods (Medieval and Early Modern). The R package *FactoMineR* (Husson, et al. 2010; Husson, et al. 2011) was used to run the MCA statistical tests. If individuals from the Medieval sample cluster near each other but apart from those of the Early Modern sample, then Hypothesis 1 will be supported. The Null Hypothesis predicts no differentiation between individuals by time period. In order for Hypothesis 2 to be supported the MCA for the female data should cluster both Medieval and Early Modern females together, but separate Medieval and Early Modern males.

Using MCA, categories do not need to be dichotomized. However, the mean measure of divergence (MMD) statistic (described below) requires dichotomization. Therefore, the MCA analysis was run using the dichotomized dataset, in order to allow for comparison to the MMD results. Although dichotomization may result in a reduction in the amount of variance, it increases sample-sizes for categories, allowing for stronger interpretation of the results.

Significance of eigenvalues for the MCA dimensions was determined following Greenacre (2006). Unlike in PCA, eigenvalues never exceed 1.000 in correspondence analysis. In order to determine if an eigenvalue is significant, Greenacre (2006) first suggests determining a threshold:

$$Threshold = \frac{1}{Q}$$

where Q is the number of variables in the matrix. Then dividing the eigenvalues by the threshold and retaining the dimensions that exceed the value 1.

$$\text{Retain if, } \frac{eigenvalue}{threshold} > 1$$

A MANOVA test was used as an omnibus test to identify group differences between sites and time periods, using the MCA dimensions with significant eigenvalues. Pillai's trace, Wilks

lambda, Hotelling-Lawley trace and Roy tests were used to test how well the dimensions predict site name and time period. If all four omnibus tests produce significant results, then there is clear and strong support for a difference between time periods. The *stats* package of R was used to run the MANOVA analysis (R Core Team, 2017).

As a follow-up to significant results of the MANOVA test, a descriptive discriminant analysis (DDA) was performed. The *candisc* package for R was used to run the DDA using the significant dimensions from the MCA (Friendly and Fox, 2017). The results of DDA using the *candisc*() function identify not only which canons can successfully separate individuals into groups, but also how distinctive the groups are from one another and which variables (in this case which MCA dimensions) contribute most to group separation.

Mean measure of divergence (MMD) is a commonly used distance statistic for categorical data to measure the amount of dissimilarity between groups of individuals described by dichotomous variables (Guatelli-Steinberg, et al. 2001; Hallgrimsson, et al. 2004; Harris, 2008; Harris and Sjøvold, 2004; Irish, 1997, 1998a, 1998b, 1998c, 1998d, 2000, 2006, 2010; Ishida and Dodo, 1990; Johnson and Lovell, 1995; Komesu, et al. 2008; Lukacs and Pal, 2013; Nikita, 2015; Nikita, et al. 2012a, 2012b; Prowse and Lovell, 1996; Santos 2018; Shigematsu, et al. 2004; Sjøvold 1973, 1977; Ullinger, et al. 2005). It was developed by C. A. B. Smith for use by Grewal (1962) to estimate biological divergence among mice using nonmetric skeletal traits. A. Caroline Berry and R. J. Berry popularized MMD for human non-metric cranial traits, due to its flexibility and ability to be used even in the presence of many missing values (Berry and Berry, 1967, 1972; Berry, et al. 1967; R. J. Berry, 1968; A. C. Berry, 1976). A low MMD value signifies a high amount of similarity between the samples (Irish, 2005, 2010). A high MMD value signifies a high amount of dissimilarity between the samples (Irish, 2005, 2010). One

drawback to MMD is that it requires dichotomization of variables (Sjøvold, 1977). The dichotomization procedures for this study followed Thompson (2013) (see above). Sjøvold (1977) developed a modification of the MMD for small samples, and Freeman and Tukey's (1950) angular transformation is often used with the MMD to stabilize variance between small samples (although Irish (2010) and Sjøvold (1977) still recommend a minimum of 15-20 observations) and corrects for trait frequencies that are either very low (≤ 5%) or very high (≥ 95%). MMD uses summary data, "which means that all cases can be included regardless of completeness" (Irish, 2010:525), and missing data is therefore of minimal concern for this statistic. The non-MUIP dataset was used to run the MMD analysis. Sjøvold (1973:216; 1977) stated that if the MMD is two times greater than its standard deviation then a statistically significant difference exists at a 0.025 level (Irish, 2005). If the MMD value for comparing the Medieval and Early Modern samples is two times greater than the standard deviation (a high MMD value), then Hypothesis 1 will be supported. If the MMD value is low, then the null hypothesis will be supported. If the MMD value is high for males but low for females when comparing the Medieval to Early Modern samples, then Hypothesis 2 will be supported.

The MMD analysis was run using the R package *AnthropMMD* (Santos 2017, 2018). *AnthropMMD* uses the formula for MMD recalled by Nikita (2015, 2017), and follows the methodological advice of Harris and Sjøvold (2004). *AnthropMMD* offers a simple user-friendly interface for the calculation of MMD, using a graphical user interface (GUI) coded using the R package *shiny* (Chang, et al. 2017). *AnthropMMD* also offers plotting capabilities and automatic features for selection of the most useful variables (Santos, 2018). The MMD is calculated in the *AnthropMMD* package knowing only the sample sizes and the frequency of each trait within compared groups, and is defined by the formula:

$$MMD = \frac{1}{r}\sum_{i=1}^{r}\left[(\emptyset_{1i} - \emptyset_{2i})^2 - \left(\frac{1}{n_{1i}+0.5} + \frac{1}{n_{2i}+0.5}\right)\right]$$

where r is the number of dichotomous traits, n_{1i} and n_{2i} are the numbers of individuals examined for the ith trait in samples 1 and 2 respectively, and $\emptyset_{1i}$ and $\emptyset_{2i}$ are the angular transformations of the relative frequencies of the ith traits in the two samples, given in radians (Green, et al. 1979; Santos, 2018). The Freeman and Tukey (1950) angular transformation was used to calculate the MMD statistics in this study due to smaller site-sample sizes. Any trait that was observed on fewer that 10 individuals was dropped from the analysis by default using the *AnthropMMD* package. Traits with a negative measure of divergence were also removed from the comparisons. The final trait lists are included in the MMD analysis results. Due to site-sample sizes, the MMD analyses could only be performed using the total sample datasets. No female-only or male-only comparisons were possible.

Multidimensional scaling (MDS) is a technique used to visually summarize biological distances (such as those produced from MMD). MDS provides a spatial representation of 1 to *n* dimensions consisting of a geometric configuration of points. MDS starts with a matrix of similarity (or dissimilarity) scores between cases (Drennan, 2009). Through trial-and-error, the analysis creates a configuration of points representing each of the cases in the dataset. These points are then placed in space so that pairs of points correspond best to the rank order of the similarity coefficients in space (Drennan, 2009). Points are compared to their original values (submitted from the original distance matrix) and adjusted until minimum stress and maximum distance values are reached (Irish, 2010). The lower the stress value, the better the rank order correlation between similarity scores and distances between pairs of points (Drennan, 2009). The stress value indicates how accurate the picture is, the general rule of thumb is that a stress value of about 0.1500 or lower is associated with interpretable configurations and is usually achieved

within three dimensions (Drennan, 2009). The R package *AnthropMMD* (Santos, 2018) produced the distance matrix that was used for the MDS. The R package *MASS* (Venables and Ripley, 2002), was used to produce the MDS plot. If no meaningful patterning is identified in the scaling configuration of individuals, then it is likely the null hypothesis is supported and no identifiable differences between the Medieval and Early Modern populations could be discerned. If the scaling configuration separates Medieval individuals from Early Modern individuals, then this would support Hypothesis 1.

CHAPTER VII

RESULTS

The following chapter presents the results of the multivariate statistical analyses. The chapter is organized by dataset. Unless stated otherwise, the statistical analyses presented in this chapter used the reduced and imputed dataset. Summary statistics of the final datasets can be found in Appendix A. The demographic breakdowns of each dataset can be found in Appendix B. Only significant tests are presented in this chapter, Appendix C contains the insignificant results. Additionally, only time period comparisons are presented in this chapter, comparisons by site are presented in Appendix D.

For each data set, the principal components analysis (PCA) for the metric data or multiple correspondence analysis (MCA) for non-metric data was run and significant eigenvalues were identified (Table 7-1). Dimensions with significant eigenvalues were then subjected to a MANOVA test (Table 7-2). Significant MANOVA tests were followed up with descriptive discriminate analysis (DDA) to identify if the dimensions could successfully separate individuals based on time period. Finally, the PCA/MCA analysis was returned to and examination of the component loadings and one-way factor analyses were used to identify which variables characterize each dimension. The chapter concludes with a Hypothesis 2 of the results in relation to the project hypotheses.

Table 7 - 1: Significant eigenvalues from PCA and MCA for total sample comparisons.

		Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8
TOTAL SAMPLE									
Dental Metric (n=139)	Eigenvalue	8.37	1.90	1.46	1.16				
	% Variance	41.86	9.48	7.32	5.82				
	Cumulative %	41.9	51.4	58.7	64.5				
Cranial Metric (n=132)	Eigenvalue	4.14	2.25	1.70	1.46	1.22	1.02		
	% Variance	0.24	0.13	0.10	0.09	0.07	0.06		
	Cumulative %	0.24	0.38	0.48	0.56	0.63	0.69		
Dental Non-metric (n=140)	Eigenvalue	0.16	0.1	0.09	0.08	0.08	0.07	0.07	0.07
	% Variance	15.69	10.34	9.02	8.17	7.95	7.21	7.14	6.67
	Cumulative %	15.69	26.03	35.05	43.21	51.20	58.40	65.52	72.19
Cranial Non-metric (n=245)	Eigenvalue	0.11	0.09	0.07	0.07	0.06	0.06	0.05	0.05
	% Variance	10.73	8.76	7.02	6.61	6.34	6.08	5.46	5.34
	Cumulative %	10.73	19.49	26.51	33.12	39.46	45.54	51.00	56.34
Cr. NM Adult Only (n=140)	Eigenvalue	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.05
	% Variance	9.18	8.23	7.70	7.24	6.63	6.08	5.81	5.30
	Cumulative %	9.18	17.42	25.11	32.36	38.98	45.07	50.87	56.18
MALE SAMPLE									
Dental Metric (n=53)	Eigenvalue	9.60	2.43	1.32	1.11				
	% Variance	0.48	0.12	0.07	0.06				
	Cumulative %	0.48	0.60	0.67	0.72				
Cranial Metric (n=62)	Eigenvalue	5.26	1.98	1.73	1.23	1.09	1.04		
	% Variance	0.31	0.12	0.10	0.07	0.06	0.06		
	Cumulative %	0.31	0.43	0.53	0.60	0.66	0.73		
Dental Non-metric (n=53)	Eigenvalue	0.18	0.13	0.10	0.09	0.09	0.08	0.07	
	% Variance	17.74	12.78	10.38	9.37	8.58	7.91	7.15	
	Cumulative %	17.74	30.52	40.89	50.26	58.80	66.80	73.90	
Cranial Non-metric (n=68)	Eigenvalue	0.11	0.10	0.10	0.08	0.07	0.07	0.06	0.05
	% Variance	11.46	9.77	9.68	8.38	7.19	6.81	5.82	5.30
	Cumulative %	11.46	21.23	30.91	39.29	46.48	53.29	59.11	64.41
FEMALE SAMPLE									
Dental Metric (n=58)	Eigenvalue	7.81	2.20	1.82	1.33	1.13			
	% Variance	0.39	0.11	0.09	0.07	0.06			
	Cumulative %	0.39	0.50	0.59	0.66	0.71			
Cranial Metric (n=70)	Eigenvalue	3.57	2.70	1.82	1.59	1.39	1.02		
	% Variance	0.21	0.16	0.11	0.09	0.08	0.06		
	Cumulative %	0.21	0.37	0.48	0.57	0.65	0.71		
Dental Non-metric (n=58)	Eigenvalue	0.15	0.12	0.11	0.09	0.09	0.08	0.07	
	% Variance	15.36	11.82	11.30	9.46	8.65	7.62	7.07	
	Cumulative %	15.36	27.18	38.48	47.94	56.59	64.20	71.28	
Cranial Non-metric (n=75)	Eigenvalue	0.10	0.09	0.08	0.07	0.07	0.07	0.06	0.06
	% Variance	10.84	9.27	8.22	7.75	7.16	7.00	6.26	5.93
	Cumulative %	10.80	20.10	28.30	36.10	43.20	50.20	56.51	62.43
INDETERMINATE SAMPLE									
Dental Metric (n=28)	Eigenvalue	7.83	2.23	1.88	1.47	1.26	1.01		
	% Variance	0.39	0.11	0.09	0.07	0.06	0.05		
	Cumulative %	0.39	0.50	0.60	0.67	0.73	0.78		
Dental Non-metric (n=29)	Eigenvalue	0.29	0.12	0.11	0.10	0.09	0.07		
	% Variance	28.63	11.65	11.30	9.54	9.23	6.79		
	Cumulative %	28.63	40.28	51.58	61.12	70.35	77.14		
Cranial Non-metric (n=102)	Eigenvalue	0.13	0.11	0.09	0.07	0.07	0.06	0.05	
	% Variance	13.28	11.09	9.12	7.77	7.34	6.09	5.37	
	Cumulative %	13.30	24.40	33.50	41.30	48.60	54.70	60.06	

The PCA and MCA were initially run in order to identify which dimensions had significant eigenvalues. For the metric datasets, PCA dimensions with eigenvalues greater than one were considered significant. Following Greenacre (2006), for the non-metric datasets eigenvalues were considered significant when the eigenvalue divided by its threshold was greater than one. The dental non-metric threshold was determined to be 0.067 (1/15 variables); the cranial non-metric threshold was 0.053 (1/19 variables) (Greenacre 2006). Table 7-1 contains the significant eigenvalues for each sample as well as the percent variance and the cumulative variance percentage for each significant PCA/MCA dimension.

A one-way multivariate analysis of variance (MANOVA) test was run in order to determine if differences from the PCA and MCA were greater than expected by chance. The multivariate null hypothesis was that the group (population) centroids would not differ by time period. The Bartlett-Pillai, Wilks lambda, Hotelling-Lawley trace, and Roy criterions were used to identify if the PCA/MCA dimensions correlated with time period. Of the four tests for significance used, the Roy criterion is the most liberal measure and therefore a significant value using the Roy criterion cannot be given complete confidence (Huberty and Olejnik 2006:51). Consequently, tests with a significant Roy test alone were treated as if they were insignificant. Results of the MANOVA analyses by time period are presented in Table 7-2.

Table 7 - 2: MANOVA results by time period.

Time Period	Dim. used	n	Pillai	F	p-value	Wilks	F	p-value	Hotelling-Lawley	F	p-value	Roy	F	p-value
Total Sample														
Dent Metric	4	139	0.03	1.16	0.33	0.97	1.16	0.33	0.03	1.16	0.33	0.03	1.16	0.33
Cr. Metric	6	132	0.19	4.84	0.00	0.81	4.84	0.00	0.23	4.84	0.00	0.23	4.84	0.00
Dent NM	8	140	0.31	7.23	0.00	0.69	7.23	0.00	0.44	7.23	0.00	0.44	7.23	0.00
Cr. NM	8	245	0.10	3.31	0.00	0.90	3.31	0.00	0.11	3.31	0.00	0.11	3.31	0.00
Cr. NM Adult	8	130	0.17	3.04	0.00	0.83	3.04	0.00	0.20	3.04	0.00	0.20	3.04	0.00
Male Sample														
Dent Metric	4	53	0.98	1.3	0.28	0.90	1.3	0.28	0.11	1.3	0.28	0.11	1.3	0.28
Cr. Metric	6	62	0.35	4.88	0.00	0.65	4.88	0.00	0.53	4.88	0.00	0.53	4.88	0.00
Dent NM	7	53	0.21	1.73	0.13	0.79	1.73	0.13	0.27	1.73	0.13	0.27	1.73	0.13
Cr. NM	8	68	0.14	1.16	0.34	0.86	1.16	0.34	0.16	1.16	0.34	0.16	1.16	0.34
Female Sample														
Dent Metric	5	58	0.33	5.15	0.00	0.67	5.15	0.00	0.50	5.15	0.00	0.50	5.15	0.00
Cr. Metric	6	70	0.21	2.73	0.02	0.79	2.73	0.02	0.26	2.73	0.02	0.26	2.73	0.02
Dent NM	7	58	0.35	3.89	0.00	0.65	3.89	0.00	0.54	3.89	0.00	0.54	3.89	0.00
Cr. NM	8	75	0.17	1.64	0.13	0.83	1.64	0.13	0.20	1.64	0.13	0.20	1.64	0.13
Indeterminate Sample														
Dent Metric	6	28	0.24	1.09	0.40	0.76	1.09	0.40	0.31	1.09	0.40	0.31	1.09	0.40
Dent NM	6	29	0.81	15.9	0.00	0.19	15.9	0.00	4.32	15.9	0.00	4.32	15.9	0.00
Cr. NM	7	102	0.07	1.01	0.43	0.93	1.01	0.43	0.07	1.01	0.43	0.07	1.01	0.43

As a follow-up to the MANOVA results, a descriptive discriminate analysis (DDA) was performed for each dataset. The basic question of concern is whether the PCA and MCA dimensions can be used to identify group membership. The groups in question are the pre-Ottoman and Ottoman periods.

In addition, the PCA/MCA results were explored using the *dimdesc* function of the *FactoMineR* package which performed a one-way analysis of variance test to identify variables (including supplementary variables such as time period) that significantly correlated with each dimension (Le et al. 2008). The R^2 and *p*-values are provided for any significant correlations between individuals and time period.

In addition, the total sample non-metric datasets were also subjected to mean measure of divergence (MMD). Mean measure of divergence (MMD) is used to identify group differences

between time periods. MMD uses frequency counts in its calculation and does not require complete datasets. For this study the MMD analysis used the reduced non-metric dataset prior to multiple imputation. The MMD analysis is not affected by the estimation of missing variables. However, sample size can be an issue. Due to sample size differences between groups (see demographics of datasets in Appendix B), only the total sample datasets could be used with confidence and therefore no comparisons using the male only or female only samples are presented. MMD values that exceeded twice the standard deviation for the value are considered significant (Harris and Sjøvold 2004). The initial data (see Appendix A for frequency counts by site) was first reduced by exclusion of traits that had fewer than 10 observations then was further reduced to include only traits with a positive overall measure of divergence (MD).

The follow-up analyses for the samples are organized by sample and data-type and are presented in the following sections. The total sample comparisons are presented first, followed by the male-only, female-only and indeterminate-only samples.

Total sample comparisons

The significant dimensions of the PCA and MCA analyses for the male sample can be found in Table 7-1. The significant dimensions for each dataset were submitted to a MANOVA test to identify group separation by site name (Table 7-2). The dental metric, cranial metric, dental non-metric, and cranial non-metric results for the total sample are presented in this section. In addition, the cranial non-metric results using an adult only sample are presented.

Dental metric – total sample (n=139)

The first four dimensions of the dental metric – total sample (n=139) had significant eigenvalues and represent 64.5% of the cumulative variance in the sample (Table 7-1). For the dental metric – total sample none of the MANOVA by time period results were signficant (Table 7-2). Therefore, the dental metric – total sample does not differ by time period and the null hypothesis cannot be disproven. Since the results of the MANOVA tests were insignificant, the follow-up DDA, component loadings and one-way analysis of variance of the PCA dimensions for the dental metric – total sample are not provided here, and instead can be found in Appendix C (Table C-1, Figure C-1 through Figure C-5).

Cranial metric – total sample (n=132)

The first six PCA dimensions of the cranial metric – total sample (n=132) had significant eigenvalues and represented 69% of the cumulative variance in the sample (Table 7-1). For the cranial metric – total sample all four of the MANOVA significance tests were significant (Table 7-2). Therefore, differences between time periods are identified using the cranial metric – total sample.

Results of the DDA analysis of the first six principal components and time period identified a significant correlation with Canon 1 (F=4.84, *p*-value=0.000018) (Figure 7-1): individuals from the Ottoman period were positively correlated, while individuals from the pre-Ottoman period were negatively correlated with Canon 1. There was only one canon for this comparison. Dimension 1, Dimension 4 and Dimension 6 were all positively correlated, while Dimension 2, Dimension 3 and Dimension 5 were negatively correlated with Canon 1.

Dimension 2, Dimension 3 and Dimension 5 had the largest standard coefficients and contributed most to the formation of Canon 1.

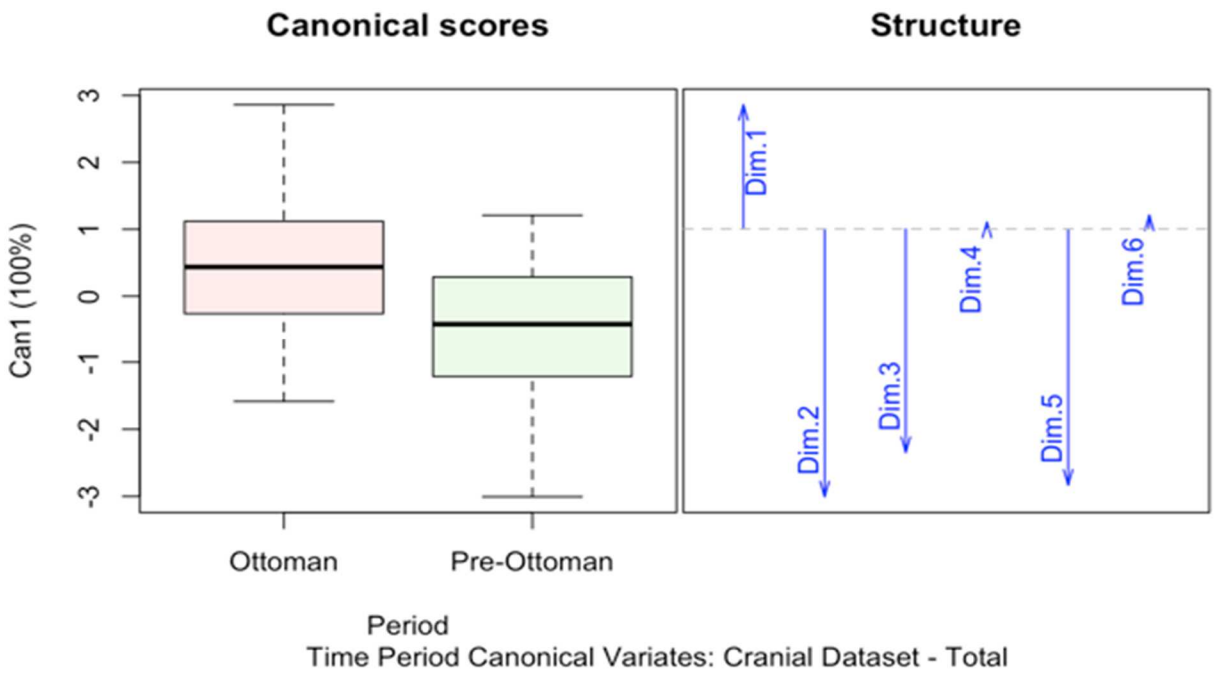

Figure 7 - 1: Canonical variate 1 by time period for the cranial metric - total sample (n=132).

The PCA of the cranial metric – total sample was explored using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each PCA dimension (Husson, et al. 2011). Figure 7-2 through Figure 7-4 present the individuals factor plots for the first six PCA dimensions. The component loadings of each of the first six PCA dimensions are presented in Table 7-3. One-way analysis of variance identified Dimension 1, Dimension 4, and Dimension 6 as not separating individuals by time period. Dimension 2, Dimension 3, and Dimension 5 showed significant separation of individuals by time period, as well as with the DDA analysis.

Dimension 2 represented 13.2% of the sample variance and separated measurements of the orbit (negative) from mandibular measurements (positive) (Table 7-3). One-way analysis of variance of the PCA dimensions identified Dimension 2 as separating individuals by time period (R^2= 0.07, p-value = 0.00) (Figure 7-2): the pre-Ottoman period was positively correlated, while the Ottoman period was negatively correlated. Pre-Ottoman individuals had larger mandibular measurements, making them positively correlated on Dimension 2. Ottoman individuals had larger orbital measurements, making them negatively correlated on Dimension 2.

Dimension 3 represented 10% of the sample variance and separated measurements of the cranial vault and base (positive) from measurements of the nose and forehead (negative) (Table 7-3). One-way analysis of variance of the PCA dimensions identified Dimension 3 as separating individuals by time period (R^2=0.05, p=0.01) (Figure 7-3): the pre-Ottoman period is positively correlated while the Ottoman period is negatively correlated on Dimension 3. Pre-Ottoman individuals had larger cranial vault and base measures, making them positively correlated with Dimension 3. Ottoman individuals had larger nose and forehead measurements, making them negatively correlated with Dimension 3.

Dimension 5 represented 7% of the sample variance and separated mandibular and cranial breadth measurements (negative) from nasal and orbital height and parietal chord measurements (positive) (Table 7-3). One-way analysis of variance of the PCA dimensions, identified Dimension 5 as separating individuals by time period (R^2=0.06, *p*-value=0.00) (Figure 7-4): the pre-Ottoman period is positively correlated, while the Ottoman period is negatively correlated on PC5. The pre-Ottoman individuals had larger nasal and orbital height and parietal chord measurements, making them positively correlated with Dimension 5. The Ottoman

individuals had larger mandibular and cranial breadth measurements, making them more negatively correlated with Dimension 5.

Table 7 - 3: PCA component loadings and eigenvalues for cranial metric - total sample (n=132).

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Cranial Base Length	0.30	0.25	0.08	-0.15	0.15	-0.28	-0.06
Max Alveolar Length	0.25	0.21	0.12	-0.01	0.16	-0.40	0.20
Biauricular Breadth	0.28	-0.26	0.08	0.21	-0.17	0.17	0.16
Min Frontal Breadth	0.39	-0.09	-0.20	-0.15	-0.12	0.22	-0.10
Upper Facial Breadth	0.42	-0.14	-0.09	-0.07	-0.14	0.04	0.02
Nasal Height	0.12	0.02	-0.17	0.47	0.50	0.08	0.29
Orbit Breadth	0.19	-0.40	-0.08	0.28	-0.04	-0.42	0.00
Orbit Height	0.16	-0.31	0.06	0.28	0.35	0.27	-0.36
Biorbital Breadth	0.39	-0.22	-0.06	-0.13	-0.12	-0.08	0.09
Interorbital Breadth	0.27	0.13	-0.16	-0.44	0.07	0.31	0.17
Parietal Chord	0.13	0.22	0.01	-0.16	0.52	-0.07	0.17
Occipital Chord	0.03	-0.11	0.59	-0.13	0.00	0.19	0.20
For Magnum Breadth	0.12	-0.08	0.38	-0.20	0.28	-0.01	-0.63
Mastoid Length	0.06	-0.06	0.57	0.09	-0.11	0.06	0.36
Thickness Mental Foramen	0.21	0.27	0.07	0.14	-0.30	-0.35	-0.22
Min Ramus Breadth	0.17	0.40	0.17	0.40	-0.14	0.12	-0.14
Max Ramus Breadth	0.17	0.42	-0.05	0.24	-0.14	0.39	-0.09
Eigenvalues	4.14	2.25	1.70	1.46	1.22	1.02	0.92
% Variance	0.24	0.13	0.10	0.09	0.07	0.06	0.05
Cumulative %	0.24	0.38	0.48	0.56	0.63	0.69	0.75

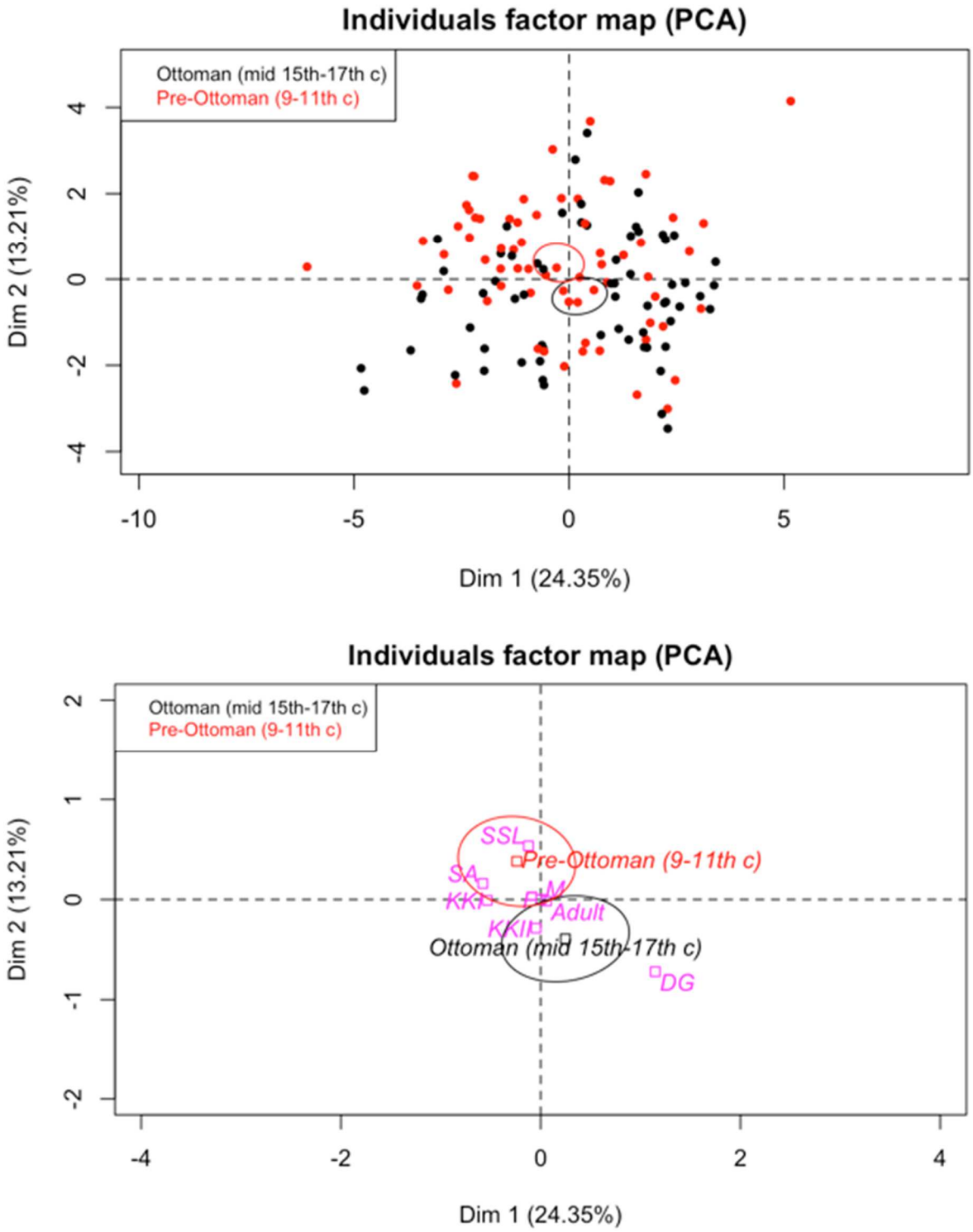

Figure 7 - 2: Upper: Dim 1 and Dim 2 individuals factor plot (PCA) for cranial metric – total sample (n=132), colored by time period. Lower: Individual data points are removed and barycenters of the individuals belonging to each time period are retained.

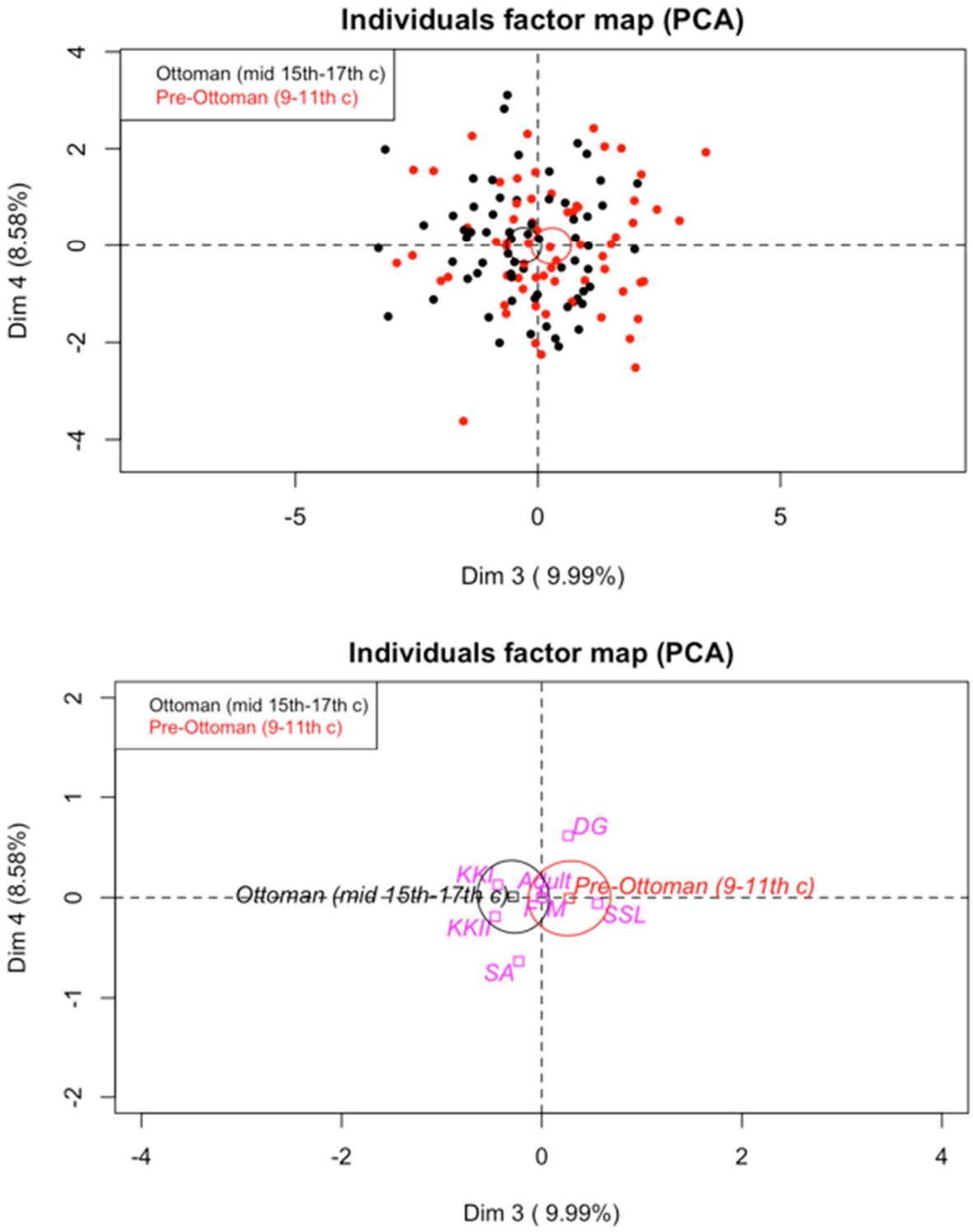

Figure 7 - 3: Upper: Dim 3 and Dim 4 individual factor plot (PCA) for cranial metric - total sample (n=132), colored by time period. Lower: Individual data points are removed and barycenters of the individuals belonging to each time period are retained.

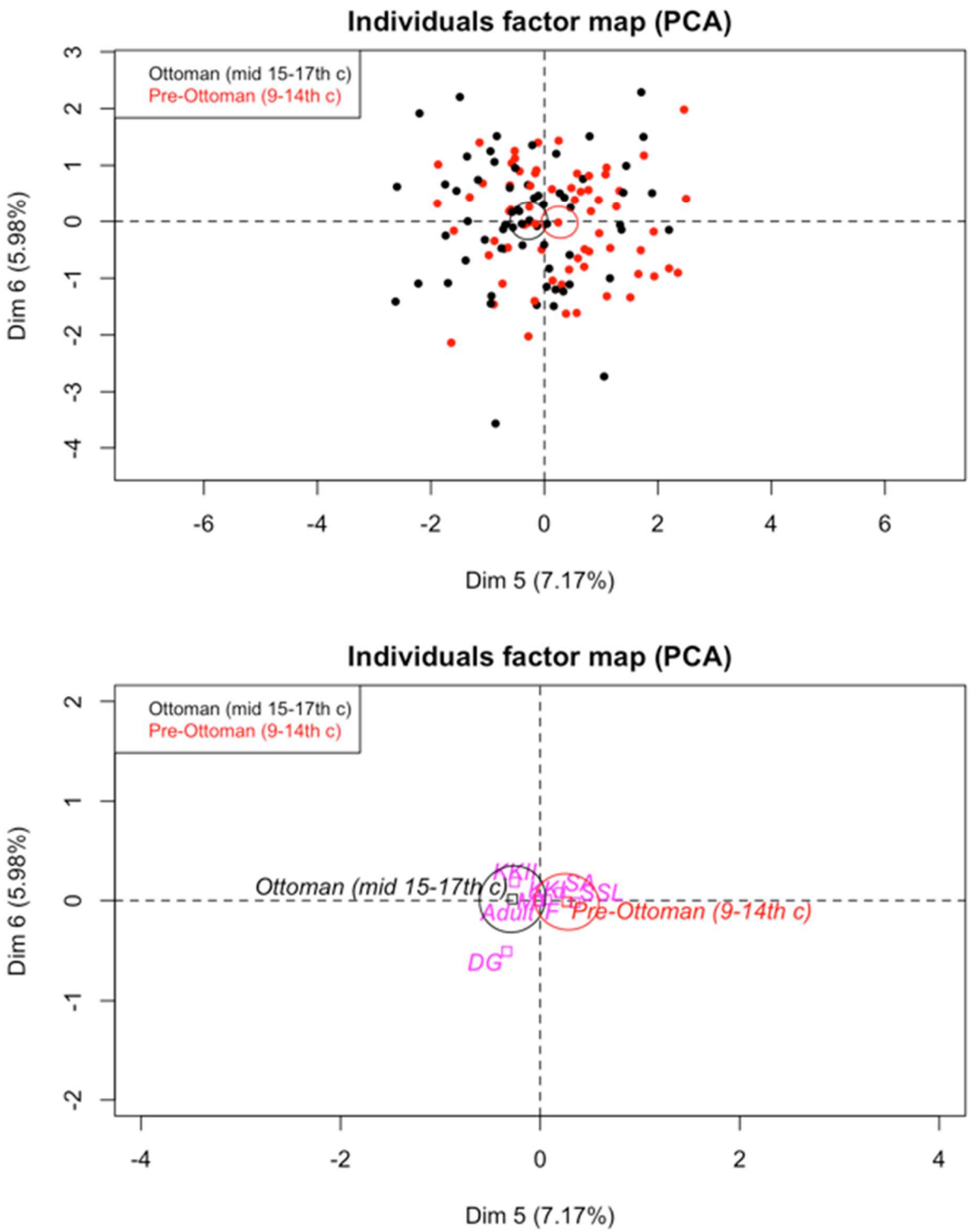

Figure 7 - 4: Upper: Dim 5 and Dim 6 individuals factor plot (PCA) for cranial metric – total sample (n=132), colored by time period. Lower: Individual data points are removed and barycenters of the individuals belonging to each time period are retained.

Dental non-metric – total sample (n=140)

For the dental non-metric – total sample (n=140) the first eight MCA dimension eigenvalues were significant and represented 72.19% of the cumulative variance in the sample (Table 7-1). For the dental non-metric – total sample all four of the MANOVA significance tests were significant (Table 7-2). Therefore, differences between time periods were identified using the dental non-metric – total sample.

The results of the DDA analysis using the first eight MCA dimensions by time period also found significant differences between individuals when grouped by time period (Canon 1: F=7.23, p-value=0.00) (Figure 7-5). The Ottoman period is positively correlated, while the pre-Ottoman period is negatively correlated with Canon 1. Dimension 2, Dimension 4, Dimension 5, Dimension 7 and Dimension 8 are positively correlated, while Dimension 1, Dimension 3, and Dimension 6 are negatively correlated with Canon 1. Dimension 1 and Dimension 2 have the largest standard coefficients and therefore contribute most to the formation of Canon 1.

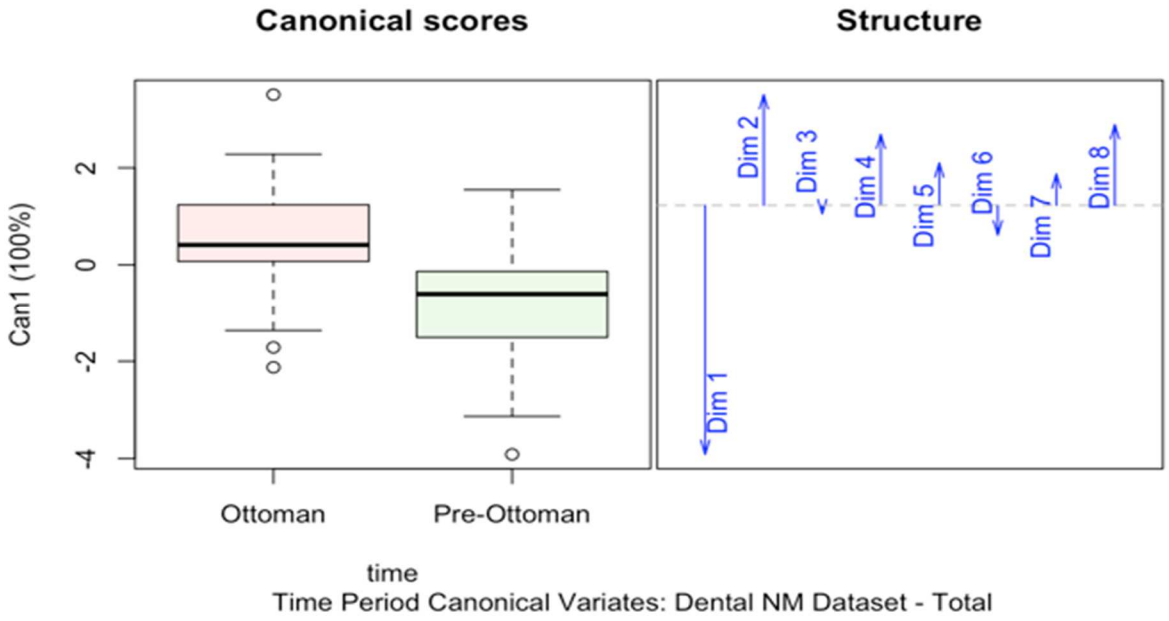

Figure 7 - 5: Canonical variate 1 by time period for the dental non-metric - total sample (n=140).

The MCA of the dental non-metric – total sample was explored using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each MCA dimension (Husson, et al. 2011). Using factor analysis, the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table 7-4. Only the first two dimensions significantly separated individuals by time period, which is consistent with the DDA results. The individual factor plots of the first two dimensions are presented in Figure 7-6; the remaining dimensions' individual factor plots are presented in Appendix C (Figure C-6 through Figure C-8), as they did not separate individuals by time period.

Dimension 1 accounted for 15.69% of the sample variance and separated individuals by time period (R^2=0.2125, p-value=0.00) (Figure 7-6). The component loadings of Dimension 1 identified the presence of UM2 Carabelli's trait, UM3 hypocone, UM3 mesial paracone tubercle, and UM3 metaconule to be positively correlated, and the absence of these traits to be negatively correlated. The individuals from the pre-Ottoman sample have higher frequencies of Carabelli's trait, hypocones, mesial paracone tubercles and metaconules, while individuals from the Ottoman sample have lower frequencies of these traits. These frequency findings show that individuals from the pre-Ottoman period are positively correlated, while individuals from the Ottoman period are negatively correlated on Dimension 1 (Figure 7-6).

Dimension 2 accounts for 10.34% of the sample variance and separated individuals by time period (R^2=0.0418, p-value=0.0154) (Figure 7-6). The component loadings of Dimension 2 identify the presence of UP4 mesial accessory ridges, the presence of UM2 parastyle, and the absence of the UM2 metacone to be positively correlated, while the absence of UP4 mesial accessory ridges, the absence of UM2 parastyle and the presence of the UM2 metacone are

negatively correlated. The individuals from the Ottoman period have higher frequencies of UP4 mesial accessory ridges presence, UM2 parastyle presence, and UM2 metacone absence. Individuals from the pre-Ottoman period have lower frequencies of these traits. Individuals from the Ottoman period being positively correlated, while individuals from the pre-Ottoman period are negatively correlated on Dimension 2 (Figure 7-6).

Table 7 - 4: MCA component loadings and eigenvalues for dental non-metric - total sample (n=140).

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8
UI1 Double Shoveling - A	-0.18	-0.47	0.01	0.25	-0.50	0.03	0.06	0.77
UI1 Double Shoveling - P	1.51	3.94	-0.07	-2.09	4.16	-0.28	-0.54	-6.41
LC Double Root - A	0.02	0.03	0.30	0.06	-0.09	-0.70	0.11	-0.26
LC Double Root - P	-0.22	-0.43	-4.35	-0.94	1.29	10.17	-1.56	3.82
UI1 Radical Number - 2+ Radicals	-1.29	0.77	-0.48	0.18	1.19	-1.13	0.61	-0.17
UI1 Radical Number - One Radical	1.49	-0.88	0.55	-0.20	-1.38	1.30	-0.71	0.20
UP4 Mesial Accessory Ridges - A	-0.07	-0.58	-0.18	0.07	-0.15	0.25	0.20	-0.45
UP4 Mesial Accessory Ridges - P	0.87	6.86	2.16	-0.81	1.70	-2.91	-2.36	5.30
LP4 Multiple Lingual Cusps - A	-0.75	1.41	0.02	2.12	-1.08	1.42	-1.95	-1.22
LP4 Multiple Lingual Cusps - P	0.47	-0.88	-0.01	-1.33	0.68	-0.89	1.23	0.77
UM2 Carabelli's - A	-0.69	-0.14	0.05	-0.19	-0.26	0.18	0.22	-0.15
UM2 Carabelli's - P	4.96	1.00	-0.39	1.40	1.91	-1.32	-1.61	1.07
UM2 Metacone Cusp 3 - A	0.56	5.38	-3.24	-1.10	-4.73	0.15	8.67	3.13
UM2 Metacone Cusp 3 - P	-0.04	-0.37	0.22	0.08	0.33	-0.01	-0.60	-0.21
UM3 Mesial Paracone Tubercle - A	-0.44	0.06	0.13	-0.37	-0.35	-0.01	0.12	-0.09
UM3 Mesial Paracone Tubercle - P	5.75	-0.80	-1.72	4.76	4.55	0.14	-1.59	1.16
UM2 Parastyle - A	-0.10	-0.27	-0.17	0.10	0.33	0.05	0.24	-0.10
UM2 Parastyle - P	2.70	7.25	4.67	-2.77	-8.90	-1.47	-6.59	2.77
LM3 Congenital Absence - Tooth Absent	1.29	-0.67	11.31	-2.35	-1.50	4.53	2.50	-3.93
LM3 Congenital Absence - Tooth Present	-0.06	0.03	-0.51	0.11	0.07	-0.20	-0.11	0.18
UM3 Hypocone Cusp 4 - A	-0.98	-0.02	0.08	-0.66	0.20	-0.09	-0.60	-0.20
UM3 Hypocone Cusp 4 - P	2.83	0.05	-0.24	1.91	-0.59	0.27	1.75	0.59
UM3 Metaconule Cusp 5 - A	-0.97	-0.33	0.06	0.65	0.08	-0.49	-0.62	0.76
UM3 Metaconule Cusp 5 - P	2.42	0.83	-0.15	-1.62	-0.21	1.22	1.55	-1.91
UM2 Root Number - 1-2 Roots	-1.60	2.51	0.24	3.59	0.39	1.44	1.98	-0.89
UM2 Root Number - 3+ Roots	0.47	-0.74	-0.07	-1.06	-0.12	-0.43	-0.59	0.26
UM2 Cusp Number - 3 Cusps	-1.97	2.83	4.36	-4.24	7.76	5.97	0.71	5.67
UM2 Cusp Number - 4+ Cusps	0.10	-0.15	-0.23	0.22	-0.41	-0.31	-0.04	-0.30
LM2 Groove Pattern - Non-Y	-0.01	0.28	-0.84	-0.53	-0.16	0.09	-0.33	-0.22
LM2 Groove Pattern - Y	0.07	-1.78	5.34	3.39	1.02	-0.60	2.10	1.37
Eigenvalue	0.16	0.1	0.09	0.08	0.08	0.07	0.07	0.07
% Variance	15.69	10.34	9.02	8.17	7.95	7.21	7.14	6.67
Cumulative %	15.69	26.03	35.05	43.21	51.20	58.40	65.52	72.19

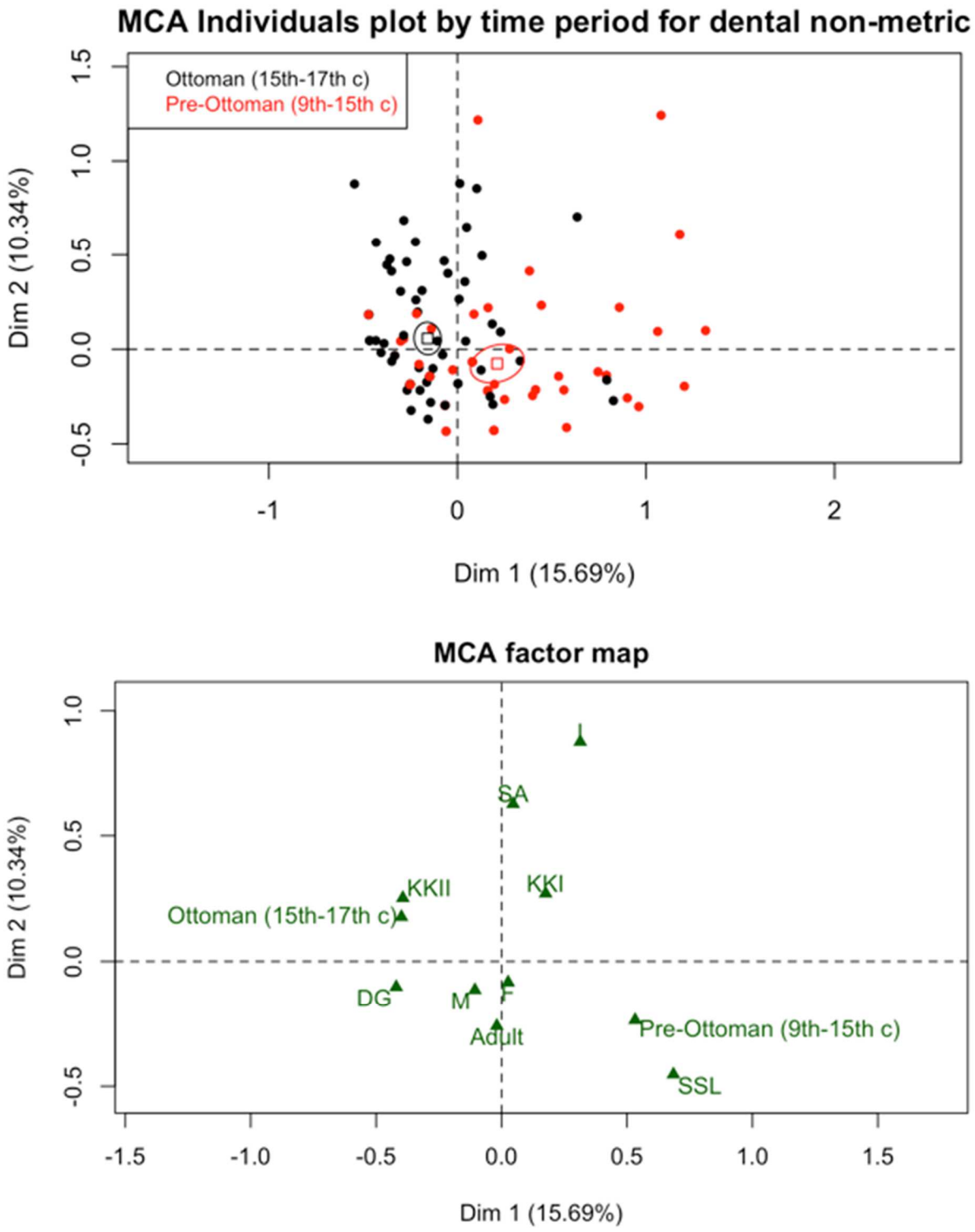

Figure 7 - 6: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for dental non-metric - total sample (n=140), colored by time period. Lower: Individual data points are removed and barycenters of the supplementary variables are retained.

The time period results of the MMD analysis for the dental non-metric – total sample are presented in Table 7-5. After removal of traits with a negative overall measure of divergence (MD), only five traits remained for the MMD analysis. Frequency counts for these traits by time period are presented in Table 7-6. With only five traits used to produce the distances in Table 7-5, any significant results must be treated with some caution and corroborated with additional evidence. There were significant differences between the pre-Ottoman and Ottoman periods. These results are consistent with those of the dental metric analysis as well as with the MCA analyses. Therefore, the significant difference between the pre-Ottoman and Ottoman periods using MMD is likely a true difference.

Table 7 - 5: MMD value (upper right) and associated SD value (lower left), for the dental non-metric - total sample, by time period.

	Ottoman (15th-17th c)	Pre-Ottoman (9th-15th c)
Ottoman (15th-17th c)		0.195*
Pre-Ottoman (9th-15th c)	0.035	

* Marks a significant value

Table 7 - 6: Number of individuals, frequencies of active variables within each time period, and overall measure of divergence of active variables, for the dental non-metric – total sample.

	UI1 Double Shoveling	UM2 Carabelli's	UM3 Mesial Paracone Tubercle	UM2 Root #	LM1 Cusp #
n Ottoman (15th-17th c)	56	54	31	35	53
n Pre-Ottoman (9th-15th c)	28	48	24	28	41
Frequency Ottoman (15th-17th c)	0.107	0.074	0.097	0.571	0.302
Frequency Pre-Ottoman (9th-15th c)	0.321	0.271	0.292	0.786	0.098
Overall MD	0.123	0.159	0.019	0.009	0.127

Cranial non-metric – total sample (n=245)

For the cranial non-metric – total sample (n=245) the first eight eigenvalues were significant and represent 56.35% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – total sample all four of the MANOVA significance tests were significant

(Table 7-2). Therefore, differences between time periods are identified using the cranial non-metric – total sample.

Results of the DDA analysis of the first eight MCA dimensions and time period identified a significant correlation with Canon 1 (Canon 1: F=3.31, *p*-value=0.00) (Figure 7-7): the Ottoman period is negatively correlated, while the pre-Ottoman period is positively correlated with Canon 1. There is only one canon for this comparison. Dimension 3, Dimension 6, and Dimension 7 are positively correlated, while Dimension 1, Dimension 2, Dimension 4, Dimension 5, and Dimension 8 are negatively correlated on Canon 1. Dimension 3, Dimension 5 and Dimension 7 have the largest standard coefficients and therefore contribute most to the formation of Canon 1.

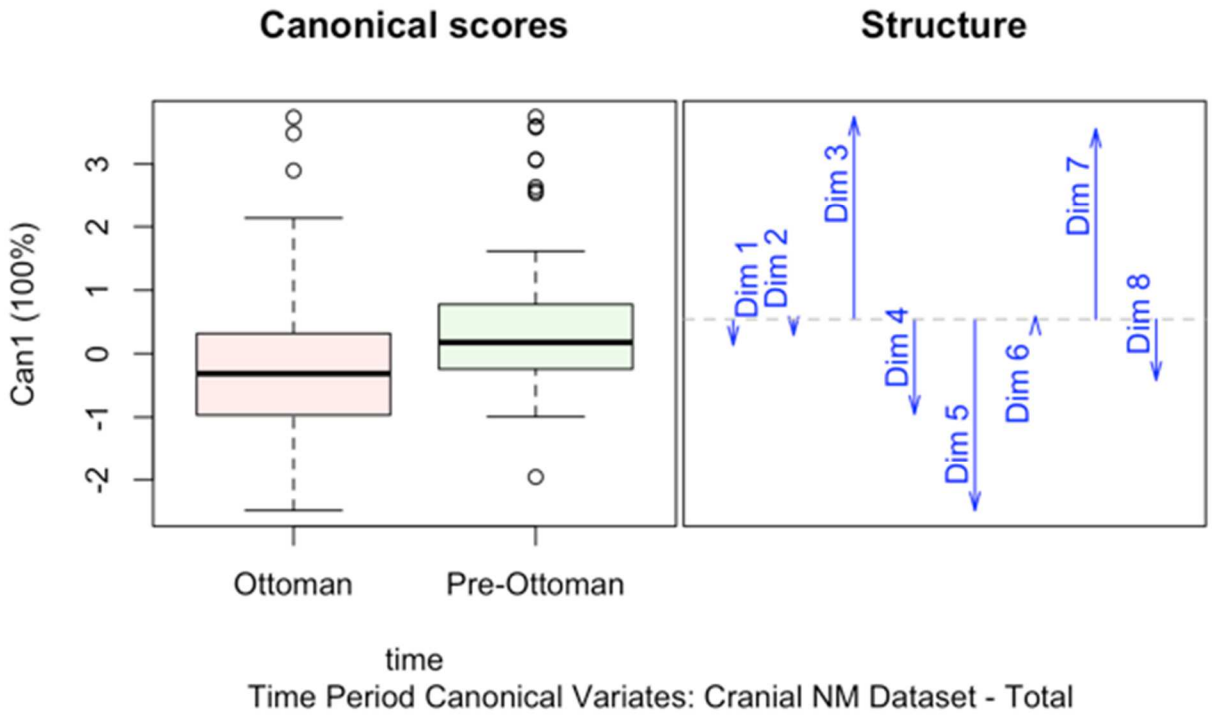

Figure 7 - 7: Canonical variate 1 by time period for cranial non-metric dataset - total sample (n=245).

The MCA of the cranial non-metric – total sample was explored using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each MCA dimension (Husson, et al. 2011). The variables that contribute significantly to the formation of each dimension are highlighted in gray in Table 7-7. Examination of the dimensions using one-way analysis of variance showed Dimension 1, Dimension 2, Dimension 4, Dimension 6, Dimension 7 and Dimension 8 did not separate individuals by time period and therefore the individual factor plots for these dimensions are presented in Appendix C (Figure C-9 through Figure C-12). Dimension 3 and Dimension 5 did separate individuals by time period.

Dimension 3 accounted for 7.02% of the sample variance and separated individuals by time period (R^2=0.0324, p-value=0.0047) (Figure 7-8). Dimension 3 was characterized most by the positive correlation of the following traits: frontal grooves-absent, mylohyoid bridging-present, and basilar-sphenoid bridging-present; and the negative correlation of the opposite of these traits: frontal grooves-present, mylohyoid bridging-absent, and basilar-sphenoid bridging-absent (Table 7-7). Individuals from the pre-Ottoman period had higher frequencies for the frontal groove-presence, mylohyoid bridging-presence, and basilar-sphenoid bridging-presence; making these individuals positively correlated with Dimension 3. Individuals from the Ottoman period had higher frequencies of frontal grooves-presence, mylohyoid bridging-absence, and basilar-sphenoid bridging-absence, making these individuals negatively correlated with Dimension 3. Age and sex did not separate individuals on Dimension 3 (Figure 7-8).

Dimension 5 accounted for 6.34% of the sample variance and separated individuals by time period (R^2=0.0290, *p*-value=0.0076) (Figure 7-9). Dimension 5 was characterized by the positive correlation of the following traits: parietal foramen-absent, pharyngeal tubercle-absent,

ossicle at asterion-present, mylohyoid bridging-absent and condylar canal-absent; and the negative correlation of the opposite of those traits: parietal foramen-present, pharyngeal tubercle-present, ossicle at asterion-absent, mylohyoid bridging-present and condylar canal-present. Individuals from the Ottoman period had higher frequencies of parietal foramen-absence, pharyngeal tubercle-absence, ossicle at asterion-presence, mylohyoid bridging-absence and condylar canal-absence, making the Ottoman individuals positively correlated on Dimension 5. Individuals from the pre-Ottoman period had higher frequencies of parietal foramen-presence, pharyngeal tubercle-presence, ossicle at asterion-absence, mylohyoid bridging-presence and condylar canal-presence, making the pre-Ottoman individuals negatively correlated on Dimension 5. However, age (R^2=0.0844, *p*-value=0.0000) and sex (R^2=0.0779, *p*-value=0.0001) also separated individuals on Dimension 5 (Figure 7-9): indeterminate subadults were positively correlated, while adults, both male and female, were negatively correlated with Dimension 5. The variables contributing to the formation of Dimension 5 could also be interpreted as being affected by differential growth and therefore Dimension 5 as separating individuals more by age than by time period or sex. Koprivno-Križ II contributes a high number of subadult individuals to the final cranial non-metric dataset, 64 subadults or 26% the total sample. It would appear that the unusually high number of subadult individuals at the Koprivno-Križ II site is affecting the separation of individuals on Dimension 5. Therefore, an adult-only sample was also tested to see if the significant separations by time period remained in the absence of subadult individuals.

Sex also separated individuals on Dimension 2 (R^2=0.0390, *p*-value=0.0081) (Figure 7-8): with indeterminate individuals positively correlated and female individuals negatively correlated. Age did not significantly separate individuals on Dimension 2. No other age or sex correlations were identified using one-way analysis of variance.

Table 7 - 7: MCA component loadings and eigenvalues for the cranial non-metric - total sample (n=245).

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8
Metopic Suture - A	-0.24	0.52	-0.06	-0.40	-0.01	-0.34	-0.02	-0.39
Metopic Suture - P	4.83	-10.12	1.05	7.61	0.09	3.34	0.22	4.22
Supranasal Suture - A	0.33	-3.91	-0.29	0.92	1.19	0.51	1.10	1.29
Supranasal Suture - P	-0.19	2.29	0.17	-0.54	-0.69	-0.28	-0.61	-0.66
Frontal Grooves - A	-0.17	-0.08	0.92	-0.35	-0.25	0.08	-0.21	-0.17
Frontal Grooves - P	2.02	0.48	-5.73	2.28	1.69	-0.53	1.35	1.19
Medial Supraorbital Foramen - A	-1.91	-0.61	2.36	4.08	0.36	-0.42	-0.32	-0.38
Medial Supraorbital Foramen - P	0.91	0.29	-1.08	-1.87	-0.15	0.38	0.27	0.30
Lateral Supraorbital Foramen - A	-1.15	-1.19	0.93	-0.61	0.06	-1.07	1.52	-0.59
Lateral Supraorbital Foramen - P	1.74	1.84	-1.41	0.93	-0.09	1.67	-2.43	0.95
Parietal Foramen - A	1.39	0.19	-0.10	-3.20	3.66	0.61	0.49	2.91
Parietal Foramen - P	-0.36	-0.05	0.05	1.56	-1.62	-0.29	-0.11	-0.72
Occipital Mastoid Ossicle - A	-0.68	0.19	-0.25	0.01	-0.35	0.06	-0.13	0.69
Occipital Mastoid Ossicle - P	6.41	-1.90	2.47	-0.07	3.42	-0.63	1.25	-6.41
Occipital Foramen - A	-1.30	1.96	2.34	-0.35	1.64	-3.64	-2.23	3.56
Occipital Foramen - P	0.52	-0.71	-0.91	0.07	-0.33	0.78	0.49	-0.76
Ossicle at Asterion-A	-1.08	-0.08	0.02	-0.36	-0.85	0.09	-0.52	0.46
Ossicle at Asterion-P	5.30	0.38	-0.10	1.70	3.94	-0.41	2.25	-4.20
Condylar Canal Bridging - A	-0.16	-0.41	0.34	-0.24	0.32	0.05	-0.48	-0.28
Condylar Canal Bridging - P	1.72	4.83	-4.27	3.04	-4.09	-0.61	6.40	3.61
Pharyngeal Tubercle - A	-3.29	1.06	-0.27	1.77	2.05	0.71	0.65	0.81
Pharyngeal Tubercle - P	1.64	-0.51	0.13	-0.79	-1.94	-0.65	-0.53	-0.71
Basilar Sphenoid Bridge - A	-0.55	-0.01	-0.56	0.06	-0.17	-0.51	0.59	-0.02
Basilar Sphenoid Bridge - P	5.03	0.09	4.99	-0.59	1.54	4.78	-5.54	0.18
Flexure of Superior Sagittal Sulcus - Other	0.98	2.30	0.52	-0.54	1.66	2.06	2.03	-0.81
Flexure of Superior Sagittal Sulcus - Right	-0.33	-1.62	-0.35	0.33	-1.08	-0.65	-0.69	0.29
Biasterionic Suture - A	-0.81	-0.40	-0.27	-0.72	-0.04	0.82	0.10	-0.17
Biasterionic Suture - P	4.33	2.13	1.48	3.90	0.21	-4.29	-0.50	0.86
Mastoid Foramen - Extrasutural	2.01	-0.60	-0.71	-0.39	1.23	-3.35	-0.23	0.36
Mastoid Foramen - In Suture	-1.87	0.59	0.34	0.20	-0.68	1.87	0.12	-0.20
Parietal Notch Bone - A	-0.92	-0.19	-0.73	-0.55	0.35	-0.34	-0.25	-0.55
Parietal Notch Bone - P	4.27	0.87	3.31	2.41	-1.52	1.37	2.18	4.51
Accessory Mental Foramen - A	-0.86	-1.58	0.16	-0.13	0.35	-0.23	0.85	0.15
Accessory Mental Foramen - P	1.01	1.96	-0.20	0.16	-0.43	0.30	-1.08	-0.20
Mylohyoid Bridge - A	-0.24	-0.12	-0.67	0.19	0.25	0.06	-0.43	-0.14
Mylohyoid Bridge - P	3.48	1.79	9.00	-5.25	-6.85	-1.54	11.25	1.79
Retromolar Foramen - A	-1.11	0.84	0.76	1.00	0.77	-0.08	0.33	-0.28
Retromolar Foramen - P	2.71	-2.05	-1.94	-2.52	-1.98	0.22	-0.83	0.70
Eigenvalue	0.11	0.09	0.07	0.07	0.06	0.06	0.05	0.05
% Variance	10.73	8.76	7.02	6.61	6.34	6.08	5.46	5.34
Cumulative %	10.73	19.49	26.51	33.12	39.46	45.54	51.00	56.34

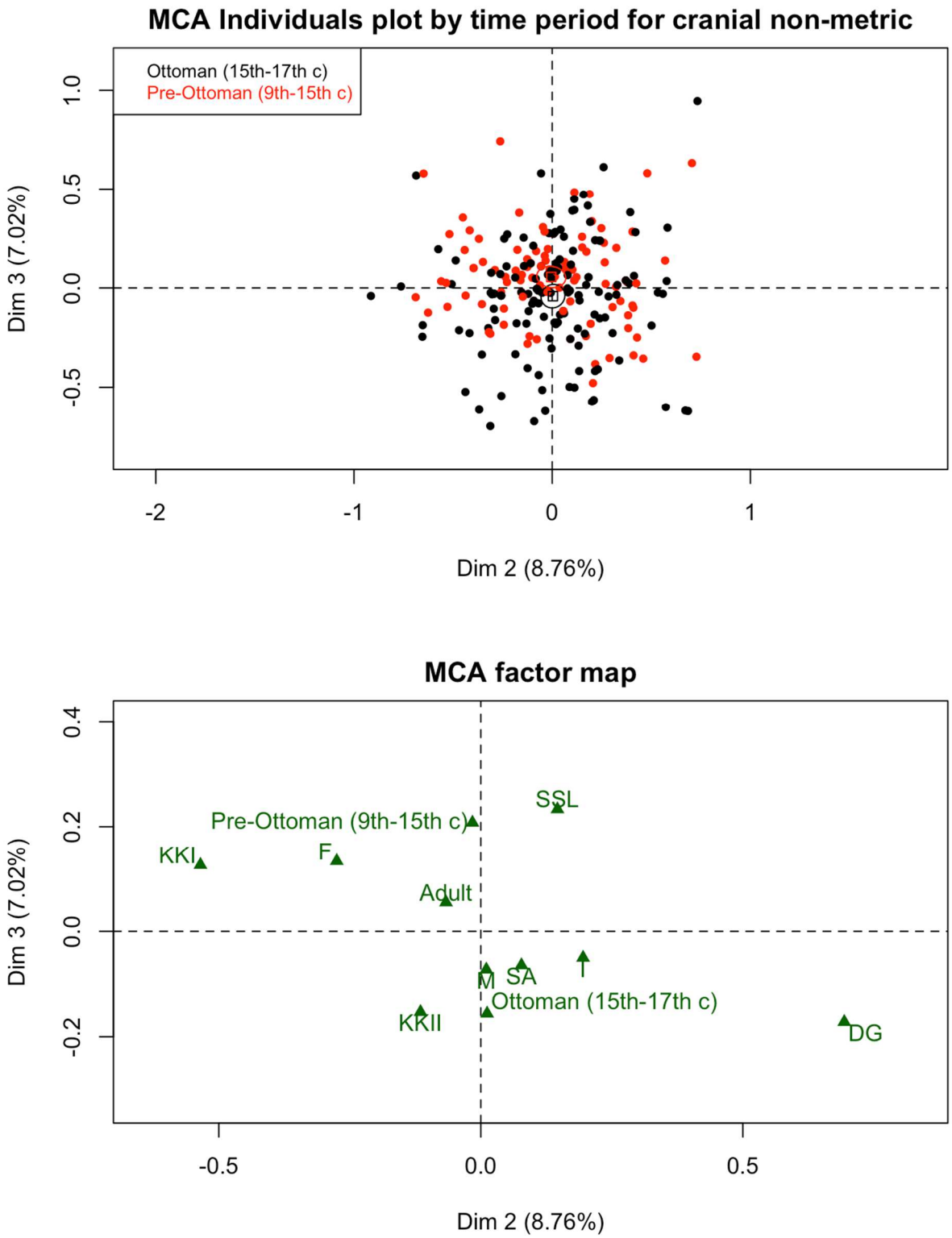

Figure 7 - 8: Upper: Dim 2 and Dim 3 individuals factor plots (MCA) for the cranial non-metric - total sample (n=245), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

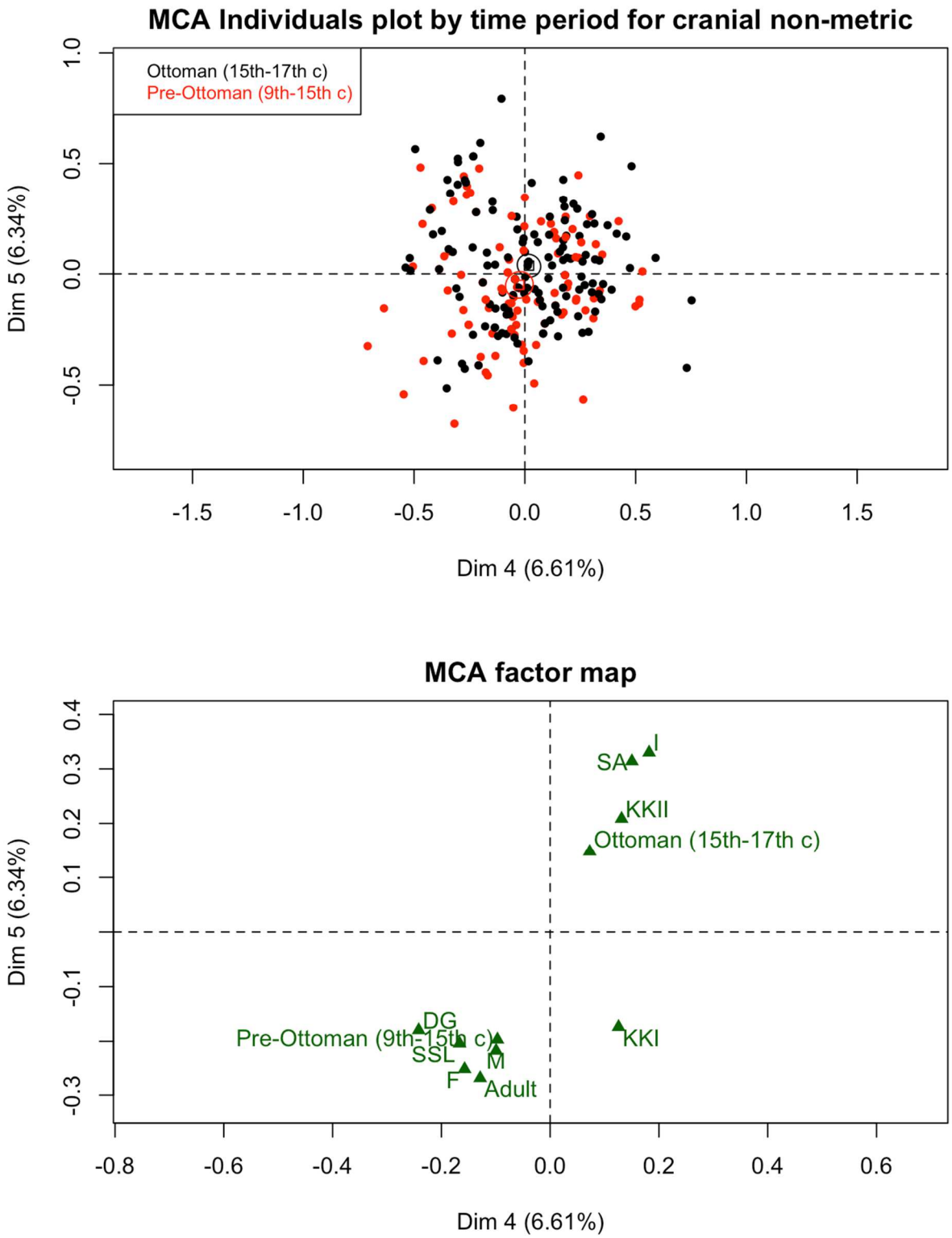

Figure 7 - 9: Upper: Dim 4 and Dim 5 individuals factor plots (MCA) for the cranial non-metric - total sample (n=245), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

The time period results of the MMD analysis for the cranial non-metric – total sample are presented in Table 7-8. After removal of traits with a negative overall measure of divergence (MD), only five traits remained for the MMD analysis. Frequency counts for these traits by time period are presented in Table 7-9. With only five traits used to produce the distances in Table 7-8, any significant results must be treated with some caution and corroborated with additional evidence. A significant difference resulted between the pre-Ottoman and Ottoman periods. These results are consistent with those of the total sample cranial metric, dental non-metric, and cranial non-metric PCA/MCA analyses. Therefore, the significant difference between the pre-Ottoman and Ottoman periods using MMD is likely a true difference.

Table 7 - 8: MMD values (upper right) and associated SD values (lower left), for the cranial non-metric dataset - total sample time period comparisons.

	Ottoman	Pre-Ottoman
Ottoman		0.126*
Pre-Ottoman	0.012	

* Marks a significant value.

Table 7 - 9: Number of individuals, frequencies of active variables within each time period, and overall measure of divergence of active variables, for the cranial non-metric dataset – total sample.

	Frontal Grooves	Medial Supraorbital Foramen	Lateral Supraorbital Foramen	Pharyngeal Tubercle	Biasterionic Suture
n Ottoman	128	135	135	113	101
n Pre-Ottoman	95	98	100	85	85
Frequency Ottoman	0.20	0.71	0.44	0.60	0.25
Frequency Pre-Ottoman	0.03	0.57	0.30	0.79	0.13
Overall MD	0.256	0.032	0.027	0.101	0.025

Cranial non-metric – adult only (n=140)

For the cranial non-metric – adult only sample (n=140) the first eight MCA dimension eigenvalues were significant and represented 56.18% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – adult only sample all four of the MANOVA

significance tests were significant (Table 7-2). Therefore, differences between sites were identified using the cranial non-metric – adult only sample.

Results of the DDA analysis of the first eight MCA dimensions and time period identified a significant correlation with Canon 1 (Canon 1: F=3.04, *p*-value=0.0038) (Figure 7-10): the Ottoman period was positively correlated, while the pre-Ottoman period was negatively correlated with Canon 1. There was only one canon for this comparison. Dimension 1, Dimension 2, Dimension 4, Dimension 5, Dimension 6, and Dimension 7 are positively correlated: while Dimension 3, and Dimension 8 are negatively correlated with Canon 1. Dimension 4, and Dimension 5 have the largest standard coefficients (followed by Dimension 1 and Dimension 3) and therefore contribute most to the formation of Canon 1 (Figure 7-10).

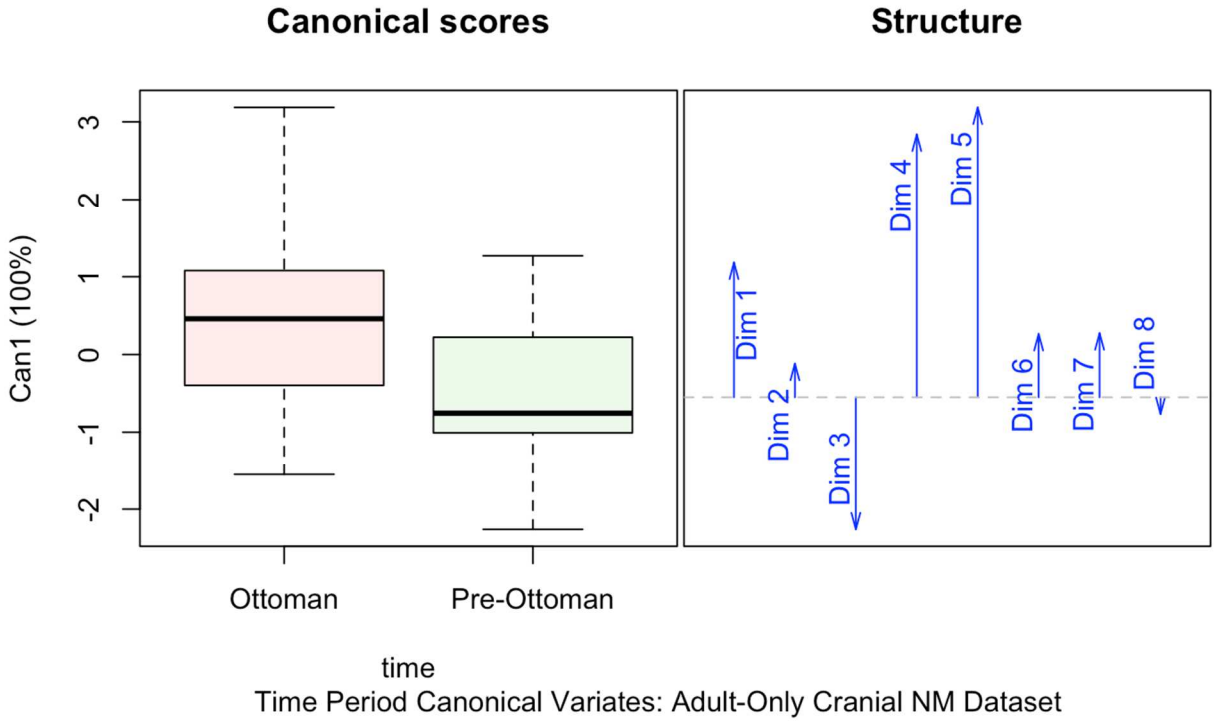

Figure 7 - 10: Canonical variate 1 by time period for the cranial non-metric – adult only sample (n=140).

The MCA of the cranial non-metric – adult only sample was explored using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each MCA dimension (Husson, et al. 2011). The variables that contribute significantly to the formation of each dimension are highlighted in gray in Table 7-10. Examination of the dimensions using one-way analysis of variance showed Dimension 1, Dimension 2, Dimension 3, Dimension 6, Dimension 7, and Dimension 8 did not separate individuals by time period and therefore the individual factor plots for these dimensions are presented in Appendix C (Figure C-13 through Figure C-16). Only Dimension 4 and Dimension 5 separated individuals by time period (Figure 7-11). Sex correlations were not identified on any of the MCA dimensions.

Dimension 4 accounted for 7.24% of the sample variance and separated individuals by time period (R^2=0.0583, *p*-value=0.0057) (Figure 7-11). Dimension 4 was characterized most by the positive correlation of the following traits: frontal grooves-present, ossicle at asterion-present, mylohyoid bridging-absent and metopic suture-present; and the negative correlation of the opposite of these traits: frontal grooves-absent, ossicle at asterion-absent, mylohyoid bridging-present, and metopic suture-absent (Table 7-10). Individuals from the pre-Ottoman period had higher frequencies of frontal grooves-absent, ossicle at asterion-absent, mylohyoid bridging-present, and metopic suture-absent: making the pre-Ottoman individuals negatively correlated with Dimension 4 (Figure 7-11). Individuals from the Ottoman period had higher frequencies of frontal grooves-present, ossicle at asterion-present, mylohyoid bridging-absent and metopic suture-present, making the Ottoman individuals positively correlated with Dimension 4 (Figure 7-11).

Dimension 5 accounted for 6.63% of the sample variance and separated individuals by time period (R^2=0.0708, *p*-value=0.0022) (Figure 7-11). Dimension 5 was characterized by the positive correlation of the following traits: pharyngeal tubercle-absent, lateral supraorbital foramen-present, flexure of the superior sagittal sulcus-right, ossicle at asterion-absent and occipital foramen-present; and the negative correlation of the opposite of those traits: pharyngeal tubercle-present, lateral supraorbital foramen-absent, flexure of the superior sagittal sulcus-other, ossicle at asterion-present and occipital foramen-absent. Individuals from the Ottoman period had higher frequencies of pharyngeal tubercle-absent, lateral supraorbital foramen-present, flexure of the superior sagittal sulcus-right, ossicle at asterion-absent and occipital foramen-present; making the Ottoman individuals positively correlate on Dimension 5. Individuals from the pre-Ottoman period had higher frequencies of pharyngeal tubercle-present, lateral supraorbital foramen-absent, flexure of the superior sagittal sulcus-other, ossicle at asterion-present and occipital foramen-absent; making the pre-Ottoman individuals negatively correlated on Dimension 5.

Table 7 - 10: MCA component loadings and eigenvalues for cranial non-metric – adult only sample (n=140).

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8
Metopic Suture - A	0.29	-0.49	-0.19	-0.42	-0.14	0.00	-0.23	0.34
Metopic Suture - P	-5.60	9.33	3.96	9.12	1.43	0.05	2.37	-3.52
Supranasal Suture - A	-2.27	2.99	-0.17	1.14	-0.75	0.11	0.25	-1.17
Supranasal Suture - P	1.39	-1.77	0.10	-0.64	0.42	-0.06	-0.13	0.58
Frontal Grooves - A	0.05	0.27	0.30	-0.97	-0.03	-0.14	-0.26	-0.14
Frontal Grooves - P	-0.62	-1.63	-1.82	6.02	0.19	0.90	1.70	0.94
Medial Supraorbital Foramen - A	-1.08	0.77	-2.81	-1.89	3.21	-0.41	2.40	0.00
Medial Supraorbital Foramen - P	0.42	-0.29	1.08	0.68	-1.10	0.30	-1.69	0.00
Lateral Supraorbital Foramen - A	-1.70	0.50	-0.64	-0.83	-1.37	0.70	0.04	-0.26
Lateral Supraorbital Foramen - P	2.52	-0.73	0.98	1.29	2.15	-1.12	-0.07	0.41
Parietal Foramen - A	0.66	-1.13	2.18	1.57	-1.74	0.90	3.56	0.58
Parietal Foramen - P	-0.16	0.26	-1.06	-0.75	0.89	-0.49	-0.91	-0.15
Occipital Mastoid Ossicle - A	-0.22	-0.66	0.04	-0.02	0.31	0.62	0.15	-0.57
Occipital Mastoid Ossicle - P	2.18	6.61	-0.43	0.15	-3.04	-5.83	-1.38	5.30
Occipital Foramen - A	2.17	0.63	-2.43	-2.59	-2.86	1.04	1.70	-1.76
Occipital Foramen - P	-0.74	-0.23	0.94	0.47	0.53	-0.19	-0.31	0.34
Ossicle at Asterion-A	-0.72	-0.75	0.21	-1.36	0.90	-0.42	0.59	0.11
Ossicle at Asterion-P	2.63	2.73	-0.75	4.68	-3.11	1.34	-1.83	-0.69
Condylar Canal Bridging - A	-0.39	0.46	0.00	-0.14	-0.06	0.20	0.04	0.22
Condylar Canal Bridging - P	4.42	-5.26	-0.06	1.64	0.70	-2.44	-0.49	-2.75
Pharyngeal Tubercle - A	0.41	-0.77	-4.66	4.16	4.82	5.08	3.20	2.10
Pharyngeal Tubercle - P	-0.04	0.07	0.38	-0.33	-0.80	-0.82	-0.56	-0.38
Basilar Sphenoid Bridge - A	-0.18	-0.79	-0.64	0.22	-0.55	0.33	-0.17	-0.58
Basilar Sphenoid Bridge - P	1.10	4.98	4.11	-1.47	3.70	-2.13	1.08	3.61
Flexure of Superior Sagittal Sulcus - Other	2.00	-0.47	1.32	-0.22	-2.18	1.66	0.77	3.96
Flexure of Superior Sagittal Sulcus - Right	-0.55	0.27	-0.74	0.13	1.39	-0.50	-0.24	-1.22
Biasterionic Suture - A	-1.32	-0.83	0.61	0.27	-0.63	0.08	-0.12	0.33
Biasterionic Suture - P	5.35	3.46	-2.47	-1.09	2.43	-0.31	0.46	-1.16
Mastoid Foramen - Extrasutural	1.57	0.10	-1.37	0.39	-1.46	-1.54	2.15	-0.33
Mastoid Foramen - In Suture	-2.16	-0.15	0.93	-0.27	1.02	1.06	-1.54	0.24
Parietal Notch Bone - A	-0.96	-0.44	-0.98	0.09	-0.43	-1.13	0.15	-0.01
Parietal Notch Bone - P	3.16	1.40	3.07	-0.29	1.26	3.18	-0.90	0.05
Accessory Mental Foramen - A	-1.20	-0.30	-0.96	-0.18	0.10	-0.86	0.57	1.59
Accessory Mental Foramen - P	1.55	0.39	1.23	0.24	-0.14	1.18	-0.81	-2.20
Mylohyoid Bridge - A	-0.08	-0.20	-0.69	0.45	0.14	-0.33	-0.39	0.25
Mylohyoid Bridge - P	0.67	1.59	5.26	-7.11	-2.17	5.63	6.94	-2.11
Retromolar Foramen - A	0.25	0.77	-1.62	-0.21	-0.09	1.54	-0.90	0.72
Retromolar Foramen - P	-0.47	-1.51	3.23	0.43	0.17	-3.03	1.70	-1.34
Eigenvalue	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.05
% Variance	9.18	8.23	7.70	7.24	6.63	6.08	5.81	5.30
Cumulative %	9.18	17.42	25.11	32.36	38.98	45.07	50.87	56.18

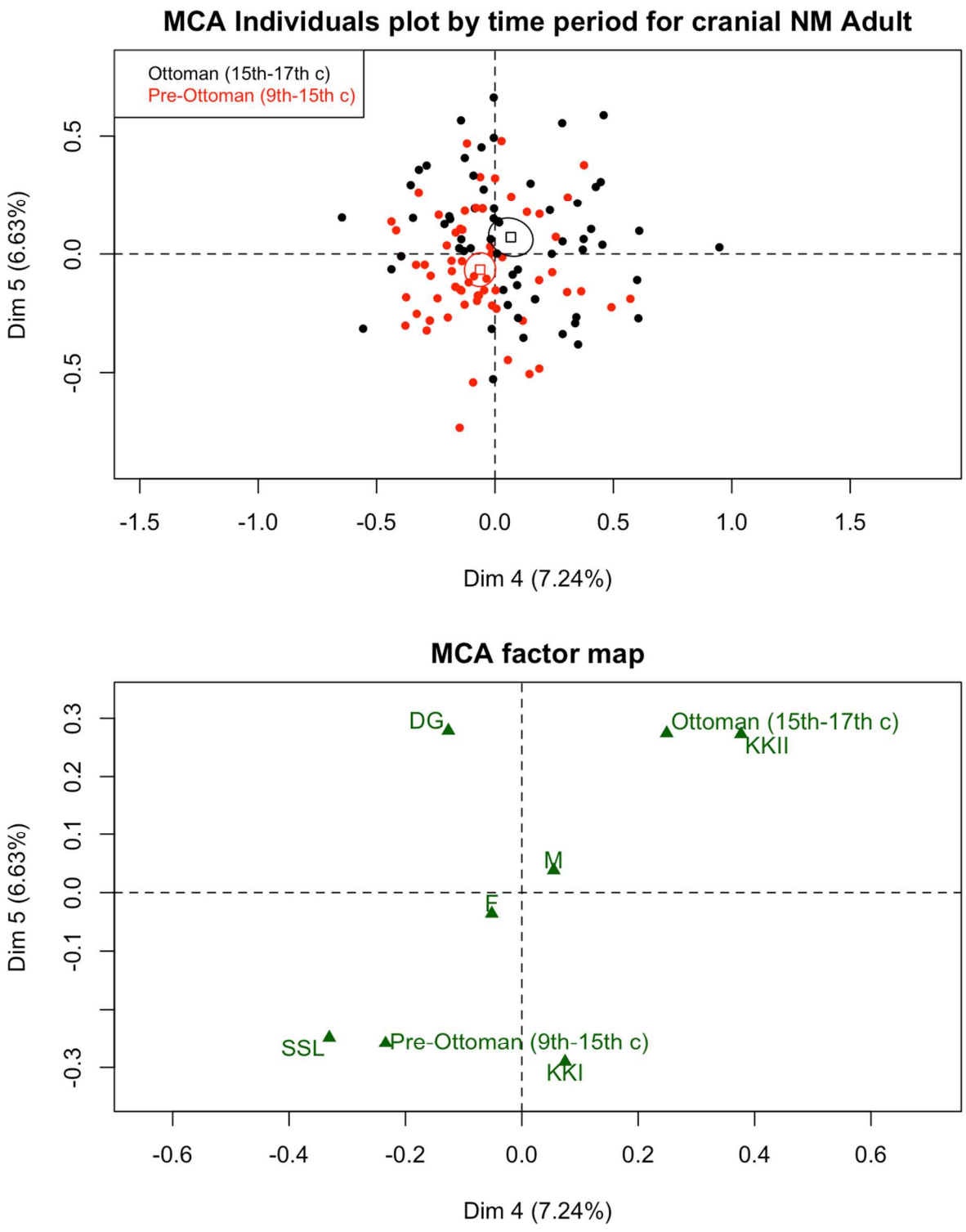

Figure 7 - 11: Upper: Dim 4 and Dim 5 individuals factor plots (MCA) for cranial non-metric – adult only sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

Male sample comparisons

The significant dimensions of the PCA and MCA analyses for the male sample can be found in Table 7-1. The significant dimensions for each dataset were submitted to a MANOVA test to identify group separation by time period (Table 7-2). The dental metric, cranial metric, dental non-metric, and cranial non-metric results for the male sample are presented in this section.

Dental metric – male sample (n=53)

The first four dimensions of the dental metric – male sample (n=53) had significant eigenvalues and represent 72% of the cumulative variance in the sample (Table 7-1). For the dental metric – male sample none of the MANOVA by time period results were significant (Table 7-2). Therefore, the dental metric – male sample does not differ by time period and the null hypothesis cannot be disproven. The follow-up DDA, component loadings and one-way analysis of variance of the PCA dimensions for the dental metric – male sample are not provided here and instead can be found in Appendix C (Table C-2, Figure C-17 and Figure C-18).

Cranial metric – male sample (n=62)

The first six PCA dimensions of the cranial metric – male sample (n=62) had significant eigenvalues and represented 73% of the cumulative variance in the sample (Table 7-1). For the cranial metric – male sample all of the MANOVA by time period results were significant (Table 7-2). Therefore, the cranial metric – male sample differs by time period.

Results of the DDA analysis of the first six PCA dimensions and time period identified a significant correlation with Canon 1 (Canon 1: F=4.88, *p*-value=0.00046) (Figure 7-12): The

Ottoman period was positively correlated, while the pre-Ottoman period was negatively correlated on Canon 1. There is only one canon for this comparison. All six dimensions were negatively correlated on Cannon 1. Dimension 2, Dimension 3 and Dimension 6 had the largest standard coefficients and therefore contributed most to the formation of Canon 1.

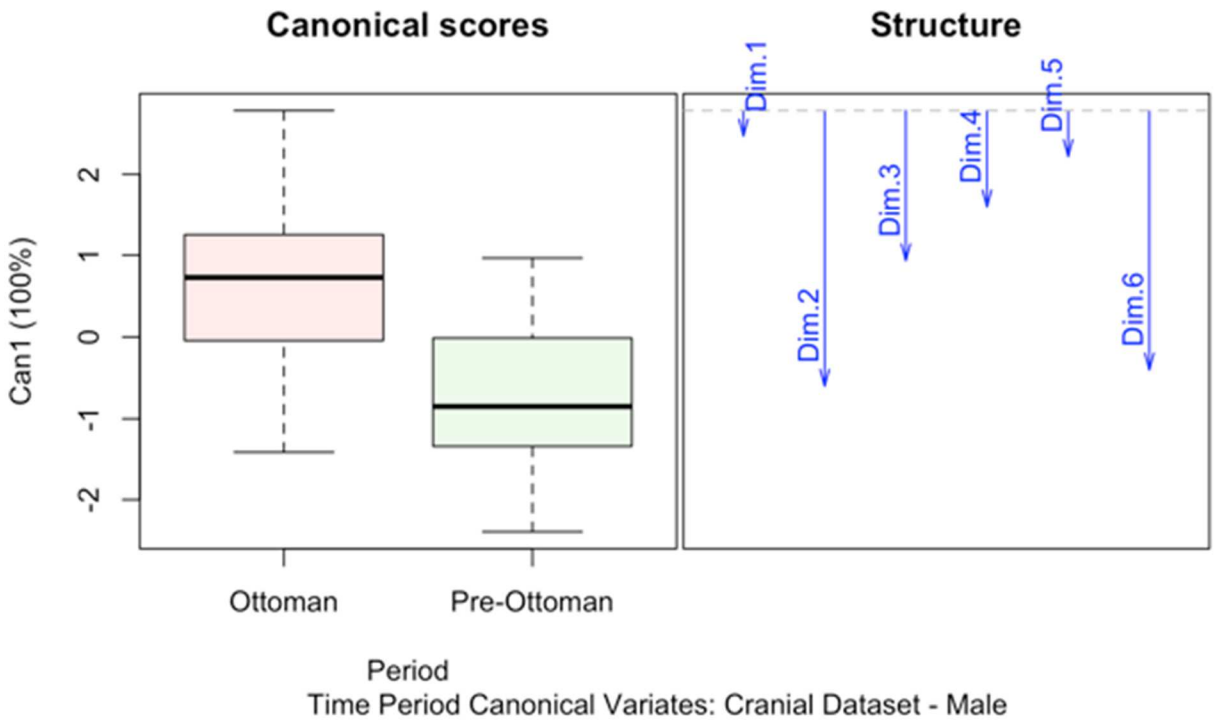

Figure 7 - 12: Canonical variate 1 by time period for cranial metric dataset - male sample (n=62).

The component loadings for the cranial metric – male sample are presented in Table 7-11. Dimension 2 and Dimension 6 successfully separated individuals by time period. Dimension 1, Dimension 3, Dimension 4, and Dimension 5 failed to separate individuals by time period. Therefore, the individuals factor plots for Dimension 3 and Dimension 4 are presented in Appendix C (Figure C-19).

Dimension 2 accounted for 11.7% of the sample variance and separated individuals by time period ($R^2 = 0.15$, *p*-value = 0.00) (Figure 7-13). Dimension 2 separated measurements of the upper face and orbit (negative) from measurements of the mandible (positive) (Table 7-11). Pre-Ottoman males had larger mandibular measurements: making them positively correlated on Dimension 2. The Ottoman males had larger upper face and orbit measures: making them negatively correlated on Dimension 2.

Dimension 6 accounted for 6% of the total sample variance and separated individuals by time period (R^2=0.20, *p*-value=0.00) (Figure 7-13). Dimension 6 separated the foramen magnum breadth (negative) from the nasal height, occipital chord, and parietal chord (positive) (Table 7-11). Pre-Ottoman males had larger nasal heights, occipital chord, and parietal chord measurements: making them positively correlated on Dimension 6. Ottoman males had larger foramen magnum breadth: making them negatively correlated on Dimension 6.

Table 7 - 11: PCA component loadings and eigenvalues for cranial metric dataset - male sample (n=62).

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Cranial Base Length	0.28	0.21	0.06	-0.18	-0.06	0.01	0.08
Max Alveolar Length	0.26	0.20	0.06	0.14	-0.27	-0.04	0.32
Biauricular Breadth	0.33	-0.11	0.01	0.19	-0.06	-0.06	-0.28
Min Frontal Breadth	0.32	-0.14	-0.13	-0.17	0.17	-0.18	-0.16
Upper Facial Breadth	0.37	-0.19	-0.05	-0.17	0.05	-0.04	-0.08
Nasal Height	0.22	-0.08	-0.27	0.41	-0.16	0.36	-0.05
Orbit Breadth	0.21	-0.40	0.25	0.07	-0.36	0.16	0.27
Orbit Height	0.18	-0.30	0.02	0.54	0.23	-0.14	-0.14
Biorbital Breadth	0.34	-0.28	0.11	-0.22	0.11	0.04	0.13
Interorbital Breadth	0.21	0.01	-0.35	-0.33	0.43	0.04	-0.03
Parietal Chord	0.19	0.21	-0.13	0.05	0.30	0.39	0.60
Occipital Chord	0.06	0.08	0.48	0.09	0.39	0.36	-0.31
For Magnum Breadth	0.09	0.07	0.33	0.19	0.27	-0.64	0.36
Mastoid Length	0.09	0.27	0.51	-0.04	0.07	0.23	-0.12
Thickness Mental Foramen	0.24	0.07	0.15	-0.33	-0.36	-0.10	-0.16
Min Ramus Breadth	0.27	0.44	0.00	0.04	-0.19	-0.08	-0.14
Max Ramus Breadth	0.19	0.43	-0.26	0.27	0.01	-0.13	-0.17
Eigenvalues	5.26	1.98	1.73	1.23	1.09	1.04	0.83
% Variance	0.31	0.12	0.10	0.07	0.06	0.06	0.05
Cumulative %	0.31	0.43	0.53	0.60	0.66	0.73	0.77

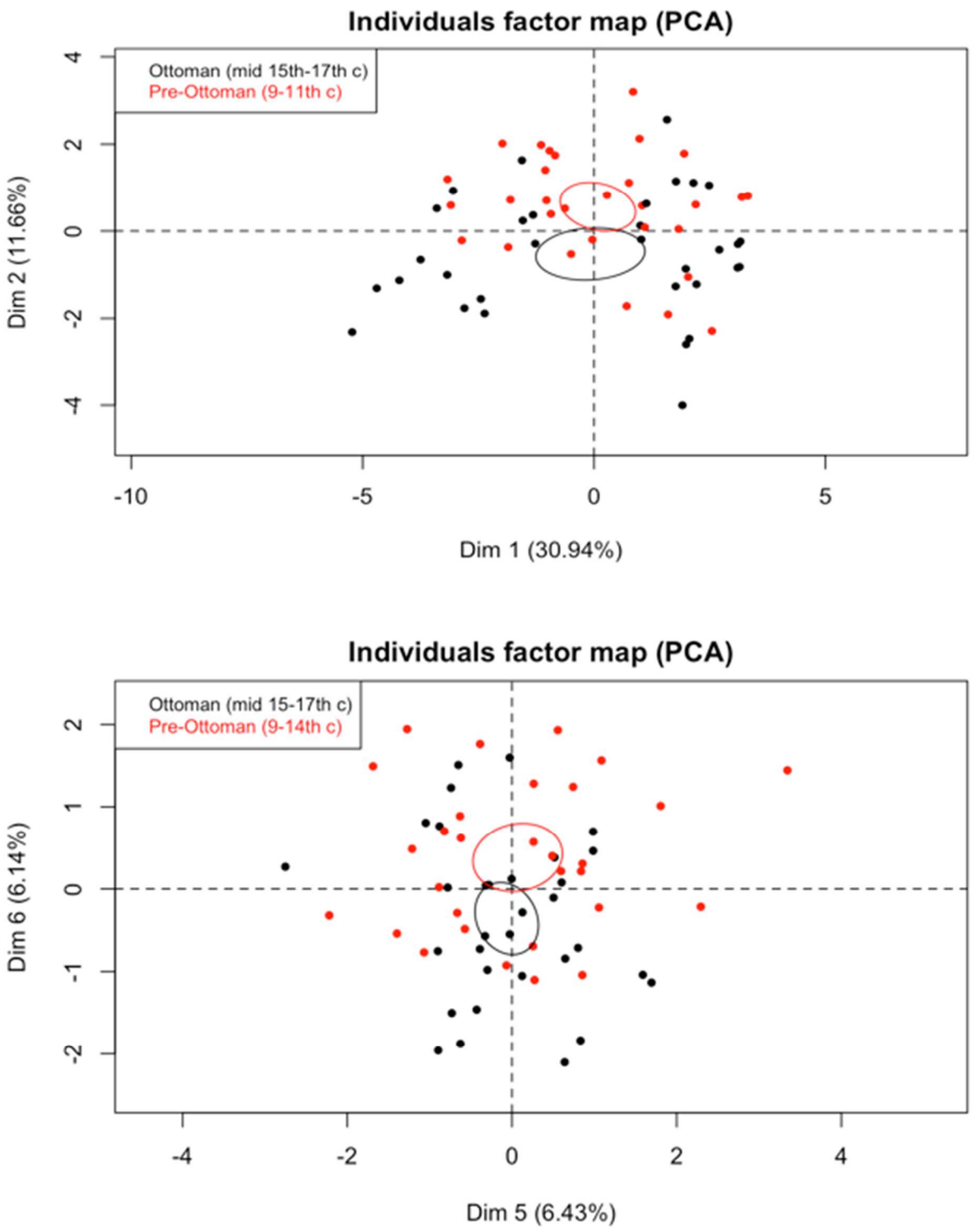

Figure 7 - 13: Upper: Dim 1 and Dim 2 individuals factor plot (PCA) for the cranial metric - male sample (n=62), colored by time period. Lower: Dim 5 and Dim 6 individuals factor plot (PCA) for the cranial metric - male sample (n=62), colored by time period.

Dental non-metric – male sample (n=53)

The first seven dimensions of the dental non-metric – male sample (n=53) had significant eigenvalues and represented 73.9% of the cumulative variance in the sample (Table 7-1). For the dental non-metric – male sample none of the MANOVA by time period results were significant (Table 7-2). Therefore, the dental non-metric – male sample does not differ by time period and the null hypothesis cannot be disproven. Since the results of the MANOVA tests were insignificant, the follow-up DDA, component loadings, and one-way analysis of variance of the PCA dimensions for the dental non-metric – male sample are not provided here and instead can be found in Appendix C (Table C-3, Figure C-20 through Figure C-22).

Cranial non-metric – male sample (n=68)

The first eight dimensions of the cranial non-metric – male sample (n=68) had significant eigenvalues and represent 64.42% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – male sample none of the MANOVA by time period results were significant (Table 7-2). Therefore, the cranial non-metric – male sample does not differ by time period and the null hypothesis cannot be disproven. Since the results of the MANOVA tests were insignificant, the follow-up DDA, component loadings and one-way analysis of variance of the PCA dimensions for the cranial non-metric – male sample are not provided here and instead can be found in Appendix C (Table C-4, Figure C-23 through Figure C-25).

Female sample comparisons

The significant dimensions of the PCA and MCA analyses for the female sample can be found in Table 7-1. The significant dimensions for each dataset were submitted to a MANOVA

test to identify group separation by time period (Table 7-2). The dental metric, cranial metric, dental non-metric, and cranial non-metric results for the female sample are presented in this section.

Dental metric – female sample (n=58)

The first five PCA dimensions of the dental metric – female sample (n=58) had significant eigenvalues and represented 71% of the cumulative variance in the sample (Table 7-1). For the dental metric – female sample all of the MANOVA by time period results were significant (Table 7-2). The dental metric – female sample differs by time period.

Results of the DDA analysis using the first five PCA dimensions by time period identified significant differences between individuals on Canon 1 (Canon 1: F=5.15, p-value=0.001) (Figure 7-14). There was only one canon for this comparison. Dimension 1 and Dimension 2 were positively correlated, while Dimension 3, Dimension 4 and Dimension 5 were negatively correlated with Cannon 1 (see Table 7-12 for component loadings of PCA dimensions). Dimension 3 and Dimension 4 had the largest standard coefficients and therefore contributed most to the formation of Canon 1.

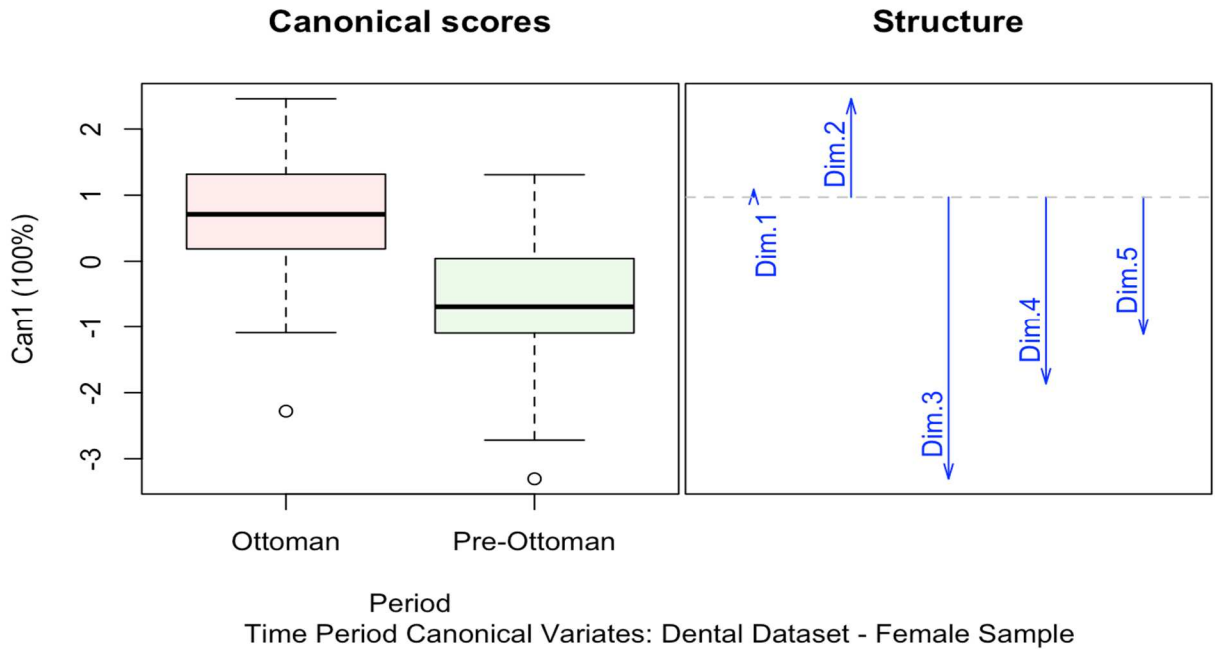

Figure 7 - 14: Canonical variate 1 by time period for the dental metric - female sample (n=58).

The PCA of the dental metric – female sample was explored by time period using a one-way analysis of variance. Dimension 3 and Dimension 4 separated individuals by time period (Figure 7-15), these dimensions also contributed most to the formation of Canon 1 of the DDA. Dimension 1, Dimension 2 and Dimension 5 failed to separate individuals by time period: the individual factor plots for these dimensions are presented in Appendix C (Figure C-23).

Dimension 3 accounts for 9.08% of the sample variance and separated individuals by time period (R^2=0.18, p-value=0.00) (Figure 7-15): pre-Ottoman females were positively correlated, while Ottoman females were negatively correlated on Dimension 3. Examination of the component loadings showed Dimension 3 to separate crown measures (negative) from CEJ measures (positive) (Table 7-12). Pre-Ottoman females had larger CEJ measures making them

positively correlated on Dimension 3. Ottoman females had larger crown measures making them negatively correlated on Dimension 3.

Dimension 4 accounts for 6.64% of the sample variance and separated individuals by time period (R^2=0.08, p-value=0.03) (Figure 7-15): pre-Ottoman females were positively correlated, while the Ottoman females were negatively correlated on Dimension 4. Examination of the component loadings showed Dimension 4 to separate maxillary (positive) from mandibular measurements (negative) (Table 7-12). Pre-Ottoman females had larger maxillary measures making them positively correlated on Dimension 4. Ottoman females had larger mandibular measurements making them negatively correlated on Dimension 4.

Table 7 - 12: PCA component loadings and eigenvalues of the dental metric - female sample (n=58).

	PC1	PC2	PC3	PC4	PC5	PC6
MD Crown UM2	0.16	-0.22	-0.41	-0.04	0.40	0.22
MD Crown LC	1.97	0.46	-1.42	0.11	-0.07	0.03
MD Crown LM1	1.51	-0.84	-0.59	-0.51	-0.35	-0.91
BL Crown UC	1.15	0.60	-0.28	0.36	-0.09	-0.29
BL Crown UM2	1.01	-0.64	0.06	-0.07	-0.40	-0.16
BL Crown LI2	0.76	0.34	-0.08	-0.25	-0.26	0.56
BL Crown LC	0.61	0.06	-0.25	0.16	-0.04	-0.19
BL Crown LP3	3.63	0.05	-0.02	-0.18	-0.29	-0.07
BL Crown LM2	1.56	-1.45	-0.07	-1.25	0.02	0.11
MD CEJ UC	0.77	0.08	0.72	1.80	0.24	0.82
MD CEJ UM1	0.75	-0.50	0.98	0.06	-0.67	-0.26
MD CEJ LI2	0.83	-0.02	0.46	-0.19	-0.03	0.41
MD CEJ LC	0.66	0.29	0.10	0.51	0.15	-0.21
MD CEJ LP4	0.24	0.13	0.58	-0.19	0.14	0.33
MD CEJ LM1	2.68	-1.47	0.03	-0.08	0.12	-0.33
BL CEJ UI2	1.29	0.86	-1.03	0.09	0.20	0.01
BL CEJ UP3	0.47	0.83	0.82	-0.40	1.09	-1.38
BL CEJ UM2	0.72	-0.85	0.31	0.53	0.24	0.13
BL CEJ LI2	0.64	0.69	-0.04	-0.29	-0.34	0.05
BL CEJ LM1	0.58	0.08	0.01	-0.25	0.67	0.22
Eigenvalue	7.81	2.20	1.82	1.33	1.13	0.91
% Variance	0.39	0.11	0.09	0.07	0.06	0.05
Cumulative %	0.39	0.50	0.59	0.66	0.71	0.76

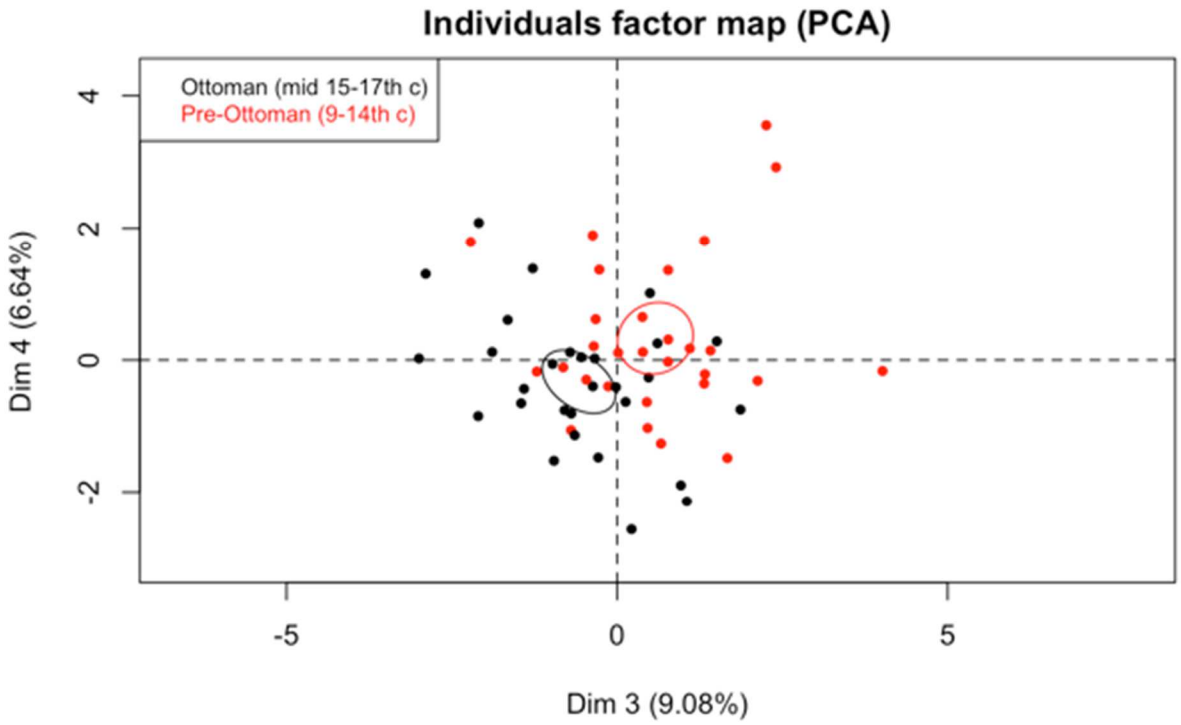

Figure 7 - 15: Dim 3 and Dim 4 individuals factor plot (PCA) for dental metric dataset - female sample (n=58). Colored by site name (upper) and time period (lower).

Cranial metric – female sample (n=70)

The first six PCA dimensions of the cranial metric – female sample (n=70) had significant eigenvalues and represented 71% of the cumulative variance in the sample (Table 7-1). For the cranial metric – female sample all of the MANOVA by time period results were significant (Table 7-2). The cranial metric – female sample differs by time period.

Results of the DDA analysis of the first six PCA dimensions and time period identified a significant correlation with Canon 1 (Canon 1: F=2.73, *p*-value=0.02) (Figure 7-30): Ottoman females were positively correlated, while pre-Ottoman females were negatively correlated on Canon 1. There was only one canon for this comparison. Dimension 1, Dimension 4 and

Dimension 6 were positively correlated, while Dimension 2, Dimension 3 and Dimension 5 were negatively correlated on Canon 1. Dimension 1, Dimension 2 and Dimension 3 had the largest standard coefficients and therefore contributed most to the formation of Canon 1.

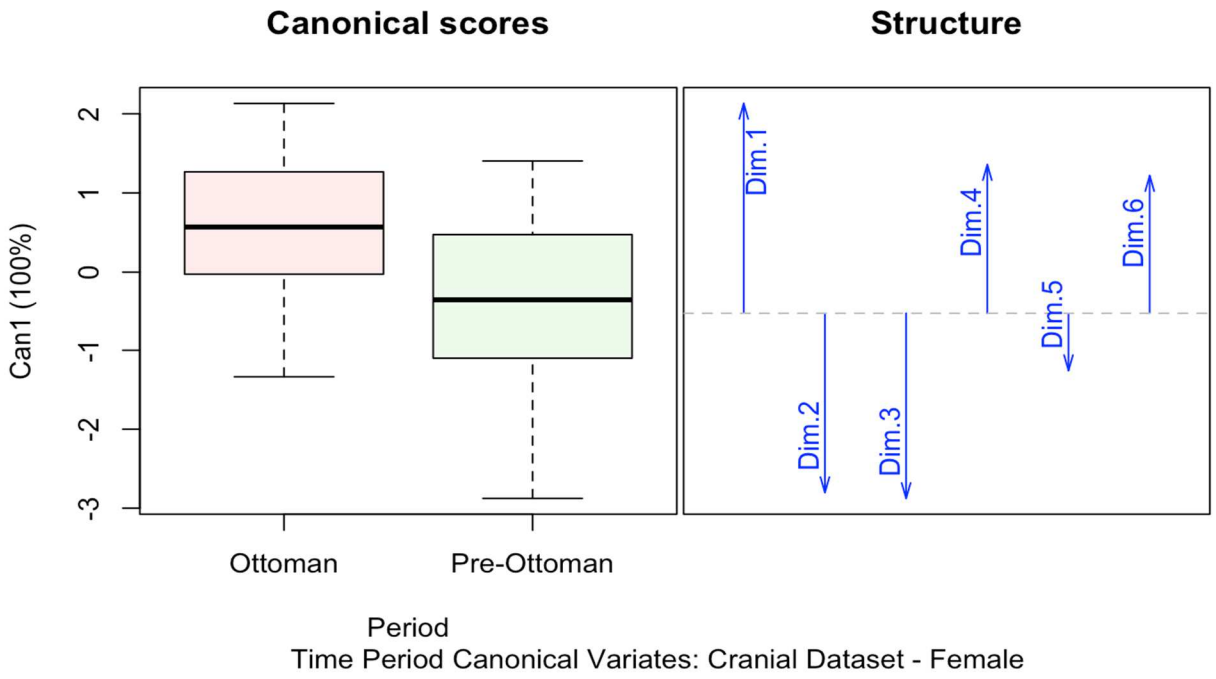

Figure 7 - 16: Canonical variate 1 by time period for the cranial metric - female sample (n=70).

The PCA of the cranial metric – female sample was explored by time period using one-way analysis of variance. Dimension 2, Dimension 3, Dimension 4, Dimension 5 and Dimension 6 failed to separate individuals well by time period; therefore the individual factor plots and component loadings for Dimensions 3 through 6 are not presented here and instead can be found in Appendix C (Figure C-27). Dimension 1 accounted for 21% of the sample variance and separated individuals by time period ($R^2 = 0.06$, p-value=0.04) (Figure 7-17): Ottoman females were positively correlated, while pre-Ottoman females were negatively correlated with Dimension 1. Examination of the component loadings for the cranial metric variables showed

Dimension 1 to be a size dimension, as all but two of the cranial measurements are positively correlated and those that are negative are near zero (Table 7-13). Therefore, Ottoman females are larger in overall cranial measurements compared to pre-Ottoman females.

Table 7 - 13: PCA component loadings and eigenvalues for the cranial metric - female sample (n=70).

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Cranial Base Length	0.30	0.29	0.18	-0.08	0.22	0.16	-0.14
Max Alveolar Length	0.23	0.22	0.22	-0.03	0.10	0.65	-0.12
Biauricular Breadth	0.20	-0.34	-0.06	0.23	-0.16	0.29	-0.01
Min Frontal Breadth	0.45	-0.02	-0.17	-0.06	-0.08	-0.23	0.18
Upper Facial Breadth	0.47	-0.10	-0.09	0.07	-0.04	-0.03	-0.04
Nasal Height	-0.06	0.02	-0.22	-0.06	0.59	0.28	0.43
Orbit Breadth	0.15	-0.34	-0.33	-0.02	0.19	0.03	-0.43
Orbit Height	0.10	-0.29	-0.07	0.12	0.52	-0.21	0.12
Biorbital Breadth	0.43	-0.14	-0.10	-0.03	-0.11	0.00	-0.06
Interorbital Breadth	0.35	0.16	0.18	-0.16	-0.14	-0.08	0.53
Parietal Chord	0.06	0.22	0.22	-0.35	0.27	-0.23	-0.17
Occipital Chord	0.00	-0.16	0.52	0.33	-0.08	-0.12	-0.01
For Magnum Breadth	0.15	-0.09	0.42	0.02	0.30	-0.32	-0.23
Mastoid Length	0.00	-0.20	0.29	0.47	0.08	0.16	0.24
Thickness Mental Foramen	0.13	0.36	-0.09	0.30	0.02	0.09	-0.33
Min Ramus Breadth	-0.04	0.32	-0.18	0.50	0.20	-0.16	-0.04
Max Ramus Breadth	0.11	0.38	-0.24	0.31	-0.08	-0.24	0.13
Eigenvalues	3.57	2.70	1.82	1.59	1.39	1.02	0.94
% Variance	0.21	0.16	0.11	0.09	0.08	0.06	0.06
Cumulative %	0.21	0.37	0.48	0.57	0.65	0.71	0.77

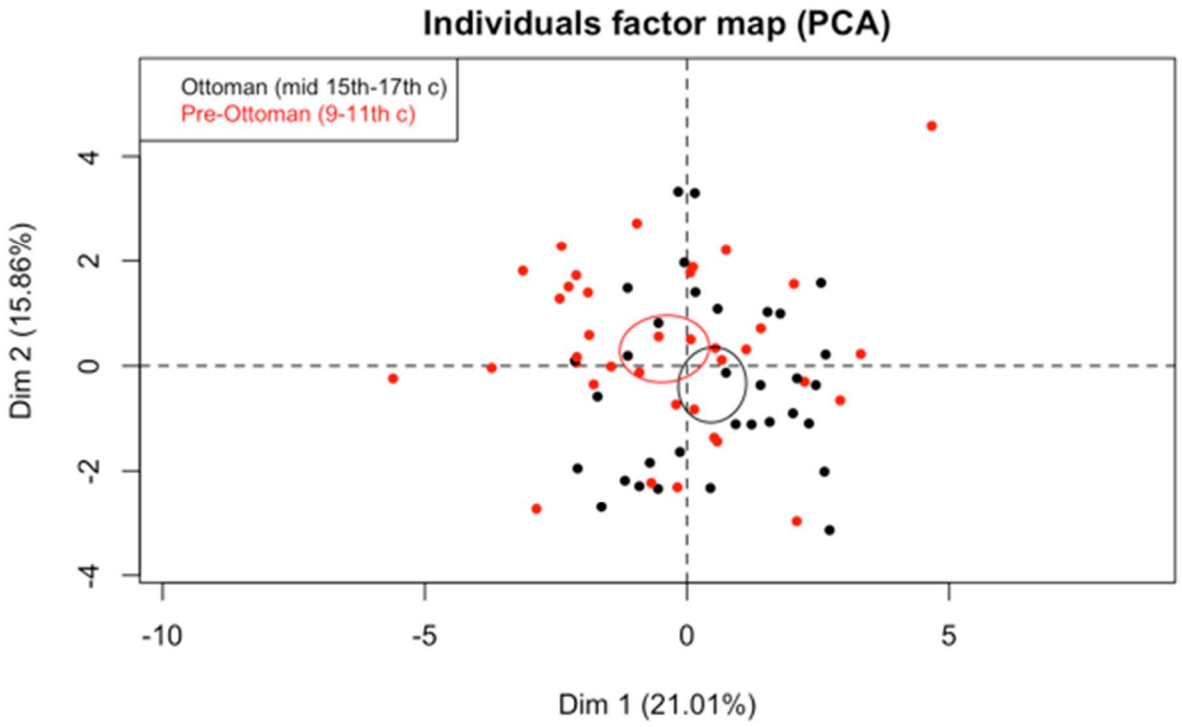

Figure 7 - 17: Dim 1 and Dim 2 individuals factor plot (PCA) for the cranial metric - female sample (n=70), colored by time period.

Dental non-metric – female sample (n=58)

The first seven MCA dimensions of the dental non-metric – female sample (n=58) had significant eigenvalues and represented 71.28% of the cumulative variance in the sample (Table 7-1). For the dental non-metric – female sample all of the MANOVA by time period results were significant (Table 7-2). Therefore, the dental non-metric – female sample differs by time period.

The results of the DDA analysis using the first seven MCA dimensions also found significant differences between individuals when grouped by time period (Canon 1: F=3.89, p-value=0.00) (Figure 7-18): pre-Ottoman females were positively correlated, while Ottoman females were negatively correlated on Canon 1. Dimension 1 and Dimension 7 are negatively

correlated, while Dimension 2, Dimension 3, Dimension 4, Dimension 5, and Dimension 6 are all positively correlated on Canon 1 (see Table 7-14 for component loadings). Dimension 1 and Dimension 7 had the largest standard coefficients and therefore contributed most to the formation of Canon 1.

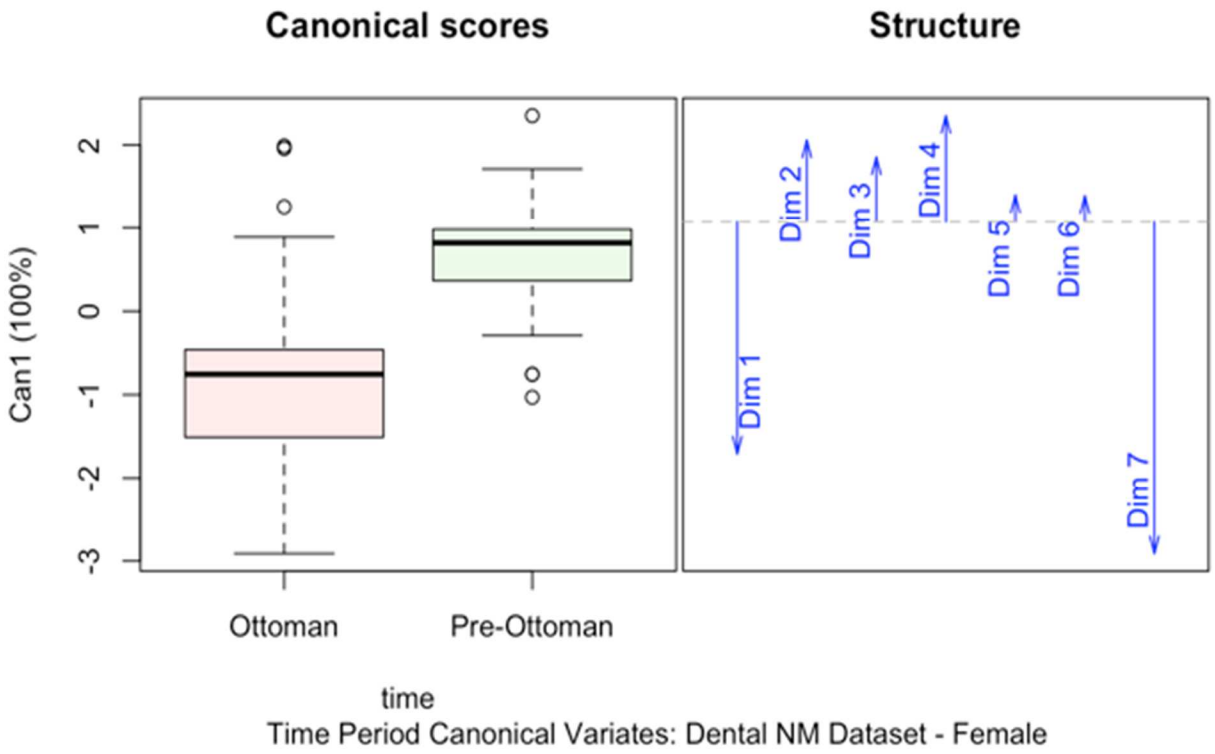

Figure 7 - 18: Canonical variate 1 by time period for the dental non-metric - female sample (n=58).

The component loadings and eigenvalues for the first seven MCA dimensions are presented in Table 7-14. Using one-way analysis of variance, the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table 7-14. One-way analysis of variance identified no separation of individuals by time period on Dimension 2 through Dimension 6. Individual factor plots for Dimension 3 through Dimension 6 are presented

in Appendix C (Figure C-28). Only Dimension 1 and Dimension 7 separated individuals by time period (Figure 7-19 and Figure 7-20).

Table 7 - 14: MCA component loadings and eigenvalues for the dental non-metric - female sample (n=58).

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7
UI1 Double Shoveling - A	-0.07	-0.39	-0.23	0.24	0.81	-0.44	-0.13
UI1 Double Shoveling - P	0.70	4.03	2.42	-2.73	-9.27	4.92	0.94
LC Double Root - A	0.60	0.35	0.20	-0.11	-0.32	-0.12	-0.61
LC Double Root - P	-3.56	-2.02	-0.88	1.67	4.73	1.79	6.49
UI1 Radical Number - 2+ Radicals	3.04	-0.39	-2.79	-3.55	-1.66	0.52	1.29
UI1 Radical Number - One Radical	-1.00	0.14	0.97	1.30	0.59	-0.14	-0.85
UP4 Mesial Accessory Ridges - A	-0.24	-0.28	-0.96	0.28	0.31	0.38	-0.32
UP4 Mesial Accessory Ridges - P	3.99	4.56	21.22	-1.48	-1.77	-2.15	3.43
LP4 Multiple Lingual Cusps - A	-0.23	-2.51	3.71	1.71	1.84	2.68	-0.46
LP4 Multiple Lingual Cusps - P	0.10	1.14	-1.67	-0.77	-0.82	-1.61	0.13
UM2 Carabelli's - A	0.40	-0.44	0.00	0.57	-0.27	0.07	-0.19
UM2 Carabelli's - P	-5.05	5.37	0.03	-7.75	3.67	-0.91	1.62
UM2 Metacone Cusp 3 - A	-2.36	-2.83	-10.49	3.36	-2.21	-3.48	8.92
UM2 Metacone Cusp 3 - P	0.10	0.11	0.32	-0.37	0.23	0.37	-0.66
UM3 Mesial Paracone Tubercle - A	0.93	-0.59	0.00	0.54	-0.39	-0.77	-0.11
UM3 Mesial Paracone Tubercle - P	-4.95	3.38	-0.02	-3.18	2.24	3.31	1.11
UM2 Parastyle - A	-0.05	0.11	-0.39	0.06	-0.07	0.18	-0.13
UM2 Parastyle - P	4.27	-9.95	46.57	-1.74	2.23	-5.49	7.51
LM3 Congenital Absence - Congenital Absence	12.66	12.51	-3.56	7.01	12.55	5.71	4.40
LM3 Congenital Absence - Tooth Present	-0.35	-0.35	0.10	-0.19	-0.34	-0.21	-0.08
UM3 Hypocone Cusp 4 - A	1.03	-0.80	-0.02	-0.60	-0.01	0.49	0.13
UM3 Hypocone Cusp 4 - P	-3.67	2.71	0.08	2.26	0.04	-1.84	-0.33
UM3 Metaconule Cusp 5 - A	1.94	-1.06	-0.86	-0.74	0.83	-0.49	-0.08
UM3 Metaconule Cusp 5 - P	-2.22	1.17	0.72	2.24	-2.40	1.44	0.16
UM2 Root Number - 1-2 Roots	3.83	3.86	-0.64	5.94	-2.97	-0.39	-0.03
UM2 Root Number - 3+ Roots	-0.35	-0.39	0.06	-0.61	0.29	0.03	0.00
UM2 Cusp Number - 3 Cusps	6.69	5.05	1.48	2.46	4.16	9.97	2.69
UM2 Cusp Number - 4+ Cusps	-0.77	-0.58	-0.23	-0.09	-0.17	-0.39	-0.20
LM2 Groove Pattern - Non-Y	-0.37	-0.72	-0.13	-0.12	-0.35	0.79	0.24
LM2 Groove Pattern - Y	4.15	8.24	1.48	1.30	3.98	-11.95	-1.73
Eigenvalue	0.15	0.12	0.11	0.09	0.09	0.08	0.07
% Variance	15.36	11.82	11.30	9.46	8.65	7.62	7.07
Cumulative %	15.36	27.18	38.48	47.94	56.59	64.20	71.28

Dimension 1 accounted for 15.36% of the sample variance and separated individuals by time period (R^2=0.1008, *p*-value=0.0152) (Figure 7-19): pre-Ottoman females were negatively correlated, while Ottoman females were positively correlated on Dimension 1. Age was not identified as a significant separating factor for Dimension 1. Dimension 1 was characterized by

the positive correlation of the UM3 hypocone-absence, UM3 mesial paracone tubercle-absence, and LM3 congenital-absence, and the negative correlation of the presence of these traits (Table 7-14). Ottoman females had higher frequencies of absence for the UM3 hypocone, UM3 mesial paracone tubercle, and LM3 congenital absence: making them positively correlated on Dimension 1. Pre-Ottoman females had higher frequencies of the presence of these traits: making them negatively correlated on Dimension 1.

Dimension 7 accounted for 7.07% of the sample variance and separated individuals by time period (R^2=0.2070, *p*-value=0.0003) (Figure 7-19): Ottoman females were positively correlated, while pre-Ottoman period females were negatively correlated on Dimension 7. However, Dimension 7 also separated individuals by age (R^2=0.0984, *p*-value=0.0165): adults were negatively correlated, while subadults were positively correlated with Dimension 7. The Koprivno-Križ II site had five female adolescents comprising 9% of the female sample (Table B-2), while the Šibenik-Sv. Lovre site had 14 middle and older adults comprising 24% of the female sample. Therefore, the time period separation on Dimension 7 may be a reflection of dental wear and demographic differences between the sites rather than phenotypic/genetic differences. Dimension 7 was characterized by the positive correlation of the UM2 metacone-absence, LC double root-presence and UM2 parastyle-absence; and the negative correlation of the UM2 metacone-presence, LC double root-absence and UM2 parastyle-presence (Table 7-14). Ottoman females had higher frequencies of UM2 metacone-absence, LC double root-presence, and UM2 parastyle-presence: making them positively correlated on Dimension 7. Pre-Ottoman females had higher frequencies of UM2 metacone-presence, LC double root-absence, and UM2 parastyle-absence: making them more negatively correlated on Dimension 7. These traits are relatively unaffected by dental wear. Therefore correlation of age with Dimension 7 may more

likely be a reflection of the demographic differences between the sites, rather than dental wear effecting trait observation.

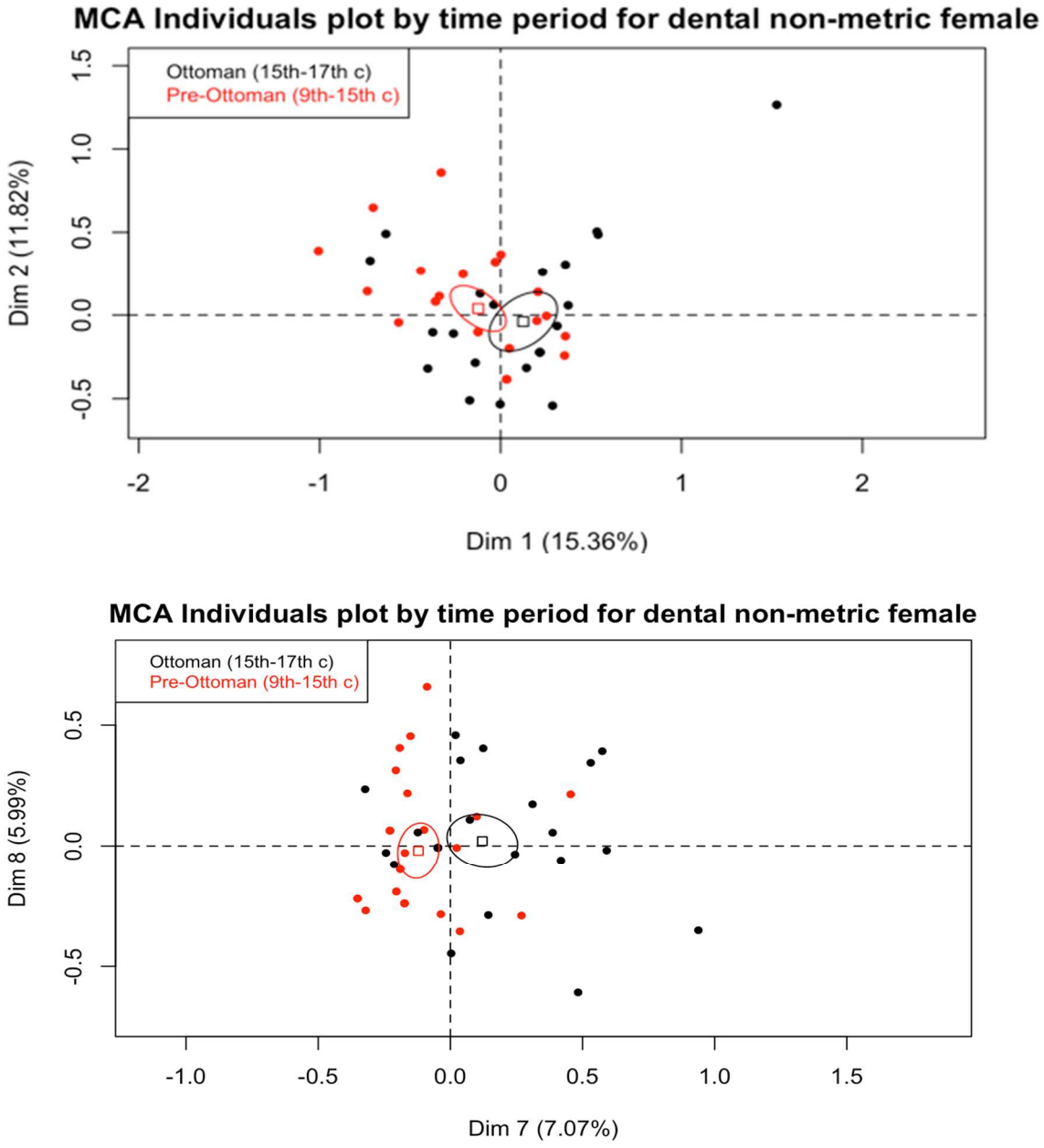

Figure 7 - 19: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the dental non-metric - female sample (n=58), colored by time period. Lower: Dim 7 and Dim 8 individuals factor plots (MCA) for the dental non-metric - female sample (n=58), colored by time period.

Cranial non-metric – female sample (n=75)

The first eight dimensions of the cranial non-metric – female sample (n=75) had significant eigenvalues and represent 62.43% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – female sample none of the MANOVA by time period results were significant (Table 7-2). The cranial non-metric – female sample does not differ by time period and the null hypothesis cannot be disproven. Since the results of the MANOVA tests were insignificant, the follow-up DDA, component loadings, and one-way analysis of variance of the PCA dimensions for the cranial non-metric – female sample are not provided here, and instead can be found in Appendix C (Table C-5, Figure C-29 through Figure C-31).

Indeterminate sample comparisons

The significant dimensions of the PCA and MCA analyses for the indeterminate sample can be found in Table 7-1. The significant dimensions for each dataset were submitted to a MANOVA test to identify group separation by time period (Table 7-2). The dental metric, dental non-metric, and cranial non-metric results for the indeterminate sample are presented in this section. Indeterminate individuals were excluded for the cranial metric comparisons due to differential growth and therefore there are no cranial metric – indeterminate sample comparisons to present.

Dental metric – indeterminate sample (n=28)

The first six PCA dimensions of the dental metric – indeterminate sample (n=28) had significant eigenvalues and represented 78.5% of the cumulative variance in the sample (Table 7-1). For the dental metric – indeterminate sample none of the MANOVA by time period results

were significant (Table 7-2). Therefore, the dental metric – indeterminate sample does not differ by time period and the null hypothesis cannot be disproven. Since the results of the MANOVA tests were insignificant, the follow-up DDA, component loadings and one-way analysis of variance of the PCA dimensions for the dental metric – indeterminate sample are not provided here, and instead can be found in Appendix C.

Dental non-metric – indeterminate sample (n=29)

The dental non-metric – indeterminate sample has a small sample size and interpretations of the results are tentative. The first six dimensions of the dental non-metric – indeterminate sample (n=29) had significant eigenvalues and represented 77.1% of the cumulative variance in the sample (Table 7-1). For the dental non-metric – indeterminate sample all of the MANOVA by time period results were significant (Table 7-2). Therefore, the dental non-metric – indeterminate sample differs by time period.

The results of the DDA analysis using the first six MCA dimensions found significant differences between individuals when grouped by time period (Canon 1: F=15.86, p-value=0.00) (Figure 7-20): the pre-Ottoman period was positively correlated, while the Ottoman period was negatively correlated with Canon 1. Dimension 1, Dimension 2, Dimension 3 and Dimension 6 are negatively correlated, while Dimension 4 and Dimension 5 are positively correlated with Cannon 1 (see Table 7-15 for component loadings). Dimension 1 and Dimension 5 have the largest standard coefficients and therefore contribute most to the formation of Canon 1.

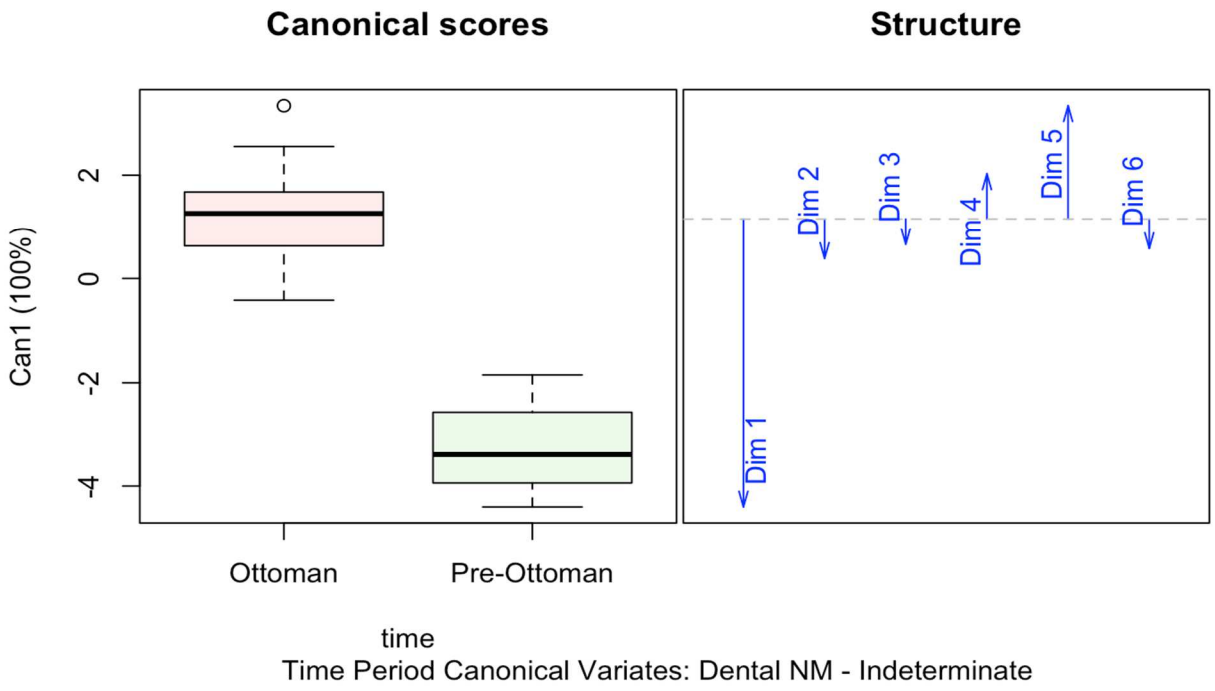

Figure 7 - 20: Canonical variate 1 by time period for the dental non-metric - indeterminate sample (n=29).

The component loadings and eigenvalues for the first six MCA dimensions are presented in Table 7-15. Using factor analysis, the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table 7-15. One-way analysis of variance of the first six MCA dimensions identified Dimension 2 through Dimension 6 as not separating individuals by time period therefore the individual factor plots for Dimension 3 through 6 are presented in Appendix C (Figure C-31).

Dimension 1 accounted for 28.63% of the sample variance and separated individuals by time period (R^2=0.667, *p*-value=0.00) (Figure 7-21): the pre-Ottoman period was positively correlated, while the Ottoman period was negatively correlated with Dimension 1. The component loadings illustrated that Dimension 1 was characterized by the positive correlation of the presence of the UM3 metaconule (cusp 5), UM2 Carabelli's cusp, UM3 hypocone (cusp 4), LP4 multiple lingual cusps, and the UI1 radical number (one radical); while the absence of these

traits and UI1 radical number (2+ radicals) were negatively correlated with Dimension 1. Indeterminate individuals from the pre-Ottoman period had higher frequencies of the UM3 metaconule-presence, UM2 Carabelli's cusp-presence, UM3 hypocone-presence, LP4 multiple lingual cusp-presence, and UI1 radical number-one radical: making them positively correlated on Dimension 1. Indeterminate individuals from the Ottoman period had higher frequencies of UM3 metaconule-absence, UM2 Carabelli's cusp-absence, UM3 hypocone-absence, LP4 multiple lingual cusp-absence, and UI1 radical number-2+ radicals; making them negatively correlated on Dimension 1.

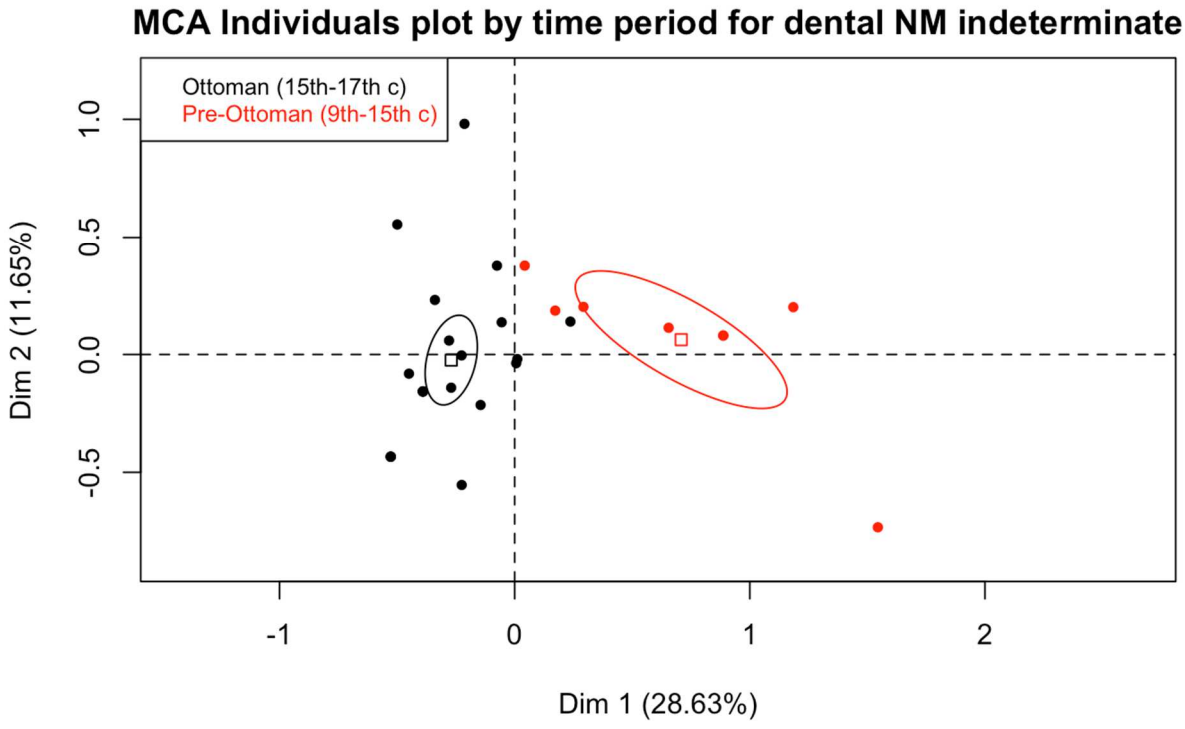

Figure 7 - 21: Dim 1 and Dim 2 individuals factor plots (MCA) for the dental non-metric – indeterminate sample (n=29), colored by time period.

Table 7 - 15: MCA component loadings and eigenvalues for the dental non-metric - indeterminate sample (n=29).

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6
UI1 Double Shoveling - A	-0.373	-0.049	-0.414	-0.789	0.416	-1.191
UI1 Double Shoveling - P	3.320	0.304	2.954	5.707	-3.428	8.863
LC Double Root - A	0.304	-1.312	-1.564	-0.051	-0.330	-0.355
LC Double Root - P	-1.673	5.844	6.746	1.593	7.142	8.913
UI1 Radical Number - 2+ Radicals	-2.488	0.430	0.172	0.862	-0.565	0.011
UI1 Radical Number - One Radical	2.918	-0.683	-0.263	-1.347	0.715	-0.013
UP4 Mesial Accessory Ridges - A	0.096	-0.798	0.805	-1.424	0.315	1.097
UP4 Mesial Accessory Ridges - P	-1.095	10.582	-10.909	2.725	-0.817	-2.739
LP4 Multiple Lingual Cusps - A	-1.681	-0.899	-0.731	1.107	0.394	0.430
LP4 Multiple Lingual Cusps - P	5.187	3.160	2.324	-3.314	-1.368	-1.524
UM2 Carabelli's - A	-0.858	0.056	0.530	0.056	-0.379	0.085
UM2 Carabelli's - P	6.266	-0.282	-3.104	-0.335	2.557	-0.518
UM2 Metacone Cusp 3 - A	-3.395	3.453	-0.067	1.531	-6.413	-0.334
UM2 Metacone Cusp 3 - P	0.160	-0.131	0.002	-0.410	1.188	0.072
UM3 Mesial Paracone Tubercle - A	-0.601	-0.261	1.353	-0.764	-0.633	-0.881
UM3 Mesial Paracone Tubercle - P	2.483	1.459	-7.295	4.204	2.822	3.802
UM2 Parastyle - A	-0.396	0.659	-0.684	-0.680	-0.274	0.556
UM2 Parastyle - P	9.792	-18.866	20.023	2.810	1.535	-2.997
LM3 Congenital Absence – Cong. Abs.	9.345	-7.113	9.226	8.725	2.520	-5.022
LM3 Congenital Absence - Tooth Present	-0.630	0.546	-0.640	-0.570	-0.191	0.389
UM3 Hypocone Cusp 4 - A	-0.721	0.102	0.511	-0.212	-0.414	0.001
UM3 Hypocone Cusp 4 - P	6.419	-0.629	-3.644	1.532	3.413	-0.004
UM3 Metaconule Cusp 5 - A	-4.005	-0.698	-0.544	0.148	0.580	-0.156
UM3 Metaconule Cusp 5 - P	4.285	0.605	0.456	-0.902	-2.443	0.764
UM2 Root Number - 1-2 Roots	-3.891	-2.673	-1.254	2.189	1.595	1.421
UM2 Root Number - 3+ Roots	1.276	1.186	0.536	-0.956	-0.564	-0.487
UM2 Cusp Number - 3 Cusps	-2.892	10.579	5.610	3.993	11.942	-7.870
UM2 Cusp Number - 4+ Cusps	0.392	-1.662	-0.901	-0.091	-0.366	0.233
LM2 Groove Pattern - Non-Y	0.368	0.483	0.164	0.298	-0.295	-0.310
LM2 Groove Pattern - Y	-6.016	-8.987	-2.760	-4.720	5.415	5.825
Eigenvalue	0.29	0.12	0.11	0.10	0.09	0.07
% Variance	28.63	11.65	11.30	9.54	9.23	6.79
Cumulative %	28.63	40.28	51.58	61.12	70.35	77.14

Cranial non-metric – indeterminate sample (n=102)

The first seven MCA dimensions of the cranial non-metric – indeterminate sample (n=102) had significant eigenvalues and represent 60.06% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – indeterminate sample none of the MANOVA by time period results were significant (Table 7-2). Therefore, the cranial non-metric – indeterminate sample does not differ by time period and the null hypothesis cannot be disproven. Since the results of the MANOVA tests were insignificant, the follow-up DDA, component

loadings, and one-way analysis of variance of the PCA dimensions for the cranial non-metric – indeterminate sample are not provided here and instead can be found in Appendix C (Table C-7, Figure C-35 through Figure C-37).

Summary of results

The results for the multivariate analysis of the cranial and dental metric and non-metric data are summarized in Table 7-16. Considering only the total, male and female samples, the cranial metric and dental non-metric datasets were the most successful at separating individuals by time period. The cranial metric dataset identified separation of individuals by time period for all three samples. The dental non-metric dataset identified significant separation of individuals by time period for the total and female samples. The dental metric dataset only identified significant separation of individuals by time period for the female sample. The cranial non-metric dataset only identified significant separation of individuals by time period for the total sample.

For the total sample comparisons, the cranial metric, cranial non-metric and dental non-metric datasets identified significant separation of individuals by time period (Table 7-16). Furthermore, for most of these datasets significant separation occurred within the first three PCA/MCA dimensions. Only the dental non-metric – total sample failed to separate individuals by time period. Significant phenotypic change between the pre-Ottoman and Ottoman periods was identified and reflects a change in population.

For the male sample comparisons, results are overall inconclusive. Only the cranial metric dataset identified significant separation of individuals by time period (Table 7-16). The remaining datasets, dental metric, dental non-metric and cranial non-metric, failed to separate

males by time period. Therefore, overall the null hypothesis of no change in the male population over time cannot be disproven.

For the female sample comparisons, the dental metric, cranial metric, and dental non-metric datasets identified significant separation of individuals by time period (Table 7-16). Furthermore, for most of these datasets significant separation occurred within the first three PCA/MCA dimensions. Only the cranial non-metric dataset failed to separate females by time period. Significant phenotypic change between the pre-Ottoman and Ottoman periods was identified among females.

For the indeterminate sample comparisons, results are largely inconclusive. Only the dental non-metric – indeterminate sample identified significant separation of individuals by time period, but the sample size (n=29) was very small for this comparison (Table 7-16). The inconclusive results of the indeterminate samples may be the result of both small sample sizes as well as a high number of infants (0-2 yrs) from the Koprivno-Križ II site included in the cranial non-metric – indeterminate sample (Table B-2). Overall, for the indeterminate sample comparisons, the null hypothesis of no change over time cannot be disproven.

Table 7 - 16: Summary of results by time period.

	n	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8	MANOVA	DDA	MMD
Total Sample												
Dental metric	139	*p>0.05*	*p>0.05*	*p>0.05*	*p>0.05*	NA	NA	NA	NA	*p>0.05*	*p>0.05*	NA
Cranial metric	132	*p>0.05*	*p=0.00*	*p*=0.01	*p>0.05*	*p*=0.00	*p>0.05*	NA	NA	*p=0.00*	*p=0.00*	NA
Dental non-metric	140	*p*=0.00	*p*=0.02	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*=0.00	*p*=0.00	*p*<0.05
Cranial non-metric	245	*p*>0.05	*p*>0.05	*p*=0.01	*p*>0.05	*p*=0.01	*p*>0.05	*p*>0.05	*p*>0.05	*p*=0.00	*p*=0.00	*p*<0.05
Cranial non-metric adult only	140	*p*>0.05	*p*>0.05	*p*>0.05	*p*=0.01	*p*=0.00	*p*>0.05	*p*>0.05	*p*>0.05	*p*=0.00	*p*=0.00	NA
Male Sample												
Dental metric	53	*p>0.05*	*p>0.05*	*p>0.05*	*p>0.05*	NA	NA	NA	NA	*p>0.05*	*p>0.05*	NA
Cranial metric	62	*p>0.05*	*p*=0.00	*p>0.05*	*p>0.05*	*p>0.05*	*p*=0.00	NA	NA	*p=0.00*	*p=0.00*	NA
Dental non-metric	53	*p*>0.05	*p*=0.03	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	NA	*p*>0.05	*p*>0.05	NA
Cranial non-metric	68	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	NA
Female Sample												
Dental metric	58	*p>0.05*	*p>0.05*	*p*=0.00	*p*=0.03	*p>0.05*	NA	NA	NA	*p*=0.00	*p=0.00*	NA
Cranial metric	70	*p*=0.04	*p>0.05*	*p>0.05*	*p>0.05*	*p>0.05*	*p>0.05*	NA	NA	*p=0.02*	*p=0.02*	NA
Dental non-metric	58	*p*=0.02	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*=0.00	NA	*p*=0.00	*p*=0.00	NA
Cranial non-metric	75	*p*>0.05	*p*=0.03	*p*=0.04	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	NA
Indeterminate Sample												
Dental metric	28	*p>0.05*	*p>0.05*	*p>0.05*	*p>0.05*	*p>0.05*	*p>0.05*	NA	NA	*p>0.05*	NA	NA
Dental non-metric	29	*p*=0.00	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	NA	NA	*p*=0.00	*p*=0.00	NA
Cranial non-metric	102	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	*p*>0.05	NA

*Dimension *p*-values are from the one-way analysis of variance test for time period. MANOVA *p*-values are those of the Pillai test. NA cells did not have the test performed. Significant values are highlighted in gray.

Hypothesis 1

The first hypothesis examined in the study was based on historical accounts stating that the Ottoman activities of the 15th century resulted in substantial decline of the original Croat population; which was accompanied by an influx of Vlach and Serbian populations from somewhere in the interior of the Balkan Peninsula. Hypothesis 1 therefore predicted that cranial and dental metric and non-metric phenotypic trait variation would reflect this change in population and sociopolitical environment. Significant differences were expected between the pre-Ottoman period population (represented by the Šibenik-Sv. Lovre and Koprivno-Križ I sites) and the Ottoman period population (represented by the Koprivno-Križ II and Drinovci-Greblje sites).

The total sample comparisons provide the bulk of the analyses used to test Hypothesis 1. The results of the total sample multivariate analyses found significant differences between individuals based on their site name and time period group membership (Table 7-16). However, the dental metric data did not identify significant differences based on time period group membership (see Table 7-16). In addition, the results of the MMD analyses identified significant differences between individuals based time period group membership for both dental as well as cranial non-metric data (see Table 7-16).

Furthermore, with the exception of the male dental metric sample, the metric analyses of the male and female samples found significant differences between individuals based on time period group membership (Table 7-16). For the non-metric data, only the dental non-metric – female sample identified significant differences based on time period group membership. For the cranial non-metric data, neither the male nor the female samples successfully separated

individuals by time period. MMD analyses could not be performed on the male and female non-metric datasets due to small sample sizes.

The majority of statistical tests support Hypothesis 1 (Table 7-16): there is an identified difference between the pre-Ottoman and Ottoman period samples based on phenotypic trait expression.

Hypothesis 2

Males are historically represented as the primary actors engaging in warfare activities, particularly during the medieval period in Europe (Dursteler, 2011; Knüsel and Smith, 2014b). Migration is typically presented as initially led by males; only later does a mature migrant stream move toward sex parity (Anthony, 1990). Thus Croat males are hypothesized to have left their communities to find and establish new homes in safer regions or have left their communities in defense of Croat territories as soldiers. In addition, the Ottoman practice of *devşirme* forcibly removed young men and boys to be recruited into the Ottoman army. Furthermore, vacated areas were likely repopulated first by Ottoman male soldiers and administrators prior to the enforcement of *sürgün* policies, forcibly moving entire populations from the interior into the region. Therefore, Hypothesis 2 predicted that males would exhibit greater differentiation between time periods than females.

Hypothesis 2 was tested by dividing the data set into two separate samples, a female sample and a male sample, that were then tested using the same multivariate strategies used on the total sample comparisons. The cranial metric analysis found similar trends for males and females, with both showing significant differences by time period. However, the dental metric and dental non-metric analyses only identified significant differences between females by time

period (Table 7-16). Cranial non-metrics were unsuccessful at separating individuals by time period for both males and females (Table 7-27). MMD analysis could not be performed, because of small sample-sizes once the datasets were split by sex.

Hypothesis 2 was not fully supported and therefore can be rejected; males do not appear to show greater differences between time periods (or sites) than females. Based on the phenotypic expression of cranial and dental metric and non-metric traits, both females and males were identified as exhibiting some differences between time periods. However, females presented more consistent differences over time than males.

CHAPTER VIII

DISCUSSION AND CONCLUSIONS

In the context of the Ottoman expansion and colonization of Croatian territories at the end of the Late Medieval period (15th – 17th centuries), historical narratives identify a large exodus of Croats. Croatian migrants fled to places of relative safety, heading first to urban centers and then moving on to the Adriatic Islands, Istria in NW Croatia, Slovenia, Austria, Hungary, or Italy (Bracewell, 1996; Goldstein, 1999b; Tanner, 2001). In addition, Ottoman-raiding parties regularly carried off thousands of people to serve the Ottoman Empire as slaves (Bracewell, 1996; Fine, 1994). Ultimately, massive depopulation occurred by the end of the 16th century.

A report by the Captain of Zadar, from the 16th century, offers a small window into the lives of the Croatian refugees who had fled to Apulia, Abruzzi and the Marches, in Italy (*Commissiones*, II, 172; as cited by Bracewell, 1996:313):

> Not knowing how to accommodate themselves to the language and customs, and not being able to bear the climate, which is very different from that here (nor can their animals, taken from one region to another, live more than two years), these poor people come back, and prefer to place themselves at the mercy of the Turks, and return to their homeland, than to remain in those places which they find disagreeable and insupportable.

Population decline during the 16th century was at least partly ameliorated by the return of some of those who had fled abroad. Venice further encouraged return migration to the central Dalmatian region by improving conditions through the repair of border fortresses and other infrastructure. Venetian authorities also carried off "potential settlers (as valuable commodities) by force from their new homes in Italy" (Bracewell, 1996:313). Despite these efforts, the impact

of return migration was small. Return migrants represented roughly 10% of the population in the Zadar region in 1670; the remainder was made up of recent immigrants from the interior hinterlands (Bracewell, 1996:312, citing Stanojević, 1970: 268-269). Ottoman efforts to repopulate abandoned regions were more successful. Once the Ottomans established control of territories in the 16th century, they began re-colonizing through a combination of incentives such as the promise of land and privileges (Bracewell, 1996), and sürgün policies of forcible migration of pastoralists from the interior. These migrants were mostly Orthodox Vlachs and Serbs (Goffman, 2002; Fine, 1994; Goldstein, 1999b; Bracewell, 1996).

Several factors acted as barriers to the movement of people. Geographic barriers, such as the Dinaric mountains which run parallel to the Dalmatian coastline meant Croatian, Venetian and Ottoman forces could harbor critical fortresses to bar the movement of people, live-stock and armies across mountain passes. Furthermore the cost of migration would have prevented the movement of poorer individuals. Such individuals fled to nearby cities and forts for protection from attacks, but these movements were either temporary or over short distances. Late Medieval Croatia was a feudal society. Consequently, in addition to the cost of moving, the rural poor may have been forced to remain to work the fields of the landed-gentry. Skilled laborers and wealthier individuals and families had more freedom both to move permanently and to move further distances.

In Late Medieval and Early Modern Croatia, state-level warfare was a major disruptive force stimulating the movement of people out of the region, as well as into the region. However, a simple total removal of one population and replacement with a new and different population is unlikely to have occurred. The combined effect of return migration and barriers preventing the movement of people may have resulted in greater continuity in the population than historic

records would suggest. The aim of this project was to examine the effect of migration on population change in the context of external state-level warfare. Specifically, the project tested if the disruptions caused by Ottoman expansion either resulted in a measurable change to the population or if continuity of population could be identified, contrary to historic narratives.

Human remains offer direct evidence of population change, through the investigation of phenotypic traits, isotopic analyses, and aDNA analysis. Isotopic and aDNA analyses are destructive and costly. The nondestructive and low-cost nature of biodistance analysis made it an appropriate initial avenue for testing the hypotheses presented in this study. These factors allowed a large sample to be analyzed and the results suggest further investigation using isotopic and aDNA analysis would be justified.

Cranial and dental metric and non-metric data were collected from four localities within the central Dalmatian region of Croatia. Sites were selected based on sample size and locality within a single region in order to control for some environmental differences. The Šibenik-Sv. Lovre and Koprivno-Križ Phase I sites represented a pre-Ottoman sample; the Koprivno-Križ Phase II and Drinovci-Greblje sites represented an Ottoman period sample.

Two hypotheses were proposed: 1) Ottoman activities during the 15th and 16th centuries led to a near total replacement of the Croat population with an Orthodox Vlach or Serb population, resulting in two populations that could be distinguished using multivariate statistical methods, 2) Ottoman activities led to different patterns of change for males and females such that males were predicted to show more differences than females due to the assumption that migration and warfare are male-led behaviors (Anthony, 1990; Dursteler, 2011). The null hypothesis predicted significant continuity across time, with no measurable differences between the pre-Ottoman and Ottoman periods.

Since previous population estimates, as well as heritability estimates for the medieval Croatian populations were unknown, model-free exploratory statistical analyses were performed. PCA with follow-up MANOVA and DDA analyses were performed using the metric datasets. MCA with follow-up MANOVA and DDA analyses, along with MMD and MDS analyses were performed using the non-metric datasets. Cranial metric, dental metric, cranial non-metric, and dental non-metric datasets were each analyzed separately. The total sample was used to address Hypothesis 1 while Hypothesis 2 required splitting the total sample by biological sex into two separate datasets, a male dataset and a female dataset.

The metric test results are summarized and presented in Table 7-9, while the non-metric test results are summarized in Table 7-27. Table 8-1 presents the overall summary of the success of each dataset in identifying a separation between individuals based on time period group membership. Table 8-2 presents the overall summary of the success of each dataset in identifying a separation between individuals based on site name group membership.

Table 8 - 1: Success of datasets in identifying differences between the pre-Ottoman and Ottoman periods.

	Cranial metric	Cranial non-metric	Dental metric	Dental non-metric
Total sample	Yes	Yes	No	Yes
Male sample	Yes	No	No	No
Female sample	Yes	No	Yes	Yes
Indeterminate sample	NA	No	No	Yes

* Based on summary of results in Table 7-16.

Table 8 - 2: Success of datasets in identifying differences between the sites.

	Cranial metric	Cranial non-metric	Dental metric	Dental non-metric
Total sample	Yes	Yes	No	Yes
Male sample	Yes	No	No	Yes
Female sample	Yes	No	Yes	Yes
Indeterminate sample	NA	No	No	Yes

* Based on summary of results in Table D-7.

The total sample statistical comparisons revealed differences between time periods (and sites) for the cranial metric, dental non-metric and cranial non-metric datasets; but no changes were identified using the dental metric data (Figure 8-1 and Figure 8-2). The female sample statistical comparisons revealed differences between sites and time periods for the cranial metric, dental metric, and dental non-metric datasets; but no changes were identified using the cranial non-metric dataset (Figure 8-1 and Figure 8-2). The male results were more variable. The male sample revealed differences between time periods using the cranial metric dataset only, while the male sample also revealed differences between sites with the dental non-metric dataset (but not between time periods) (Figure 8-1 and Figure 8-2).

Cranial metric data are more greatly influenced by environmental factors than dental metric data, due to the extended period of growth and development of cranial features compared to the reduced developmental period of dental traits (Konigsberg, 2006). If dental metric traits are therefore considered more genetically controlled, then the lack of dental metric changes among the total sample and male sample data by site name and time period (Table 8-1 and Table 8-2) could be interpreted as a reflection of true biological interactions. Under this interpretation, continuity between the total and male samples should be revealed. In addition, the significant differences identified by the cranial metrics should therefore reflect more environmental or developmental differences than genetic differences. Paleopathological studies of health and nutrition using cribra orbitalia, dental enamel hypoplasia, and periostitis have found an improvement in population health during the Early Modern period (15-18th centuries) when compared to the Late Medieval period (11-14th centuries) (Šlaus, 2002; Šlaus, et al. 2018), but a decline in population health compared to the Early Medieval period (Šlaus, 2002). Compared to continental Early Modern sites, the Koprivno Križ II data also revealed an overall improvement

in health status (Novak, et al. 2007). The apparent changes in population health may therefore explain differences between the cranial metric and dental metric results.

However, the dental non-metrics did identify significant differences between pre-Ottoman and Ottoman periods, as well as between sites for the total sample. Since agreement between dental metric and dental non-metric data is lacking, the assumption that the environment affects dental metric data less than cranial metric data does not appear to hold. More likely, the dental metric results were insignificant due to a combination of three factors. 1) Even though error rates were considered within acceptable ranges compared to the Hillson and colleagues (2005) study, the error rates from this study are slightly higher than those produced by others (Thompson, 2013; Zejdlik Passalacqua, 2015). Therefore observer inexperience may have led to a higher amount of error resulting in the homogenization of the samples. 2) In order in ensure that any differences identified were the result of biological variation rather than statistical manipulation, the multiple imputation (MUIP) process of estimating missing values was based on the total combined-site dataset rather than separating the sites prior to MUIP. Therefore, the dataset was biased toward homogenization and any differences in the variations between sites or time periods would need to be greater than the effect of the homogenization that occurred due to MUIP. 3) Even though measurements were systematically removed if they exceeded a specific wear stage (determined by the tooth class), dental wear could still act to homogenize the dental crown measures. Šlaus and colleagues (2018) did identify a reduction in dental wear from the Late Medieval to the Early Modern periods in continental Croatia, which they interpreted as reflecting a higher dependence upon protein in the diet during the Early Modern period. A dental attrition study incorporating the sites utilized in this study, or any sites from the Dalmatian region, has not been completed. In an effort to control for dental wear issues, this study included

CEJ measures, but the final dental metric dataset included both crown and CEJ measurements. A separation of the crown and CEJ measures might have yielded different results. Therefore, the limited differences in the dental metric data are more likely the result of error than a true reflection of population affinity.

Overall the total sample and female sample results support Hypothesis 1, significant changes to the population composition did occur, resulting in distinct phenotypic expressions between time periods. Phenotypically the medieval Croat population is significantly different from the Early Modern Ottoman population of Vlachs and Serbs. This does not mean that Croats did not contribute to the gene pool of the Ottoman period population; rather is suggests that their presence was too low to have a measureable effect. This result was somewhat surprising considering the movement of Slavic populations into the Balkans at the time of the Great Migration Period (Goldstein, 1999b). Vlachs, Serbs, and Croats are all Slavic groups that migrated together into the region sometime around the 7th century (Šlaus, et al. 2004). Most archaeological investigations in Croatia have focused on this migration, and have argued that Croats were a distinct group (Curta, 2006, 2010a, 2010b, 2010c; Curta and Kovalev, 2008; Dzino, 2009, 2014; Fine, 2006), linguistically and culturally. In addition, bioarchaeological investigations of the early Croat migrations in the 7th century identified measureable phenotypic differences between Croats, Avar, Bijelo Brdo and Polish groups, and Croats were identified as being most similar to Polish sites (Šlaus, et al. 2004). It would appear that nearly a millennium later Croats remained a biologically distinct group from their Slavic neighbors, as the results of the current study identified significant differences between Medieval Croat and Early Modern 'Vlach' sites.

Hypothesis 2, which predicted greater differences for males than for females over time, was not well supported by the data. The majority of the female datasets showed changes over time and by site, but the male data was more inconsistent with only cranial metric data significantly separating males by time period. Potential explanations for this pattern include, patrilineal descent with patrilocal residency, greater pre-Ottoman male contribution to the Ottoman period population through gene flow, as well as methodological sources of error.

Historic Medieval European data suggests that most medieval migrations occured over short distances, for example rural to urban movements, post-marital residency and transhumance (Kowaleski, 2013). Furthermore, medival males tended to travel further than females during their lifetimes (Kowaleski, 2013). However, greater numbers of females moved shorter distances for example from rural to urban environments, or from their natal family residency to that of their husband's family (Kowaleski, 2013; Arnold 2005). Anthropological genetics have been used to track micromovements of people, such as post-marital residency, transhumance and rural to urban movements, through the examination of mtDNA and Y-Chromosomal (NRY) DNA (Bolnick 2011; Csősz et al. 2016; Fix 2011; Seielstad et al. 1998). In contexts of patrilocal residency movements, results of genetic studies have been consistent with ethnographic, historical and archaeological sources in finding cumulative female mobility to be greater than that of males (Arnold 2005; Bolnick 2011; Kowaleski 2013; Seielstad et al. 1998). Therefore, the results could be interpreted as a reflection of partilineal descent and patrilocal residence, with women leaving their natal groups to join their husband's family at marriage (Arnold 2005:17), resulting in greater differentiation among females than among males over time. Both the Croat (pre-Ottoman) and Vlach (Ottoman) populations were known patrilocal societies; therefore this explanation may well be supported by the sex-based differences identified by this study.

Short-distance migrations, however, are difficult to identify using traditional archaeological and bioarchaeological evidence, due to the similar biology and culture of migrants and hosts at short distances from one another (Tsuda, et al. 2015). Furthermore, concluding that the results of this study reflect post-marital residency rather than population replacement must be made with extreme caution, because cranial and dental phenotypic traits are polygenetic traits and are assumed to be passed on through autosomal inheritance. Autosomal alleles during meiosis are assigned at random to the sexes in the next generation (zygote), therefore the effects of differential migration by sex can only be identified in the current post-migration generation (Cadien, et al. 1974; Kennedy, 1981), and the accretionary nature of cemetery samples prevents knowing which individuals belong to each generation. Future research using aDNA to track the accumulation of genetic variability in one subset of a population would be necessary to test the hypothesis that post-matrial residency is causing the differences observed phenotypically between the Dalmatian females and males.

The lack of identifiable phenotypic change among the male data could also be interpreted as a reflection of gene flow in the male sample, with more Croat males contributing to the later Vlach/Ottoman populations. But if Croat males were significantly contributing to the Ottoman period gene pool, we would expect to see this reflected in the female sample too, because of the polygenetic nature of phenotypic traits that are not necessarily sex-linked. In addition, data-preparation procedures removed traits that correlated with sex and should have reduced the effect of any sex-linked inheritance patterns further.

As outlined above for the total sample dental metric data several sources of error and small sample sizes, could just as easily explain the lack of identified changes in the male sample. The lack of identified changes in male dental data (both metric and non-metric) could be

attributed to: 1) a result of measurement error on the part of observer; 2) homogenization due to MUIP processes, and/or 3) dental wear acting to homogenize the data. Explanations for the lack of significant differences among males using the cranial non-metric data are less clear. The lack of identifiable differences within the male and female samples using cranial non-metric data is likely not caused by similar environmental influences. Šlaus (2002:93-94) documented better overall population health during the Early Medieval period compared to both the Late Medieval and the Early Modern periods. Since the larger of the two pre-Ottoman sites, Šibenik-Sv. Lovre, dates to the Early Modern period, the lack of identifiable differences in cranial non-metric traits is not due to similarities in health status. Furthermore, environmental differences would be more likely to influence cranial metric than cranial non-metric trait expression (Cheverud and Buikstra, 1982; Cheverud, et al. 1979), which is not the case for the Dalmatian samples. This leaves three possibilities: 1) either the cranial non-metric data is identifying continuity between the pre-Ottoman and Ottoman period samples, 2) observer error had a greater than expected effect on the dataset, or 3) data preparation procedures contributed to the homogenization of the data. MUIP of the non-metric data was performed using the entire dataset rather than separating the site data prior to MUIP. Traits with less than 5% or greater than 95% trait presence were also removed. This could have resulted in the removal of potentially helpful traits for identifying group separation by time period. Furthermore, dichotomization of traits would have additionally reduced trait variances and resulted in further homogenization.

Sample sizes for cranial and dental non-metric traits were too low to adequately perform MMD analyses using the male-only and female-only datasets. The estimation of subadult sex using odontometric logistic regression may help to further clarify what is really going on with the male data, as well as allow for the possible calculation of MMD for both the male and female

datasets. Furthermore, inclusion of subadults in the male and female samples would increase the average tooth size and therefore change the z score means of the samples and would have the potential to identify population differences over time using the dental metric data. Future research is planned to incorporate subadults into the male and female datasets.

Other forms of mobility, such as transhumance, would not have completely ceased during this turbulent period of Croatia history. However, there is little to suggest that transhumance would have had a significant effect on the results of this study as it can be assumed to have been equally active on both samples, pre-Ottoman and Ottoman. There is however a historically documented increase in pastoralism associated with the arrival of Vlach populations to the Dalmatian region (Bracewell 1996). Which would have further contributed to the overall differentiation of the pre-Ottoman from the Ottoman period populations.

The total sample data conforms to historical narratives of a change in population resulting from a combination of warfare-induced out-migration of the Croat population, followed by repopulation primarily by Orthodox Vlach pastoralists. However, migration studies and warfare studies would lead one to predict greater differences between males than between females across the time period defined by this study (Anthony, 1990; Knüsel and Smith, 2014b). This is not supported by the research data. In fact, females more consistently showed differences across time periods then males.

What do these results mean for migration and state-level warfare studies? It may indicate that the disruptive force of interstate warfare (or warfare in general) is so severe that the normal pace of migration from the initial exploration and establishment of routes by young males to the latter and larger flows of entire families or groups is altered by the need to respond to an

immediate crisis. Thus, rather than a slow progression an immediate push to seek safety drives entire communities to migrate in order to survive.

In addition, the institutionalized concepts of male-honor related to bravery in battle may have motivated more males to remain behind to either fight against the Turks, and/or to accept the risks of death or enslavement by the Turks for the advantage of potential landownership or reduced tenant farming rates (Bracewell, 1996; Dursteler, 2011; Goldstein, 1999b). Both would have been strong incentives to remain behind. If more males remained behind while more females fled the region, or to urban locations, then more Croat males would have contributed to gene flow than Croat females. Furthermore, Medieval historical demographic studies have found more women migrated from rural to urban contexts then men. Since the samples included in this study were all rural cemetery sites, a greater rural to urban migration of women could potentially be identified in the site demographics. A simple examination of the site demographics (Table 5-1) however reflects a balanced sex ratio at each site. In addition, both of these scenarios would only affect the expression of sex-linked phenotypes. Regardless, based on the overall results of this study, it would appear that in the context of the rise of state-level warfare, migration is not a male-led behavior followed by a later mature migrant stream with sex parity (Anthony, 1990). Rather this research suggests that in the context of state-level warfare, all portions of society may respond by moving away from the conflict area. In addition, in the context of forced emigration (sürgün) policies, entire populations can be moved into newly acquired territories in order to stabilize regions and promote economic recovery.

Limitations and areas of future research

One limitation of the study is that it examines a single locality. While this provides a unique context, where a single place is both sending and receiving migrants, it does not allow for an analysis of how migrants moved or how well Croats assimilated into their new homes. Historical accounts, such as that of the Captain of Zadar cited at the beginning of this chapter, offer rare glances into the experiences of Croat refugees: by documenting struggles with language barriers, climate changes, and the difficulty of re-establishing a livelihood among a foreign host society. Historic sources can provide some answers, but are anecdotal in nature and do not provide evidence of the biological consequences of these population movements and interactions. The investigation of refugee colonies and any associated cemeteries could enhance our understanding of both warfare and migration in the context of rising nation-states. Goldstein (1999b: 31) identified large Croatian settlements "founded in Burgenland in eastern Austria, the west and south of Hungary and Slovakia," and Bracewell (1996:312) identified Apulia, the Marches, Istria, the Zadar archipelago, Ancona and other towns of the western Adriatic as developing "large colonies." All of these places could potentially have Croatian settlements and cemeteries that could be identified and/or excavated and an understanding of the longer-term effects on the influx of Croatian refugees on these host societies could be further investigated.

Small sample sizes, especially once the datasets were split by sex, meant that MMD analyses could be performed on the total samples datasets only. There is a potential for the use of logistic regression analysis to predict the sex of indeterminate subadult individuals using odontometrics of the permanent dentition. This could increase sample sizes for the male and female datasets and may possibly allow for MMD analyses to be performed. An additional option, to increase sample sizes would be the use of dental enamel peptide analysis: amyl-X and

amyl-Y (Stewart et al., 2017). The expansion of the project to include additional sites from a wider geographic range, including sites in Bosnia-Herzegovina, southern and northern Dalmatia, as well as Pannonia and Hungary, could also help to increase sample sizes and strengthen the results of this analysis as well as provide information on how different areas were impacted by population change in relation to the Ottoman conflicts.

Beyond cemetery and bioarchaeological studies not much archaeology has focused on this period of Croatian history. Most settlement studies come from historic or architectural contexts rather than from archaeological investigations. Not much is understood about the daily interactions between the remaining Croats and incoming Vlachs. Did these groups live in the same villages, or in separate ones? Did they bury their dead in separate cemeteries due to different religious beliefs? If so, the sites included in this study may not be sensitive to temporal changes at all and simply reflect coincidence. Perhaps the Koprivno-Križ II and Drinovci-Greblje sites were different from the Šibenik-Sv. Lovre and Koprivno-Križ I sites as a result of segregation of people and cemeteries by religious belief (Zakrzewski, 2015). Few other Early Modern sites have been excavated in the central and southern Dalmatian region of Croatia. Future investigations of Early Modern sites, or sites that span the Late Medieval and Early Moderns periods, in the region could help to clarify whether the documented changes are the result of religious-based cemetery segregation or a reflection of a change in population. One such site is known, Dugopolje, and it is only a few kilometers from the Koprivno site (Gjurašin, 2001, 2002). The Dugopolje site was originally excluded from this study because it spans the Late Medieval and Early Modern periods (14th to 18th centuries) and could not confidently be assigned to either the pre-Ottoman or Ottoman time periods (Gjurašin 2001, 2002). Future research is

planned to investigate how the people of the Dugopolje site relate to those included in the present study.

Disease epidemics are known historically to have occurred throughout the Late Medieval period. The first epidemic of the Bubonic Plaque in Croatia is dated to 1348, and five repeated outbreaks occurred in the Zadar region between 1500 and 1636 (Grmek, 2008; Bracewell, 1996). Other epidemics included spotted typhoid fever, small pox, dysentery, influenza and a malaria outbreak in 1459 (Grmek, 2008). Famines were also a frequent problem in the 16th century, in the Zadar region alone at least six famines occurred between 1500 and 1596 (Bracewell, 1996). In a context with historically documented disease epidemics and famines an effect on growth and development of children would be expected, ultimately affecting the final phenotypic trait expression (Bogin, 2001; Grmek, 2008). Even though phenotypic biodistance analyses have proven to be consistent with genetic biodistance analyses (Howells, 1989; Cavalli-Sforza, et al. 1988, 1996; Hubbard, et al. 2015; Manica, et al. 2007; Perez, et al. 2007), phenotypic traits do reflect epigenetic and environmental stress factors. The present study identified phenotypic change (which combines genetics and epigenetics); aDNA studies would be needed to directly identify genetic changes.

Lastly, even though a change in the population was identified, how much of the population change was the result of migration with significant gene flow, a reduction in population size and genetic drift, or simply a total or near-total replacement of one group by another with limited gene flow, is unknown at this point. To better understand the biological mechanisms at work to change the population will require knowing where migrants went and came from as well as population estimates and estimates of the heritability of traits among southeastern European populations.

Conclusions

Overall, the evidence supports a change in population through time. The primary cause for this population change is argued to be the result of both warfare-related violence and the movement of people, in the form of both voluntary and involuntary migration, to and from the Dalmatian region. “Trickle-down” factors of environmental degradation, disease, and famine also contributed to population change, but are argued to have played a secondary role as disruptive factors. Contrary to expected results, the data analysis consistently identified significant differences across time periods for the female portion of the population. While analyses of the male portion of the population were more inconsistent, with only the cranial metric data identifying differences over time. This suggests, that rather than a gradual male-led migration followed later by a mature migrant stream, that the female portion migrated away and did not return, while males either returned or remained behind at a greater rate.

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APPENDIX A

SUMMARY STATISTICS OF FINAL REDUCED DATASETS BY SITE NAME AND SEX

Table A - 1: Dental metric summary statistics by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKII F	SSL F	DG M	KKI M	KKII M	SSL M	DG Ind	KKI Ind	KKII Ind	SSL Ind
Age Midpoint	n	17	18	63	41	6	7	23	22	9	8	22	14	2	3	18	5
	mean	31.9	30.1	28.8	34.7	36.0	29.4	34.7	37.6	34.2	37.7	37.3	37.9	9.8	11.3	11.0	12.9
	s.d.	14.8	13.5	16.1	13.3	13.8	12.2	13.5	11.2	13.3	9.6	12.3	11.5	4.6	3.1	7.0	1.8
MD Crown UM2	n	11	15	41	33	3	7	17	16	7	6	13	12	1	2	11	5
	mean	9.37	9.18	9.52	9.44	8.99	8.98	9.28	9.30	9.50	9.07	9.85	9.59	9.55	10.20	9.52	9.50
	s.d.	0.46	0.84	0.69	0.64	0.56	0.44	0.57	0.76	0.39	1.10	0.80	0.52	NA	0.46	0.60	0.46
MD Crown LC	n	13	16	52	33	5	7	18	18	6	7	21	12	2	2	13	3
	mean	6.67	6.68	6.65	6.63	6.40	6.58	6.61	6.38	6.88	6.76	6.76	6.96	6.73	6.72	6.54	6.84
	s.d.	0.35	0.39	0.43	0.41	0.27	0.51	0.41	0.33	0.09	0.32	0.45	0.29	0.70	0.19	0.40	0.21
MD Crown LM1	n	12	13	41	30	4	5	12	17	6	5	12	8	2	3	17	5
	mean	10.87	10.67	10.92	10.71	10.57	10.46	10.89	10.40	11.08	10.91	11.04	11.11	10.84	10.64	10.85	11.11
	s.d.	0.61	0.45	0.53	0.64	0.74	0.46	0.52	0.62	0.41	0.42	0.53	0.46	0.97	0.41	0.55	0.36
BL Crown UC	n	11	14	37	26	3	6	14	13	7	6	14	9	1	2	9	4
	mean	8.34	8.20	8.13	8.16	7.74	7.91	8.06	7.76	8.57	8.64	8.35	8.69	8.50	7.74	7.89	8.23
	s.d.	0.52	0.67	0.54	0.67	0.17	0.62	0.50	0.41	0.44	0.48	0.56	0.70	NA	0.77	0.48	0.42
BL Crown UM2	n	11	15	40	32	3	7	17	15	7	6	12	13	1	2	11	4
	mean	11.31	11.07	10.96	11.34	10.82	10.51	10.81	11.14	11.50	11.72	11.22	11.52	11.42	11.06	10.92	11.55
	s.d.	0.77	0.89	0.68	0.79	0.69	0.56	0.68	0.72	0.81	0.87	0.82	0.90	NA	0.76	0.42	0.61
BL Crown LI2	n	12	12	51	24	5	5	18	14	5	4	18	8	2	3	15	2
	mean	6.40	6.11	6.09	6.22	6.39	5.85	6.18	6.00	6.46	6.51	6.09	6.51	6.27	5.99	5.99	6.60
	s.d.	0.37	0.47	0.48	0.41	0.49	0.59	0.45	0.29	0.30	0.13	0.52	0.40	0.31	0.02	0.48	0.23
BL Crown LC	n	13	16	53	32	5	7	19	17	6	7	21	12	2	2	13	3
	mean	7.66	7.58	7.46	7.60	7.45	7.29	7.51	7.20	7.88	7.92	7.53	8.16	7.54	7.39	7.25	7.61
	s.d.	0.36	0.55	0.51	0.59	0.33	0.54	0.44	0.30	0.30	0.39	0.58	0.48	0.41	0.64	0.47	0.26
BL Crown LP3	n	15	17	45	34	5	7	16	20	9	8	20	10	1	2	9	4
	mean	7.76	7.46	7.50	7.46	7.48	7.22	7.60	7.24	7.88	7.75	7.50	7.86	8.07	7.19	7.34	7.49
	s.d.	0.41	0.50	0.48	0.52	0.26	0.33	0.52	0.49	0.43	0.54	0.45	0.40	NA	0.21	0.48	0.23
BL Crown LM2	n	11	16	37	30	4	6	15	14	6	8	13	11	1	2	9	5
	mean	9.80	9.74	9.96	9.85	9.24	9.38	9.77	9.62	10.12	10.12	10.18	10.08	10.13	9.34	9.95	9.95
	s.d.	0.52	0.70	0.54	0.64	0.14	0.35	0.50	0.58	0.36	0.80	0.47	0.72	NA	0.37	0.63	0.44
MD CEJ UC	n	16	16	45	30	6	6	18	15	9	8	17	11	1	2	10	4
	mean	5.84	5.90	5.57	5.71	5.35	5.96	5.39	5.59	6.14	6.04	5.86	5.98	6.06	5.20	5.41	5.45
	s.d.	0.50	0.65	0.50	0.64	0.18	0.85	0.36	0.69	0.40	0.45	0.52	0.57	NA	0.22	0.49	0.44
MD CEJ UM1	n	12	16	52	34	3	7	19	17	7	6	17	12	2	3	16	5
	mean	7.95	7.76	7.69	7.84	7.72	7.64	7.50	7.90	8.10	8.04	7.91	7.83	7.75	7.48	7.67	7.66
	s.d.	0.45	0.43	0.50	0.79	0.32	0.41	0.34	1.06	0.48	0.30	0.53	0.47	0.55	0.50	0.57	0.21
MD CEJ LI2	n	17	15	53	25	6	6	19	15	9	6	19	8	2	3	15	2
	mean	4.08	3.92	3.90	3.98	3.95	3.83	3.74	3.86	4.19	4.27	4.06	4.15	3.91	3.39	3.90	4.22
	s.d.	0.34	0.49	0.54	0.30	0.31	0.27	0.28	0.27	0.35	0.48	0.73	0.26	0.33	0.36	0.49	0.35

Table A – 1 Cont'd: Dental metric summary statistics by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKII F	SSL F	DG M	KKI M	KKII M	SSL M	DG Ind	KKI Ind	KKII Ind	SSL Ind
MD CEJ LC	n	17	17	54	34	6	7	20	19	9	8	21	12	2	2	13	3
	mean	5.29	5.30	5.17	5.30	5.02	5.15	5.04	5.01	5.48	5.59	5.43	5.75	5.20	4.66	4.94	5.28
	s.d.	0.41	0.52	0.51	0.44	0.29	0.47	0.36	0.24	0.27	0.41	0.57	0.33	0.95	0.49	0.45	0.35
MD CEJ LP4	n	16	17	45	36	6	7	18	21	9	8	19	12	1	2	8	3
	mean	5.15	5.06	4.93	5.03	4.95	5.00	4.76	4.98	5.28	5.25	5.13	5.16	5.09	4.51	4.81	4.87
	s.d.	0.33	0.47	0.57	0.38	0.24	0.34	0.31	0.27	0.35	0.50	0.77	0.52	NA	0.44	0.26	0.32
MD CEJ LM1	n	15	15	53	35	5	5	15	19	8	8	20	11	2	2	18	5
	mean	9.16	8.85	8.96	8.82	8.87	8.55	8.79	8.67	9.41	9.18	9.22	9.14	8.89	8.31	8.80	8.67
	s.d.	0.58	0.54	0.61	0.49	0.58	0.22	0.56	0.43	0.39	0.54	0.69	0.52	1.12	0.10	0.46	0.37
BL CEJ UI2	n	13	15	43	25	3	6	19	13	9	7	15	9	1	2	9	3
	mean	5.93	5.90	5.63	5.57	5.49	5.67	5.64	5.42	5.97	6.20	5.80	5.84	6.94	5.54	5.33	5.37
	s.d.	0.40	0.43	0.57	0.49	0.09	0.44	0.54	0.38	0.20	0.18	0.70	0.56	NA	0.43	0.23	0.50
BL CEJ UP3	n	13	15	42	33	4	6	16	19	8	7	18	11	1	2	8	3
	mean	8.35	8.34	7.87	7.97	7.88	8.06	7.76	7.92	8.56	8.68	8.03	8.01	8.59	7.98	7.74	8.14
	s.d.	0.60	0.50	0.86	0.49	0.44	0.42	1.05	0.45	0.58	0.43	0.79	0.61	NA	0.13	0.60	0.18
BL CEJ UM2	n	10	16	40	35	3	7	15	18	6	7	16	13	1	2	9	4
	mean	10.92	10.79	10.38	10.92	10.36	10.50	10.08	10.63	11.17	11.21	10.58	11.29	11.14	10.33	10.54	11.04
	s.d.	0.74	0.71	0.94	0.78	0.24	0.33	0.62	0.61	0.83	0.89	1.25	0.92	NA	0.03	0.64	0.44
BL CEJ LI2	n	15	14	48	24	6	6	16	15	7	5	17	7	2	3	15	2
	mean	6.23	6.00	5.74	6.03	6.12	5.78	5.95	5.82	6.38	6.49	5.61	6.36	6.05	5.62	5.67	6.49
	s.d.	0.38	0.52	0.78	0.49	0.53	0.47	0.57	0.32	0.22	0.26	0.98	0.58	0.23	0.36	0.73	0.37
BL CEJ LM1	n	13	13	49	35	4	4	13	19	7	7	18	11	2	2	18	5
	mean	9.00	9.02	9.00	9.03	8.80	8.70	8.86	8.88	9.17	9.30	9.30	9.30	8.81	8.72	8.78	8.98
	s.d.	0.60	0.44	0.65	0.50	0.42	0.37	0.37	0.36	0.61	0.35	0.79	0.69	1.05	0.03	0.56	0.30

Table A - 2: Cranial metric summary statistics by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKII F	SSL F	DG M	KKI M	KKII M	SSL M
Age Midpoint	n	16	19	49	48	8	9	25	28	8	10	24	20
	mean	38.9	36.3	38.9	42.1	42.1	34.5	37.2	41.7	35.7	38.0	40.6	42.6
	s.d.	14.0	11.5	12.9	12.3	16.1	14.8	14.6	12.4	11.6	7.9	10.9	12.4
Basion-Prosthion Length (ba-pr)	n	15	12	31	34	8	6	16	19	7	6	15	15
	mean	98.70	95.10	94.89	97.75	94.06	92.95	93.66	95.05	104.0	97.25	96.20	101.17
	s.d.	6.31	5.80	4.49	6.92	4.19	7.07	4.64	6.26	3.34	3.61	4.07	6.32
Maximum Alveolar Length (pr-alv)	n	16	18	39	42	8	8	18	24	8	10	21	18
	mean	53.46	51.67	51.58	52.36	51.03	49.76	50.37	50.64	55.89	53.19	52.62	54.64
	s.d.	3.34	3.54	4.03	3.85	2.76	2.15	3.66	2.90	1.67	3.78	4.12	3.82

Table A – 2 Cont'd: Cranial metric summary statistics by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKII F	SSL F	DG M	KKI M	KKII M	SSL M
Biauricular Breadth	n	16	15	38	43	8	8	19	23	8	7	19	20
	mean	126.26	123.23	124.21	120.77	122.88	120.83	122.67	116.80	129.64	125.99	125.74	125.34
	s.d.	5.28	4.18	5.24	5.72	4.84	3.16	3.67	3.67	3.20	3.54	6.17	3.97
Minimum Frontal Breadth (ft-ft)	n	16	18	47	43	8	8	24	24	8	10	23	19
	mean	99.63	97.55	98.47	96.65	97.33	96.24	98.02	96.08	101.94	98.60	98.93	97.37
	s.d.	4.15	3.58	3.96	3.90	2.90	4.09	3.62	4.27	4.05	2.91	4.32	3.34
Upper Facial Breadth (fmt-fmt)	n	16	28	48	43	8	8	25	24	8	10	23	19
	mean	107.88	104.99	105.92	104.74	105.69	102.66	104.51	103.05	110.08	106.85	107.45	106.86
	s.d.	4.18	3.58	3.85	4.32	3.11	2.39	2.63	4.02	4.09	3.32	4.40	3.80
Nasal Height (n-ns)	n	16	15	35	36	8	6	17	20	8	9	18	16
	mean	50.97	50.40	50.54	50.44	49.65	48.35	48.46	48.74	52.29	51.77	52.51	52.56
	s.d.	2.82	3.02	4.64	3.39	1.82	1.83	2.45	2.67	3.11	2.93	5.39	3.01
Orbital Breadth (mf-ec)	n	15	18	39	38	8	8	20	21	7	10	19	17
	mean	41.48	39.72	39.50	39.19	40.56	39.06	39.38	38.37	42.53	40.24	39.63	40.20
	s.d.	2.21	2.61	2.07	2.26	1.64	2.36	1.46	2.17	2.42	2.80	2.61	1.98
Orbit Height	n	15	18	39	37	8	8	20	20	7	10	19	17
	mean	32.89	31.98	32.02	32.07	32.81	31.51	31.68	31.52	32.99	32.35	32.37	32.72
	s.d.	2.12	1.76	1.67	2.29	2.02	0.59	1.55	2.01	2.39	2.28	1.77	2.49
Biorbital Breadth (ec-ec)	n	15	14	32	32	8	6	16	17	7	8	16	15
	mean	98.78	95.66	96.92	97.16	96.50	95.25	96.43	95.88	101.39	95.98	97.41	98.62
	s.d.	3.61	3.30	3.52	3.77	3.03	3.50	2.09	3.97	2.18	3.35	4.55	3.03
Interorbital Breadth (mf-mf)	n	16	19	45	41	8	9	24	23	8	10	21	18
	mean	22.59	23.14	24.53	23.99	21.13	22.51	24.28	23.42	24.06	23.71	24.80	24.72
	s.d.	2.07	3.27	2.80	2.11	1.55	4.10	2.66	1.91	1.36	2.38	2.99	2.18
Parietal Chord (b-l)	n	16	19	26	46	8	9	24	26	8	10	22	20
	mean	108.60	113.31	109.85	114.68	106.79	111.46	108.52	112.95	110.41	114.97	111.29	116.93
	s.d.	6.12	5.30	7.05	6.53	6.98	6.38	7.19	4.66	4.89	3.66	6.76	7.94
Occipital Chord (l-o)	n	16	17	43	46	8	8	23	26	8	9	20	20
	mean	96.39	95.17	94.83	99.56	95.88	94.44	93.73	96.83	96.90	95.82	96.10	103.12
	s.d.	4.90	5.44	4.89	5.80	3.78	6.18	4.51	4.91	6.04	4.98	5.10	4.94
Foramen Magnum Breadth	n	15	17	37	39	8	9	22	21	7	8	15	18
	mean	31.41	30.11	30.26	30.93	30.30	29.42	29.73	30.23	32.69	30.89	31.05	31.75
	s.d.	2.18	2.01	1.90	2.20	1.51	2.17	1.87	2.22	2.22	1.60	1.71	1.91
Mastoid Length	n	16	19	48	48	8	9	25	28	8	10	23	20
	mean	29.36	28.75	28.54	29.36	28.35	27.58	28.18	27.64	30.36	29.80	28.92	31.76
	s.d.	2.13	3.30	3.05	3.23	2.25	3.92	3.07	2.42	1.54	2.36	3.04	2.67
Body Thickness at Mental Foramen	n	16	18	47	48	8	8	24	28	8	10	23	20
	mean	12.04	11.38	11.56	11.74	10.55	10.45	11.60	11.07	13.53	12.12	11.52	12.68
	s.d.	1.99	1.63	1.69	2.02	1.58	1.14	1.82	1.87	0.93	1.62	1.57	1.89

Table A – 2 Cont'd: Cranial metric summary statistics by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKII F	SSL F	DG M	KKI M	KKII M	SSL M
Minimum Ramus Breadth	n	16	19	40	45	8	9	21	27	8	10	19	18
	mean	33.63	32.06	31.61	32.80	31.56	29.81	30.84	31.53	35.70	34.09	32.46	34.69
	s.d.	3.39	3.41	2.71	3.12	2.55	2.85	2.08	2.54	2.88	2.55	3.11	3.00
Maximum Ramus Breadth	n	16	18	36	42	8	8	20	26	8	10	16	16
	mean	43.02	44.24	43.48	44.43	41.61	41.43	42.11	43.46	44.43	46.49	45.19	46.01
	s.d.	3.53	3.93	3.53	4.31	2.20	2.84	2.48	4.84	4.16	3.20	3.96	2.75

Table A - 3: Dental non-metric trait frequencies by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKI I F	SSL F	DG M	KKI M	KKII M	SSL M	DG Ind	KKI Ind	KKII Ind	SSL Ind
Age Midpoint	n	17	18	63	42	6	7	23	22	9	8	21	15	2	3	19	5
	mean	31.9	30.1	28.2	35.5	36	29.4	34.8	38.4	34.2	37.7	37.1	38.8	9.8	11.3	10.5	12.9
	s.d.	14.8	13.4	16.4	13.8	13.8	12.2	13.7	12.0	13.3	9.6	12.6	11.7	4.6	3.1	7.0	1.8
UI1 Double Shoveling	n	14	13	42	15	4	5	13	8	8	5	14	3	2	3	15	4
	P	0	4	6	5	0	2	3	1	0	1	1	0	0	1	2	4
	% P	0	30.8	14.3	33.3	0	40	23.1	25	0	20	7.1	0	0	33.3	13.3	100
LC Double Root	n	15	15	51	37	5	7	22	20	9	7	19	13	1	1	10	4
	P	1	0	5	3	1	0	2	2	0	0	1	1	0	0	2	0
	% P	6.7	0	9.8	8.1	20	0	9.1	10	0	0	5.3	7.7	0	0	20	75
UI1 Radical#	n	15	16	52	18	4	6	21	10	9	7	17	4	2	3	14	4
	2+ Rad.	15	9	33	5	4	2	11	1	9	5	9	2	2	2	13	2
	% 2+ Rad.	100	56.2	62.5	27.8	100	33.3	52.4	20	100	71.4	52.9	50	100	66.7	92.8	50
UP4 Mesial Accessory Ridges	n	7	11	27	20	2	6	11	10	4	3	8	9	1	2	8	1
	P	1	2	7	1	0	0	4	1	0	1	1	0	1	1	2	0
	% P	14.3	18.2	25.9	5	0	0	36.4	10	0	33.3	12.5	0	100	50	25	0
LP4 Multiple Lingual Cusps	n	15	16	41	36	5	7	14	19	9	7	18	14	1	2	9	3
	P	12	10	19	24	4	5	9	14	8	4	6	7	0	1	4	3
	% P	80	62.5	46.3	66.7	80	71.4	64.3	73.7	88.9	57.1	33.3	50	0	50	44.4	100
UM2 Carabelli's Cups	n	12	15	42	33	4	7	17	15	7	6	14	13	1	2	11	5
	P	1	3	3	10	1	0	1	4	0	2	0	2	0	1	2	4
	% P	8.3	20	7.1	30.3	25	0	5.9	26.7	0	33.3	0	15.4	0	50	18.2	80
UM2 Metacone Cusp3	n	12	16	51	36	4	7	18	17	7	7	19	14	1	2	14	5
	P	11	14	45	36	3	7	15	17	7	6	18	14	1	1	12	5
	% P	91.7	87.5	88.2	100	75	100	83.3	100	100	85.7	94.7	100	100	50	85.7	100
UM3 MPT	n	9	9	22	15	4	6	9	5	4	2	7	7	1	1	6	3
	P	1	0	2	7	1	0	1	3	0	0	0	3	0	0	1	1
	% P	11.1	0	9.1	46.7	25	0	11.1	60	0	0	0	42.9	0	0	16.7	33.3

Table A – 3 Cont'd: Dental non-metric trait frequencies by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKI I F	SSL F	DG M	KKI M	KKII M	SSL M	DG Ind	KKI Ind	KKII Ind	SSL Ind
UM2 Parastyle	n	12	15	48	35	4	6	17	16	7	7	18	14	1	2	13	5
	P	0	1	3	1	0	0	1	0	0	1	1	0	0	0	1	1
	% P	0	6.7	6.2	2.9	0	0	5.9	0	0	14.3	5.6	0	0	0	7.7	20
LM3 Congenital Absence	n	12	16	47	35	5	6	18	20	6	8	19	13	1	2	10	2
	Cong Abs	1	1	2	2	1	0	0	0	0	1	2	1	0	0	0	1
	% Cong Abs	8.3	6.2	4.3	5.7	20	0	0	0	0	12.5	10.5	7.7	0	0	0	50
UM3 Hypocone Cusp4	n	13	11	26	26	4	6	11	12	8	4	9	11	1	1	6	3
	P	6	5	8	12	2	3	3	5	4	2	3	4	0	0	2	3
	% P	46.2	45.5	30.8	46.2	50	50	27.3	41.7	50	50	33.3	36.4	0	0	33.3	100
UM3 Metaconule Cusp5	n	13	11	24	24	4	6	11	11	8	4	8	10	1	1	5	3
	P	1	5	11	13	1	1	6	6	0	3	5	4	0	1	0	3
	% P	7.7	45.5	45.8	54.2	25	16.7	54.5	54.5	0	75	62.5	40	0	100	0	100
UM2 Root#	n	6	11	29	17	3	6	11	9	3	4	12	7	0	1	6	1
	3+ Root	3	7	17	15	1	3	8	8	2	3	7	6	0	1	2	1
	% 3+ Root	50	63.6	58.6	88.2	33.3	50	72.7	88.9	66.7	75	58.3	85.7	0	100	33.3	100
UM2 Cusp#	n	12	13	45	34	4	6	17	17	7	5	14	12	1	2	14	5
	4+ Cusp	10	13	41	33	3	6	15	16	7	5	13	12	0	2	13	5
	% 4+ Cusp	83.3	100	91.1	97.1	75	100	88.2	94.1	100	100	92.9	100	0	100	92.9	100
LM2 Groove Pattern	n	9	13	40	30	4	5	14	13	4	6	12	12	1	2	14	5
	Non-Y	6	12	32	23	3	4	12	10	2	6	9	8	1	2	11	5
	% Non-Y	66.7	92.3	80	76.7	75	80	85.7	76.9	50	100	75	66.7	100	100	78.6	100

Table A - 4: Cranial non-metric trait frequencies by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKII F	SSL F	DG M	KKI M	KKII M	SSL M	DG Ind	KKI Ind	KKII Ind	SSL Ind
Age Midpoint	n	22	25	118	80	8	9	27	31	10	9	27	22	4	7	64	27
	mean	32.1	28.2	20.7	29.9	42.0	34.5	38.0	42.3	34.8	39.1	40.7	43.6	5.6	6.0	5.1	4.6
	s.d.	18.3	17.7	20.2	20.8	16.1	14.8	14.7	12.4	12.6	9.3	11.4	11.7	5.5	5.4	8.0	4.5
Metopic Suture	n	21	25	95	67	8	9	26	27	10	9	27	22	3	7	42	18
	P	0	6	11	2	0	2	4	2	0	1	3	0	0	3	4	0
	% P	0	24	11.6	3	0	22.2	15.4	7.4	0	11.1	11.1	0	0.0	42.9	9.5	0.0
Supranasal Suture	n	20	25	101	64	8	9	26	26	8	9	26	21	4	7	49	17
	P	18	11	51	38	8	2	12	13	7	5	12	16	3	4	27	9
	% P	90	44	50.5	59.4	100	22.2	46.2	50	87.5	55.6	46.2	76.2	75.0	57.1	55.1	52.9
Frontal Grooves	n	22	24	106	71	8	9	25	28	10	9	26	21	4	6	55	22
	P	6	1	20	2	2	0	3	2	2	1	7	0	2	0	10	0
	% P	27.3	4.2	18.9	2.8	25	0	12	7.1	20	11.1	26.9	0	50.0	0.0	18.2	0.0

Table A – 4 Cont'd: Cranial non-metric trait frequencies by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKII F	SSL F	DG M	KKI M	KKII M	SSL M	DG Ind	KKI Ind	KKII Ind	SSL Ind
Medial Supraorbital Foramen	n	21	25	114	73	8	9	26	28	9	9	27	21	4	7	61	24
	P	18	15	78	41	7	2	19	17	7	7	18	12	4	6	41	12
	% P	85.7	60	68.4	56.2	87.5	22.2	73.1	60.7	77.8	77.8	66.7	57.1	100.0	85.7	67.2	50.0
Lateral Supraorbital Foramen	n	21	25	114	75	8	9	26	29	9	9	27	21	4	7	61	25
	P	14	8	45	22	6	2	7	5	5	4	13	8	3	2	25	9
	% P	66.7	32	39.5	29.3	75	22.2	26.9	17.2	55.6	44.4	48.1	38.1	75.0	28.6	41.0	36.0
Parietal Foramen	n	21	24	98	66	8	9	27	29	9	9	26	20	4	6	45	17
	P	14	21	73	45	7	9	21	20	5	7	20	14	2	5	32	11
	% P	66.7	87.5	74.5	68.2	87.5	100	77.8	69	55.6	77.8	76.9	70	50.0	83.3	71.1	64.7
Occipito-Mastoid Ossicle	n	19	21	77	58	7	8	25	26	8	9	22	20	4	4	30	12
	P	0	3	11	7	0	0	4	4	0	3	3	2	0	0	4	1
	% P	0	14.3	14.3	6	0	0	16	15.4	0	33.3	13.6	10	0.0	0.0	13.3	8.3
Occipital Foramen	n	20	23	93	72	8	8	26	29	8	8	20	20	4	7	47	23
	P	12	21	74	53	4	1	24	22	6	8	18	14	2	12	32	17
	% P	60	9.3	79.6	73.6	50	12.5	92.3	75.9	75	100	90	70	50.0	171.4	68.1	73.9
Ossicle at Asterion	n	19	20	75	58	7	8	24	27	8	8	23	20	4	4	28	11
	P	3	6	21	9	0	3	10	2	2	2	5	5	1	1	6	2
	% P	15.8	30	28	15.5	0	37.5	41.7	7.4	25	25	21.7	15	25.0	25.0	21.4	18.2
Condylar Canal	n	22	23	96	70	8	8	26	25	10	8	20	19	4	7	50	26
	P	2	1	4	9	2	1	0	3	0	0	2	2	0	0	2	4
	% P	9.1	4.3	4.2	12.9	25	12.5	0	12	0	0	10	10.5	0.0	0.0	4.0	15.4
Pharyngeal Tubercle	n	22	21	91	64	8	9	25	23	10	7	21	20	4	5	45	21
	P	17	18	51	49	6	9	21	21	10	6	16	20	1	3	14	8
	% P	22.7	85.7	56	76.6	75	100	84	91.3	100	85.7	76.2	100	25.0	60.0	31.1	38.1
Basilar-Sphenoid Bridges	n	20	22	91	64	8	8	23	24	8	7	18	18	4	7	50	22
	P	3	2	13	4	2	1	5	2	1	0	3	2	0	1	5	0
	% P	15	9.1	14.3	6.2	25	12.5	21.7	8.3	12.5	0	16.7	11.1	0.0	14.3	10.0	0.0
Flexure of Superior Sagittal Sulcus	n	21	22	88	73	8	9	20	30	9	8	18	21	4	5	50	22
	Non-right	6	9	25	27	1	4	5	7	3	3	5	8	2	2	15	12
	% Non-right	28.6	40.9	28.4	37	12.5	44.4	25	23.3	33.3	37.5	27.8	38.1	50.0	40.0	30.0	54.5
Biasterionic Suture	n	20	21	81	64	8	8	25	30	8	9	23	21	4	4	33	13
	P	6	2	19	9	3	0	5	3	1	2	9	3	2	0	5	3
	% P	30	9.5	23.5	14.1	37.5	0	20	10	12.5	22.8	39.1	14.3	50.0	0.0	15.2	23.1
Mastoid Foramen Extrasutural	n	22	19	91	65	8	8	26	28	10	8	26	21	4	3	39	16
	Extrasutural	8	9	47	26	5	4	13	12	0	3	16	8	3	2	18	6
	% Extrasut.	36.4%	47.4	51.6	40	62.5	50	50	42.9	0	37.5	61.5	38.1	75.0	66.7	46.2	37.5
Parietal Notch Bone	n	21	21	82	60	8	9	25	26	9	8	24	20	4	4	33	14
	P	4	4	17	16	2	1	5	6	2	3	4	7	0	0	8	3
	% P	19	19	20.7	26.7	25	11.1	20	23.1	22.2	37.5	16.7	35	0.0	0.0	24.2	21.4

Table A – 4 Cont'd: Cranial non-metric trait frequencies by site and sex.

		DG Total	KKI Total	KKII Total	SSL Total	DG F	KKI F	KKII F	SSL F	DG M	KKI M	KKII M	SSL M	DG Ind	KKI Ind	KKII Ind	SSL Ind
Accessory Mental Foramen	n	22	25	114	76	8	9	26	30	10	9	26	19	4	7	62	27
	P	11	8	48	34	2	3	11	8	6	3	12	10	3	2	25	16
	% P	50	32	42.1	44.7	25	33.3	42.3	26.7	60	33.3	46.2	52.6	75.0	28.6	40.3	59.3
Mylohyoid Bridge	n	22	24	103	73	8	9	24	30	10	9	23	18	4	6	56	25
	P	3	2	2	7	2	0	1	5	1	2	0	1	0	0	1	1
	% P	13.6	8.3	1.9	9.6	25	0	4.2	16.7	10	22.2	0	5.6	0.0	0.0	1.8	4.0
Retromolar Foramen	n	18	18	79	73	8	8	25	30	10	8	22	19	0	2	32	24
	P	5	8	28	22	1	4	7	11	4	4	11	6	0	0	10	5
	% P	27.8	44.4	35.4	30.1	12.5	50	28	36.7	40	50	50	31.6	0.0	0.0	31.3	20.8

APPENDIX B

FINAL REDUCED DATASETS' DEMOGRAPHIC BREAKDOWNS

Table B - 1: Final site demographics of metric datasets.

Dental Metric Dataset						Cranial Metric Dataset					
	Age	M	F	I	**Sum**		Age	M	F	I	**Sum**
Šibenik-Sv Lovre	Infant (0-2)	0	0	0	**0**	Šibenik-Sv Lovre	Infant (0-2)	0	0	0	**0**
	Child (2-6)	0	0	0	**0**		Child (2-6)	0	0	0	**0**
	Juvenile (6-10)	0	0	0	**0**		Juvenile (6-10)	0	0	0	**0**
	Adolescent (10-18)	0	2	5	**7**		Adolescent (10-18)	0	2	0	**2**
	Young Adult (18-35)	7	6	0	**13**		Young Adult (18-35)	7	5	0	**12**
	Middle Adult (35-50)	4	11	0	**15**		Middle Adult (35-50)	5	12	0	**17**
	Older Adult (50+)	3	3	0	**6**		Older Adult (50+)	8	9	0	**17**
	Sum	**14**	**22**	**5**	**41**		**Sum**	**20**	**28**	**0**	**48**
Koprivno-Križ I	Infant (0-2)	0	0	0	**0**	Koprivno-Križ I	Infant (0-2)	0	0	0	**0**
	Child (2-6)	0	0	0	**0**		Child (2-6)	0	0	0	**0**
	Juvenile (6-10)	0	0	1	**1**		Juvenile (6-10)	0	0	0	**0**
	Adolescent (10-18)	1	1	2	**4**		Adolescent (10-18)	1	1	0	**2**
	Young Adult (18-35)	1	4	0	**5**		Young Adult (18-35)	1	4	0	**5**
	Middle Adult (35-50)	5	1	0	**6**		Middle Adult (35-50)	7	1	0	**8**
	Older Adult (50+)	1	1	0	**2**		Older Adult (50+)	1	3	0	**4**
	Sum	**8**	**7**	**3**	**18**		**Sum**	**10**	**9**	**0**	**19**
Koprivno-Križ II	Infant (0-2)	0	0	0	**0**	Koprivno-Križ II	Infant (0-2)	0	0	0	**0**
	Child (2-6)	0	0	1	**1**		Child (2-6)	0	0	0	**0**
	Juvenile (6-10)	0	0	11	**11**		Juvenile (6-10)	0	0	0	**0**
	Adolescent (10-18)	2	5	5	**12**		Adolescent (10-18)	2	5	0	**7**
	Young Adult (18-35)	5	6	0	**11**		Young Adult (18-35)	2	5	0	**7**
	Middle Adult (35-50)	9	9	1	**19**		Middle Adult (35-50)	10	7	0	**17**
	Older Adult (50+)	6	3	0	**9**		Older Adult (50+)	10	8	0	**18**
	Sum	**22**	**23**	**18**	**63**		**Sum**	**24**	**25**	**0**	**49**
Drinovci-Greblje	Infant (0-2)	0	0	0	**0**	Drinovci-Greblje	Infant (0-2)	0	0	0	**0**
	Child (2-6)	0	0	0	**0**		Child (2-6)	0	0	0	**0**
	Juvenile (6-10)	0	0	1	**1**		Juvenile (6-10)	0	0	0	**0**
	Adolescent (10-18)	2	0	1	**3**		Adolescent (10-18)	1	0	0	**1**
	Young Adult (18-35)	3	3	0	**6**		Young Adult (18-35)	3	3	0	**6**
	Middle Adult (35-50)	3	2	0	**5**		Middle Adult (35-50)	3	2	0	**5**
	Older Adult (50+)	1	1	0	**2**		Older Adult (50+)	1	3	0	**4**
	Sum	**9**	**6**	**2**	**17**		**Sum**	**8**	**8**	**0**	**16**

Table B - 2: Final site demographics of non-metric datasets.

Dental non-metric dataset						Cranial non-metric dataset					
	Age	M	F	I	**Sum**		Age	M	F	I	**Sum**
Šibenik-Sv Lovre	Infant (0-2)	0	0	0	**0**	Šibenik-Sv Lovre	Infant (0-2)	0	0	11	**11**
	Child (2-6)	0	0	0	**0**		Child (2-6)	0	0	10	**10**
	Juvenile (6-10)	0	0	0	**0**		Juvenile (6-10)	0	0	1	**1**
	Adolescent (10-18)	0	2	5	**7**		Adolescent (10-18)	0	2	5	**7**
	Young Adult (18-35)	7	6	0	**13**		Young Adult (18-35)	6	6	0	**12**
	Middle Adult (35-50)	4	10	0	**14**		Middle Adult (35-50)	7	13	0	**20**
	Older Adult (50+)	4	4	0	**8**		Older Adult (50+)	9	10	0	**19**
	Sum	**15**	**22**	**5**	**42**		**Sum**	**22**	**31**	**27**	**80**
Koprivno-Križ I	Infant (0-2)	0	0	0	**0**	Koprivno-Križ I	Infant (0-2)	0	0	1	**1**
	Child (2-6)	0	0	0	**0**		Child (2-6)	0	0	3	**3**
	Juvenile (6-10)	0	0	1	**1**		Juvenile (6-10)	0	0	1	**1**
	Adolescent (10-18)	1	1	2	**4**		Adolescent (10-18)	1	1	2	**4**
	Young Adult (18-35)	1	4	0	**5**		Young Adult (18-35)	1	4	0	**5**
	Middle Adult (35-50)	5	1	0	**6**		Middle Adult (35-50)	6	1	0	**7**
	Older Adult (50+)	1	1	0	**2**		Older Adult (50+)	1	3	0	**4**
	Sum	**8**	**7**	**3**	**18**		**Sum**	**9**	**9**	**7**	**25**
Koprivno-Križ II	Infant (0-2)	0	0	0	**0**	Koprivno-Križ II	Infant (0-2)	0	0	30	**30**
	Child (2-6)	0	0	2	**2**		Child (2-6)	0	0	16	**16**
	Juvenile (6-10)	0	0	11	**11**		Juvenile (6-10)	0	0	12	**12**
	Adolescent (10-18)	2	5	5	**12**		Adolescent (10-18)	2	5	4	**11**
	Young Adult (18-35)	5	6	0	**11**		Young Adult (18-35)	3	6	0	**9**
	Middle Adult (35-50)	8	9	1	**18**		Middle Adult (35-50)	11	8	1	**20**
	Older Adult (50+)	6	3	0	**9**		Older Adult (50+)	11	8	1	**20**
	Sum	**21**	**23**	**19**	**63**		**Sum**	**27**	**27**	**64**	**118**
Drinovci-Greblje	Infant (0-2)	0	0	0	**0**	Drinovci-Greblje	Infant (0-2)	0	0	2	**2**
	Child (2-6)	0	0	0	**0**		Child (2-6)	0	0	0	**0**
	Juvenile (6-10)	0	0	1	**1**		Juvenile (6-10)	0	0	1	**1**
	Adolescent (10-18)	2	0	1	**3**		Adolescent (10-18)	2	0	1	**3**
	Young Adult (18-35)	3	3	0	**6**		Young Adult (18-35)	3	3	0	**6**
	Middle Adult (35-50)	3	2	0	**5**		Middle Adult (35-50)	4	2	0	**6**
	Older Adult (50+)	1	1	0	**2**		Older Adult (50+)	1	3	0	**4**
	Sum	**9**	**6**	**2**	**17**		**Sum**	**10**	**8**	**4**	**22**

APPENDIX C

NON-SIGNIFICANT RESULTS

In order to streamline and clearly present the statistical comparisons in the results chapter, the results of insignificant comparisons are provided here. Each section is organized by the dataset under investigation. A brief summary of any significant results are presented before the insignificant results are presented.

Dental metric – total sample (n=139)

The first four components of the dental metric – total sample dataset had significant eigenvalues and represented 64.5% of the cumulative variance in the sample (Table 7-1). MANOVA analysis of the first four principal components did not identify significant group separation by time-period (Table 7-2). Therefore the descriptive discriminate analysis, and one-way analysis of variance of the PCA are presented here.

Results of the DDA analysis using the first four PCA dimensions by time period also found no significant differences between individuals (Canon 1: F=1.16, p-value=0.33) (Figure C-1); this is consistent with the dental metric PCA and MANOVA results.

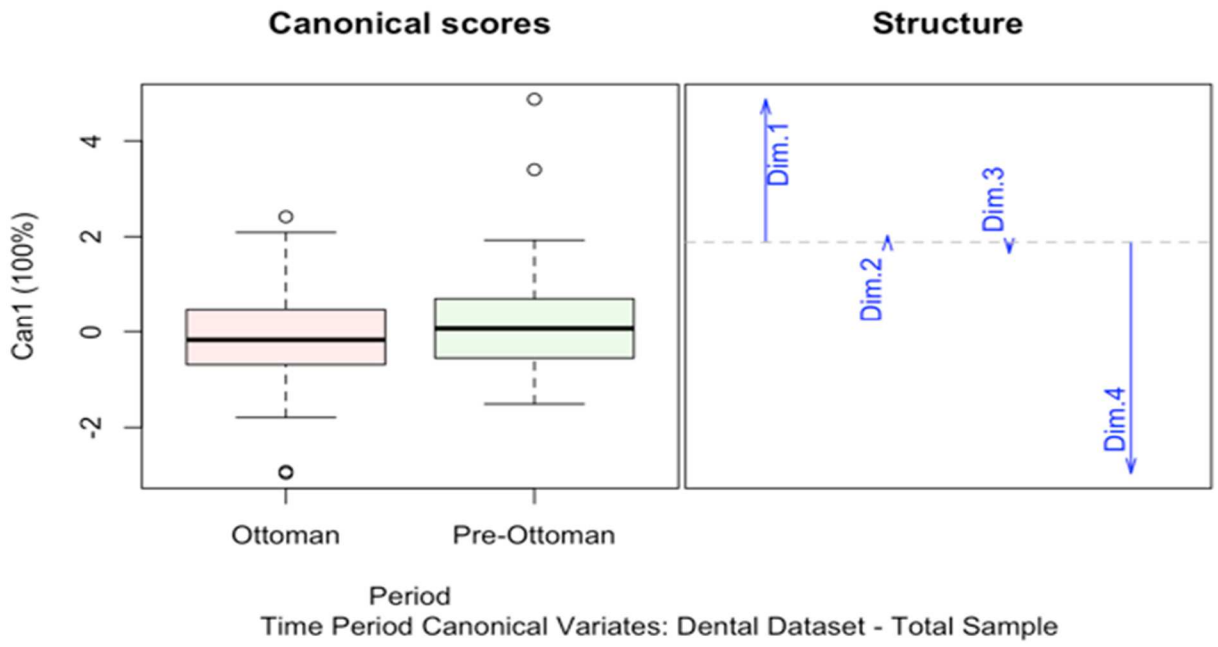

Figure C - 1: Canonical variate 1 by time period for dental metric dataset - total sample (n=139).

The dental metric – total sample was explored by time period using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each PCA dimension (Husson, et al. 2011). Figure C-2 and Figure C-3 present the individual factor plots for the first four PCA dimensions, colored by time period. Dimension 1 through Dimension 4 do not separate individuals by time period. Since the dimensions do not separate individuals by time period, further elaboration of which variables significantly contribute to the formation of each dimension have been omitted but the component loadings and eigenvalues are presented in Table C-1.

The dental metric dataset was standardized by sex; therefore the individuals do not correlate with sex on the first four principal components. Figure C-4 plots the individuals by sex. The barycenters for each sex (M, F, I) are centered at zero. Figure C-5 plots the individuals according to age. There is little separation of individuals based on age in the dental metric

dataset. Overall, the dental metric dataset does not separate individuals by time period, sex or age.

Table C - 1: PCA component loadings and eigenvalues of dental metric dataset - total sample (n=139).

	PC1	PC2	PC3	PC4	PC5
MD Crown UM2	0.12	0.20	-0.39	0.53	0.27
MD Crown LC	2.01	-0.40	-0.06	0.11	-0.02
MD Crown LM1	1.39	0.34	-0.67	0.21	-0.75
BL Crown UC	1.18	-0.51	0.13	-0.04	0.46
BL Crown UM2	0.98	0.35	-0.34	-0.37	-0.30
BL Crown LI2	0.76	-0.46	0.02	0.18	-0.33
BL Crown LC	0.64	-0.22	-0.16	-0.01	0.13
BL Crown LP3	2.69	-0.06	0.03	-0.12	-0.34
BL Crown LM2	1.40	1.06	-0.68	0.23	-0.04
MD CEJ UC	1.26	-0.21	0.13	-0.55	0.87
MD CEJ UM1	0.88	0.54	0.10	-0.88	-0.14
MD CEJ LI2	0.71	0.37	0.51	0.33	-0.43
MD CEJ LC	0.78	-0.03	0.24	0.12	0.38
MD CEJ LP4	0.33	0.24	0.66	0.19	-0.18
MD CEJ LM1	2.09	1.51	0.03	0.02	0.11
BL CEJ UI2	1.28	-0.98	-0.27	0.03	0.06
BL CEJ UP3	0.83	-0.08	0.83	-0.35	0.94
BL CEJ UM2	0.77	0.57	-0.51	-0.64	0.24
BL CEJ LI2	0.61	-0.73	-0.12	-0.17	-0.21
BL CEJ LM1	0.61	0.04	-0.06	0.28	0.11
Eigenvalue	8.37	1.90	1.46	1.16	0.97
% Variance	41.86	9.48	7.32	5.82	4.83
Cumulative %	41.9	51.4	58.7	64.5	69.3

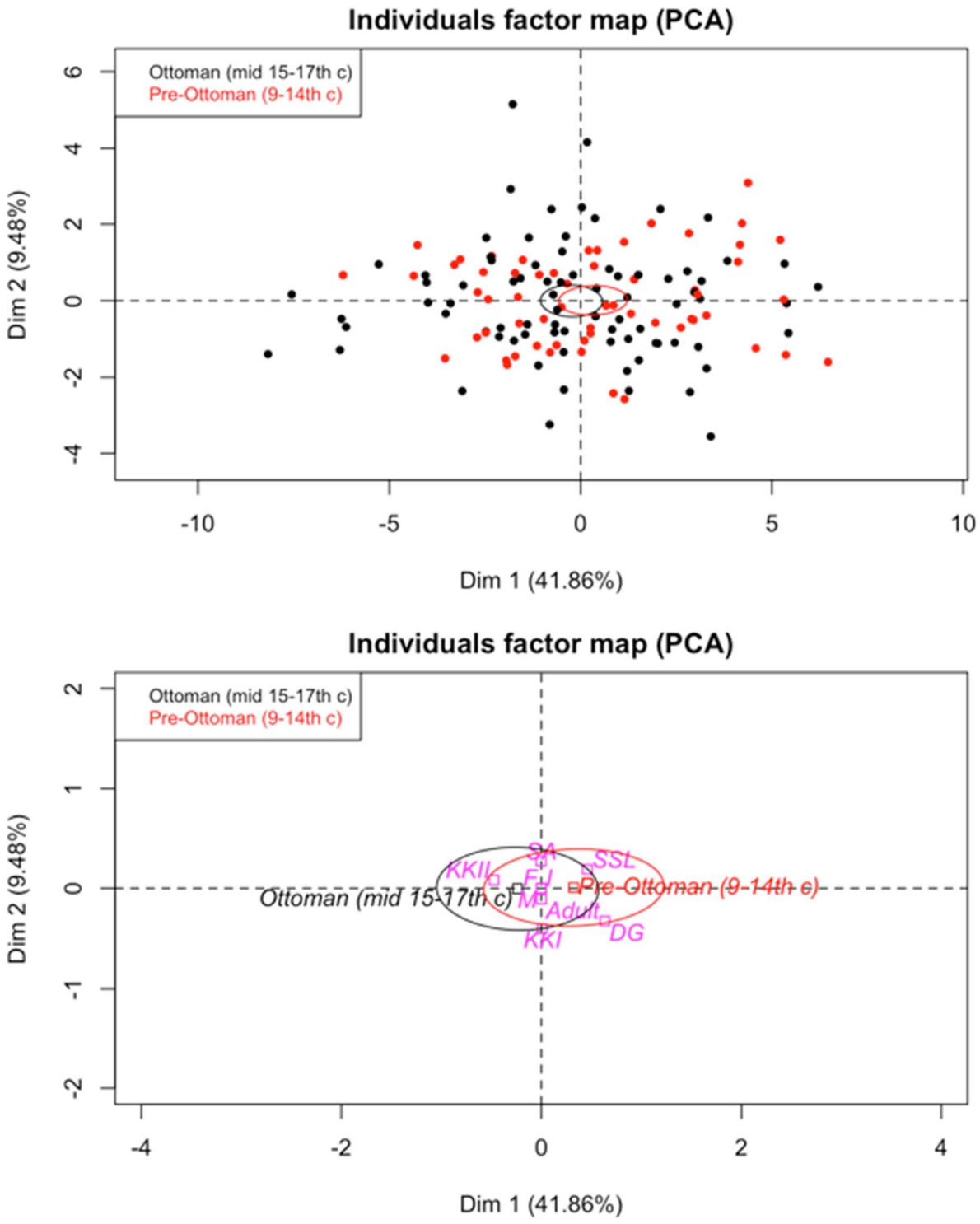

Figure C - 2: Upper: Dim 1 and Dim 2 individuals factor plot (PCA) for dental metric dataset - total sample (n=139), colored by time period. Lower: Individual data points are removed and barycenters of the individuals belonging to each time period are retained.

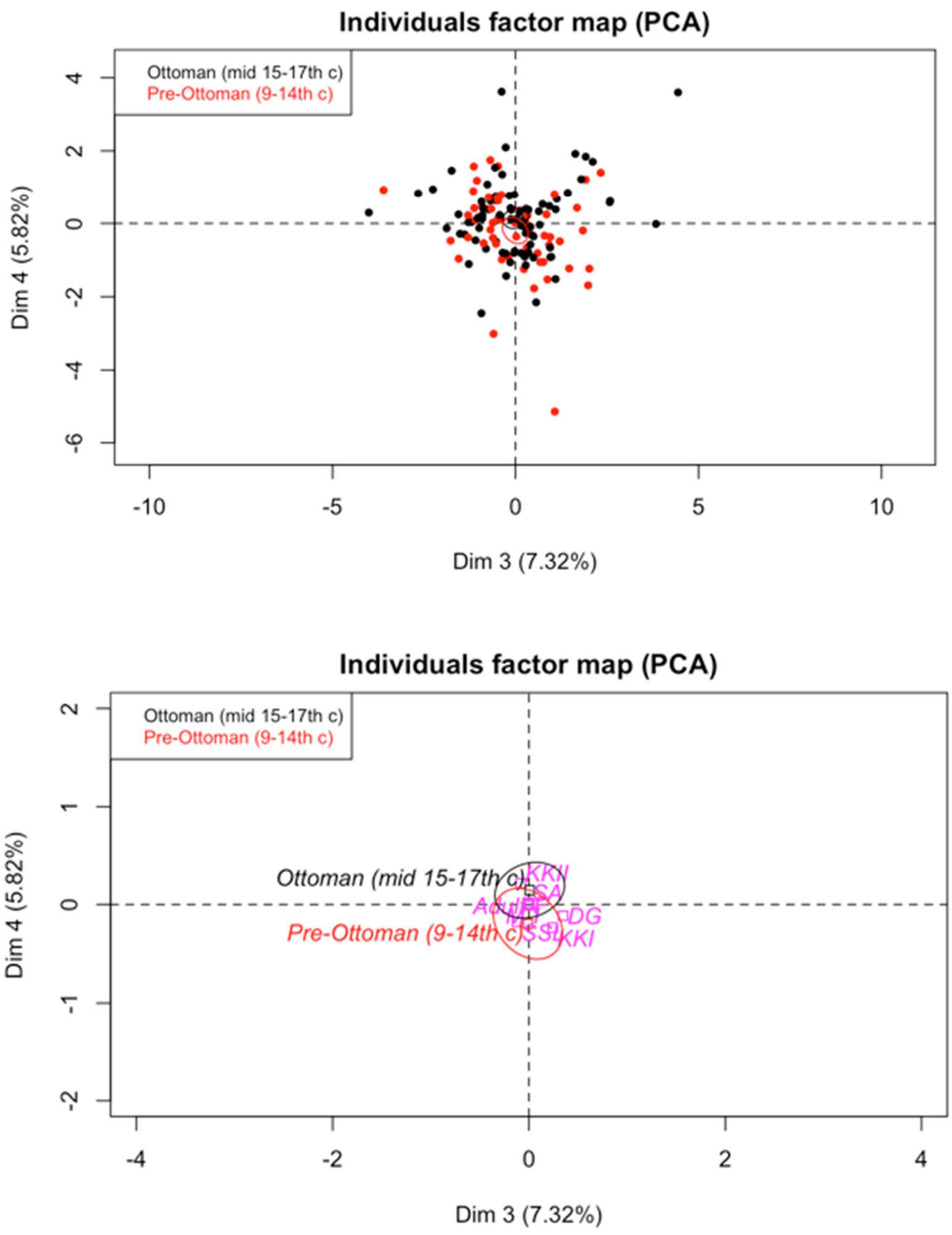

Figure C - 3: Upper: Dim 3 and Dim 4 individuals factor plot (PCA) for dental metric dataset - total sample (n=139), colored by time period. Lower: Individual data points are removed and barycenters of the individuals belonging to each time period are retained.

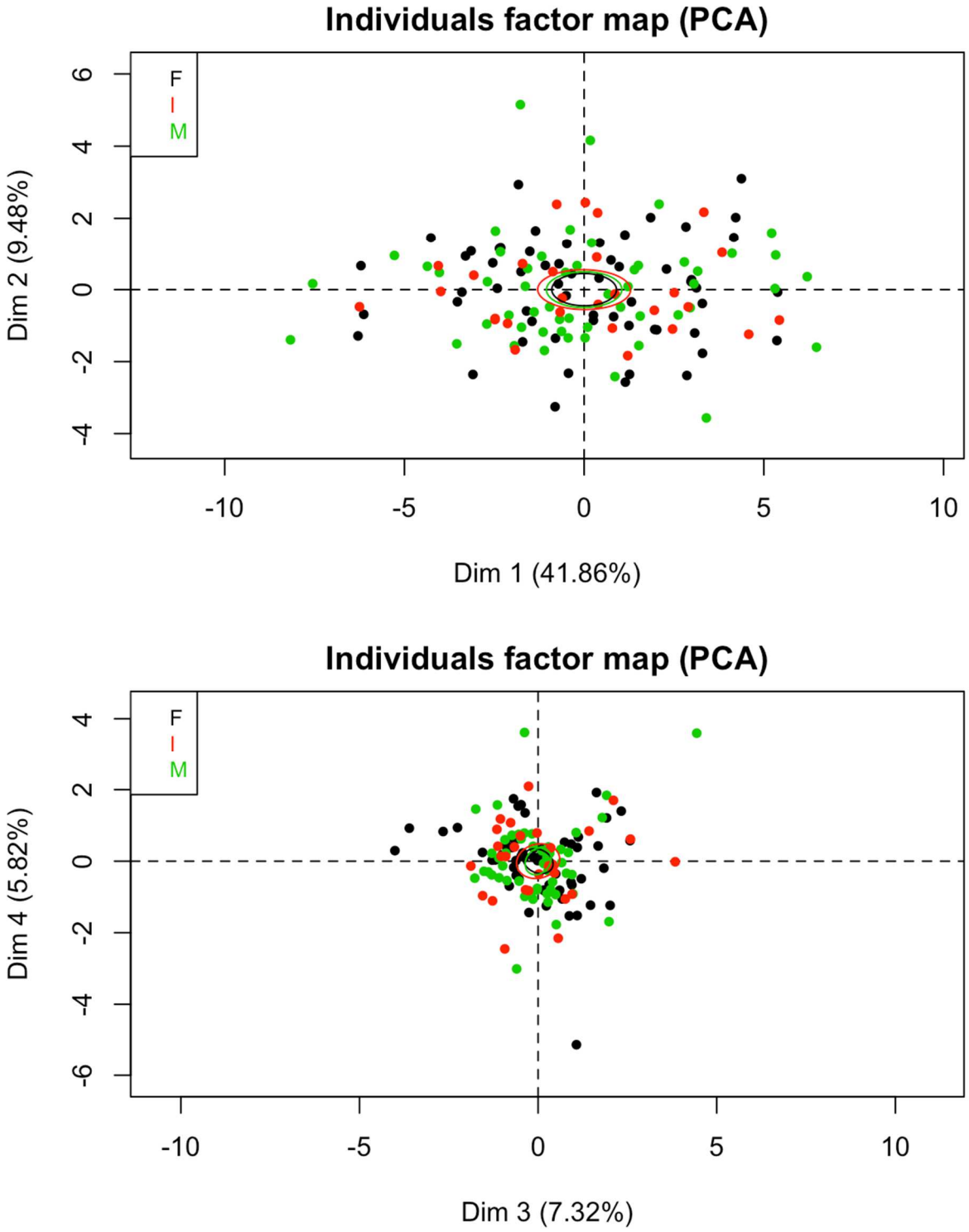

Figure C - 4: Individuals factor plot (PCA) for the first four principal components of the dental metric dataset - total sample (n=139), colored by sex.

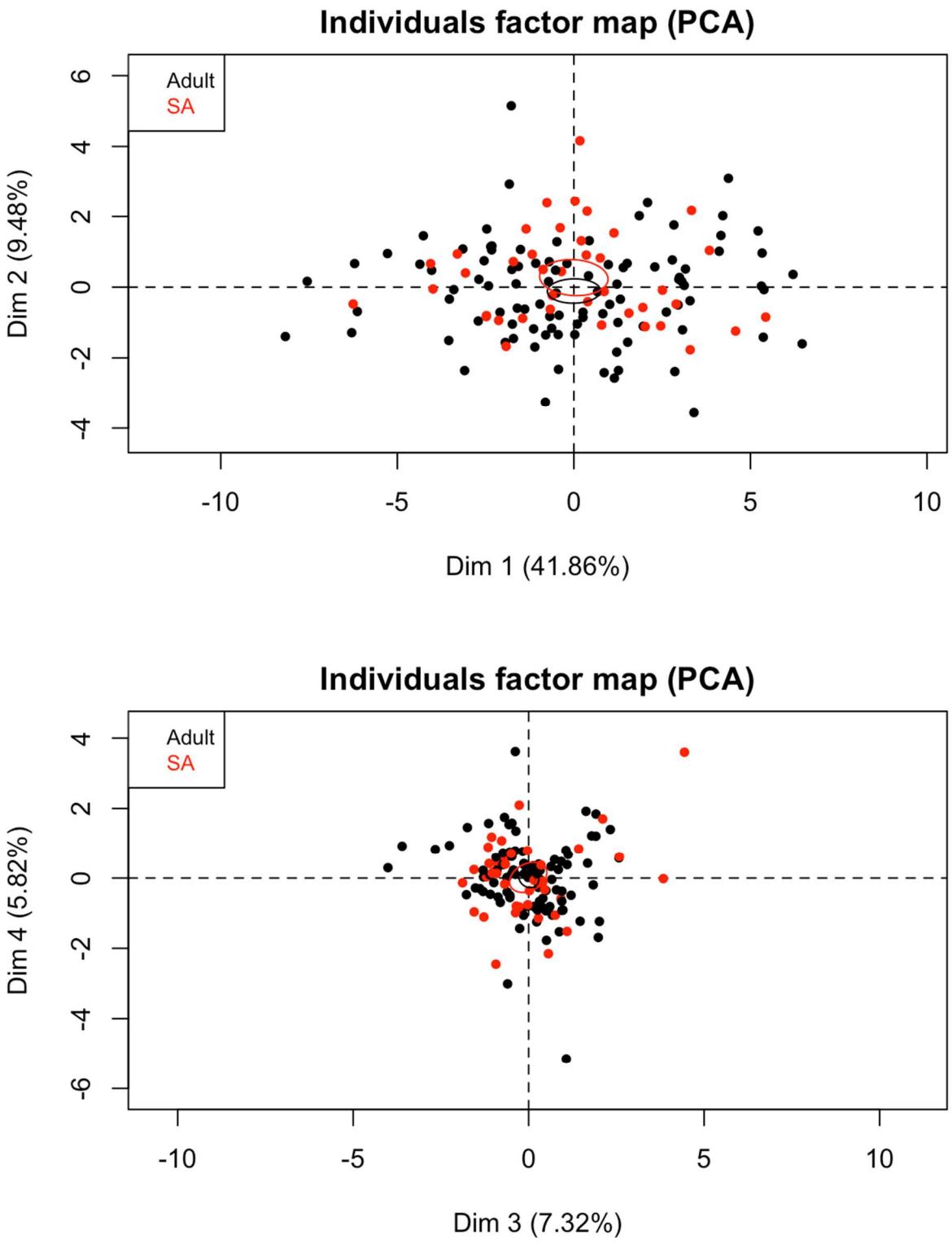

Figure C - 5: Individuals factor plot (PCA) for the first four principal components of the dental metric dataset - total sample (n=139), colored by age.

Dental non-metric – total sample (n=140)

Results of the dental non-metric – total sample multivariate statistical analyses are presented in Chapter 7: Results. The MCA individual factor plots for Dimension 3 through Dimension 8 did not separate individuals by time period and therefore the individual factor plots for these dimensions are presented here in Figure C-6 through Figure C-8.

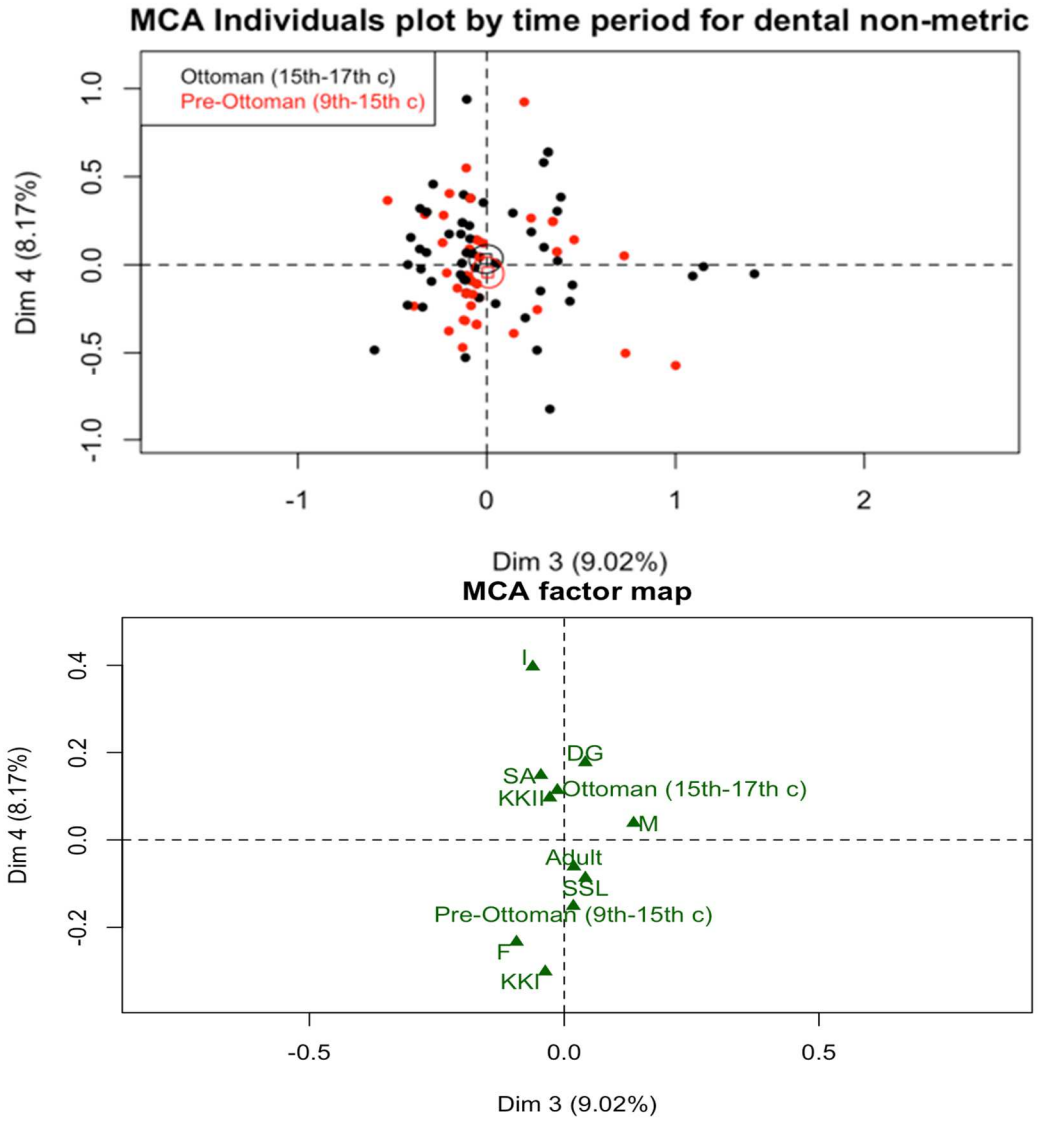

Figure C - 6: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for the dental non-metric - total sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

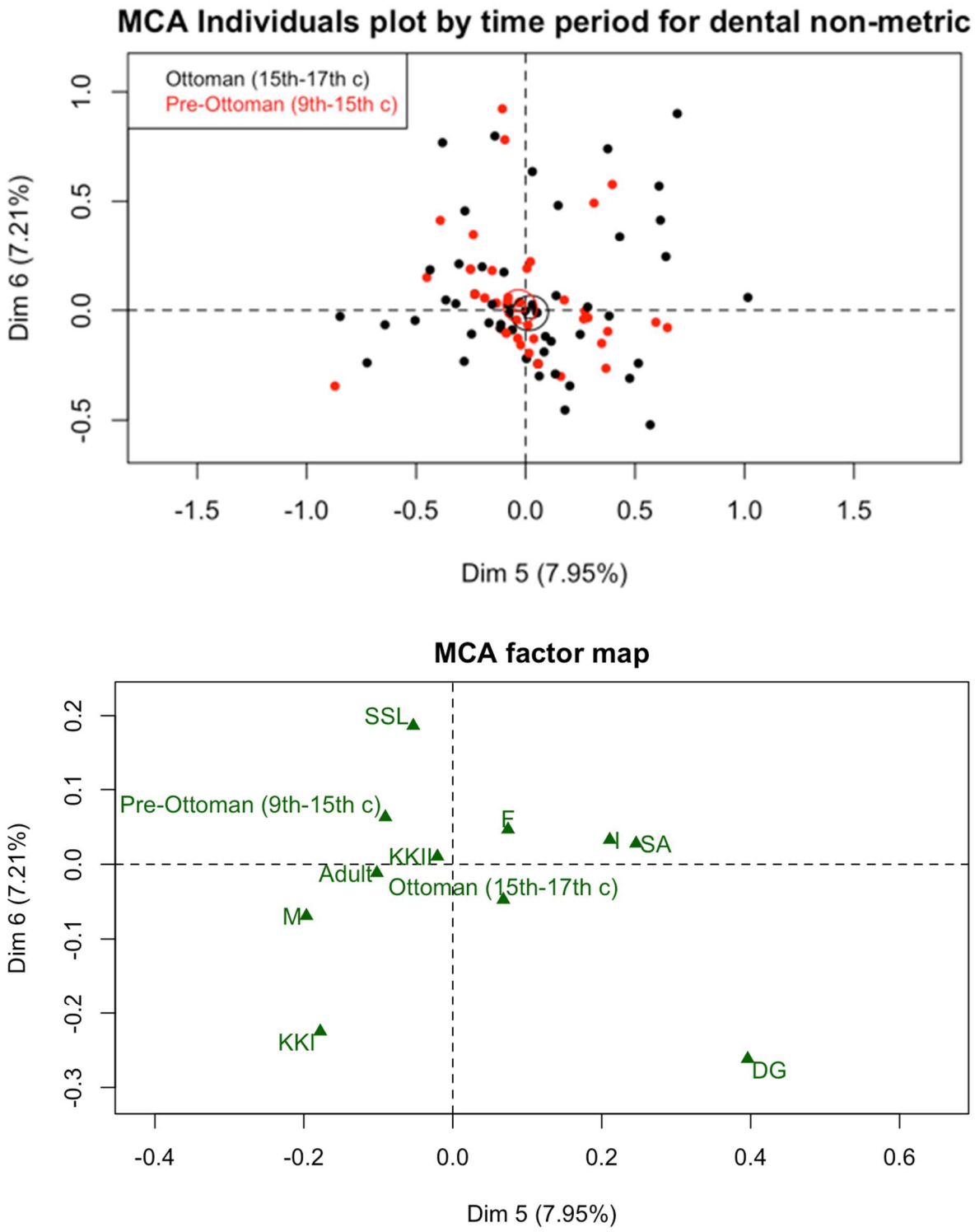

Figure C - 7: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the dental non-metric - total sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

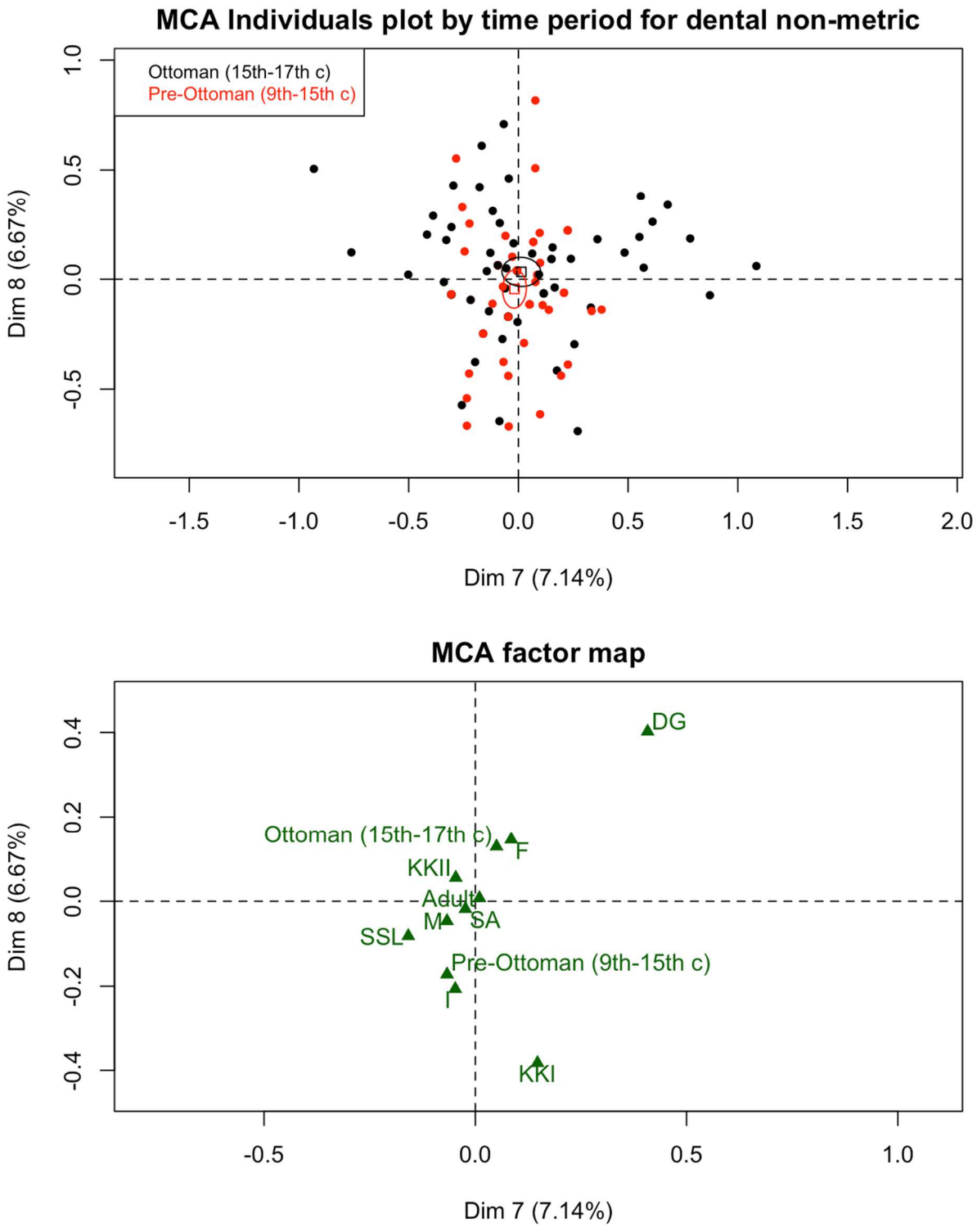

Figure C - 8: Upper: Dim 7 and Dim 8 individuals factor plots (MCA) for the dental non-metric - total sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

Cranial non-metric – total sample (n=245)

Results of the cranial non-metric – total sample multivariate statistical analyses are presented in Chapter 7: Results. Examination of the dimensions using one-way analysis of variance showed Dimension 1, Dimension 2, Dimension 4, Dimension 6, Dimension 7 and Dimension 8 did not separate individuals by time period and therefore the individual factor plots for these dimensions are presented in Figure C-9 through Figure C-12.

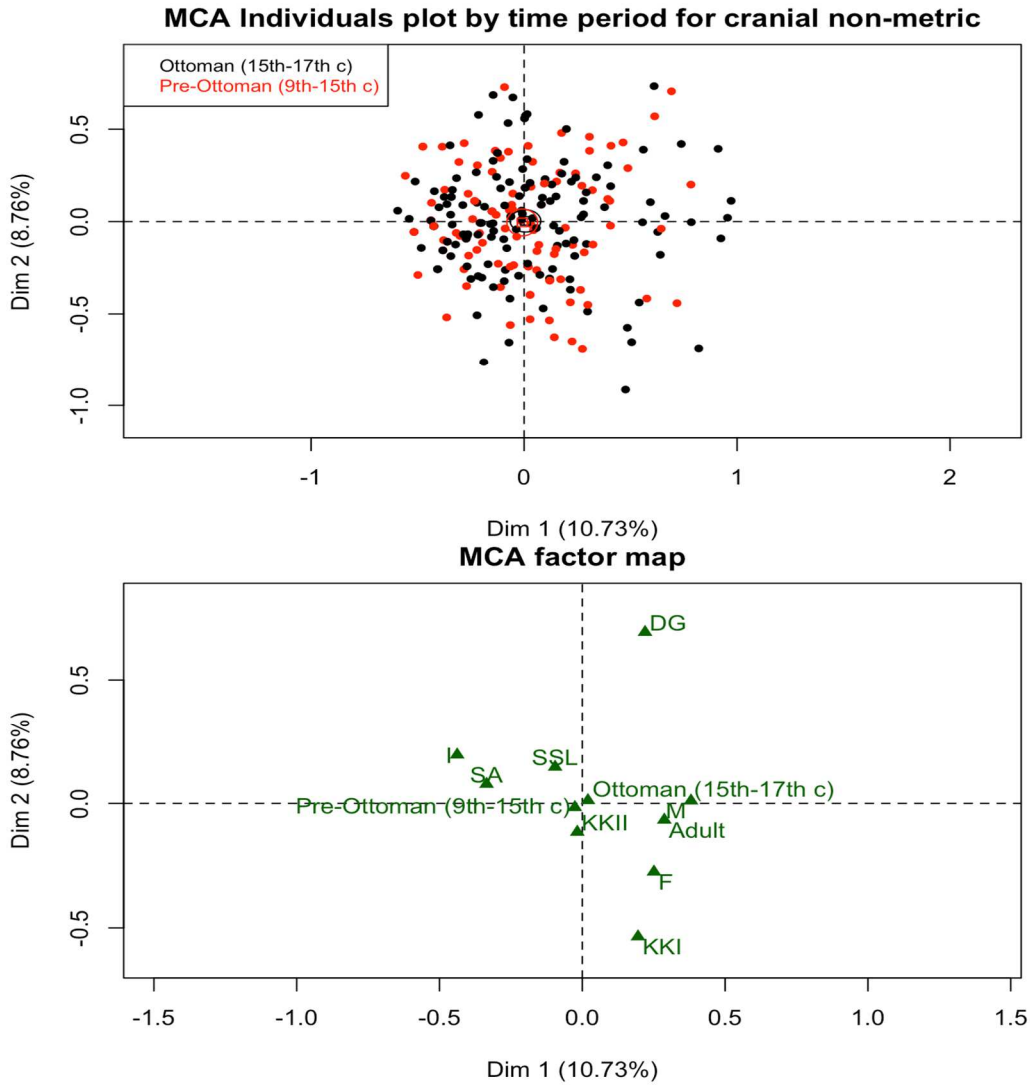

Figure C - 9: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the cranial non-metric - total sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

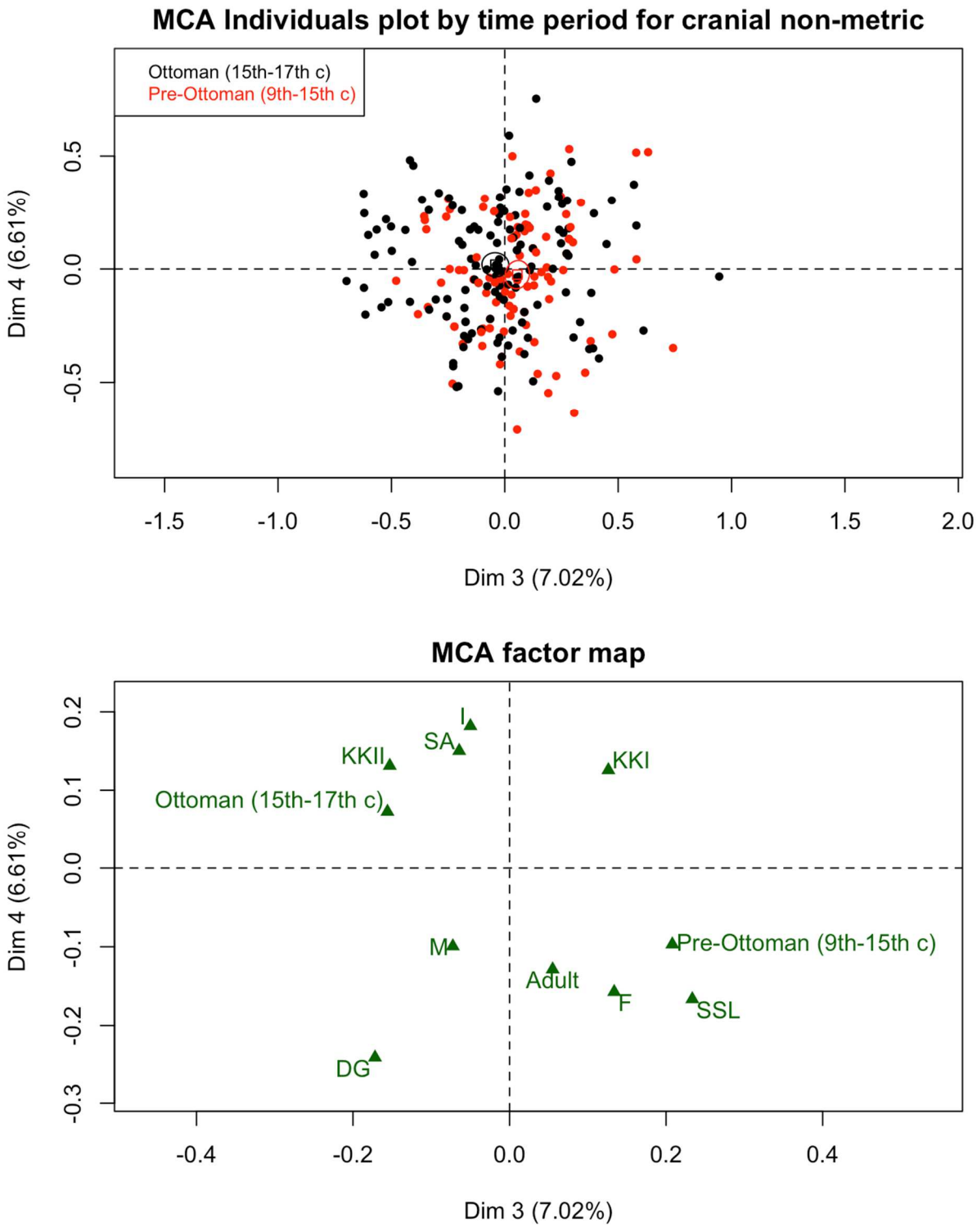

Figure C - 10: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - total sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

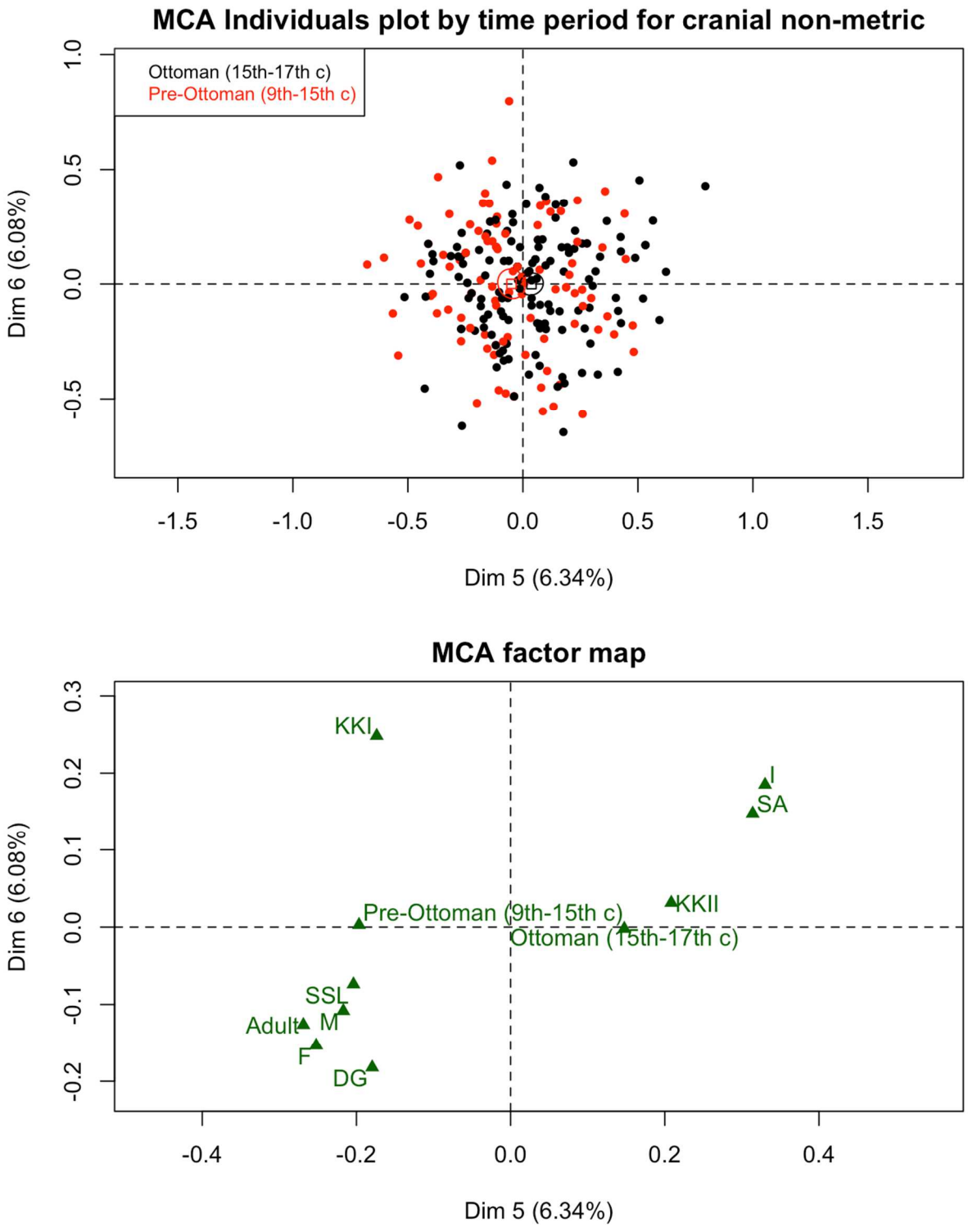

Figure C - 11: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the cranial non-metric - total sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

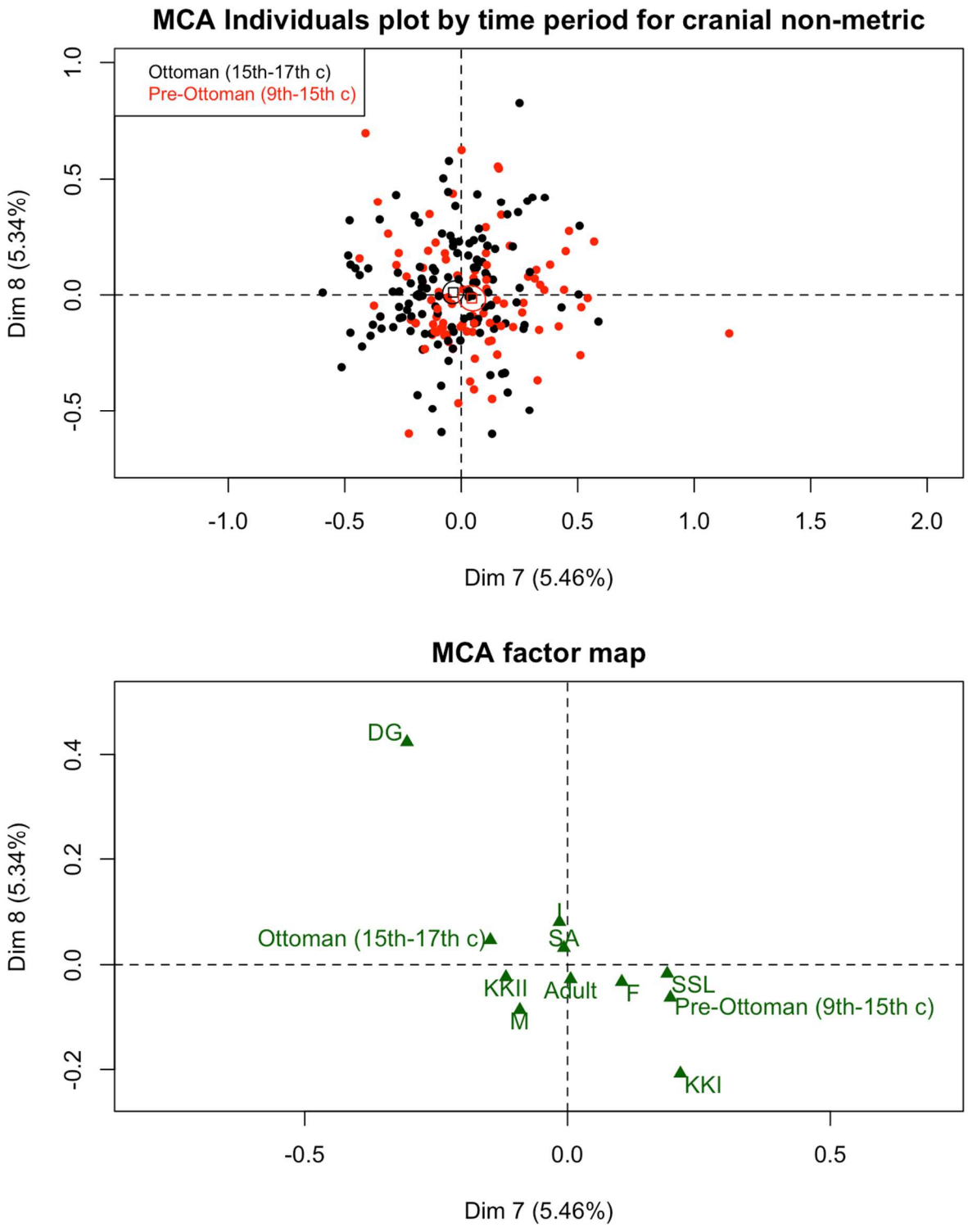

Figure C - 12: Upper: Dim 7 and Dim 8 individuals factor plots (MCA) for the cranial non-metric - total sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

Cranial non-metric – adult only sample (n=140)

Results of the cranial non-metric – total sample multivariate statistical analyses are presented in Chapter 7: Results. The MCA individual factor plots for Dimension 1, Dimension 2, Dimension 4, Dimension 6, Dimension 7, and Dimension 8 did not separate individuals by time period and therefore the individual factor plots for these dimensions are presented here in Figure C-13 through Figure C-16.

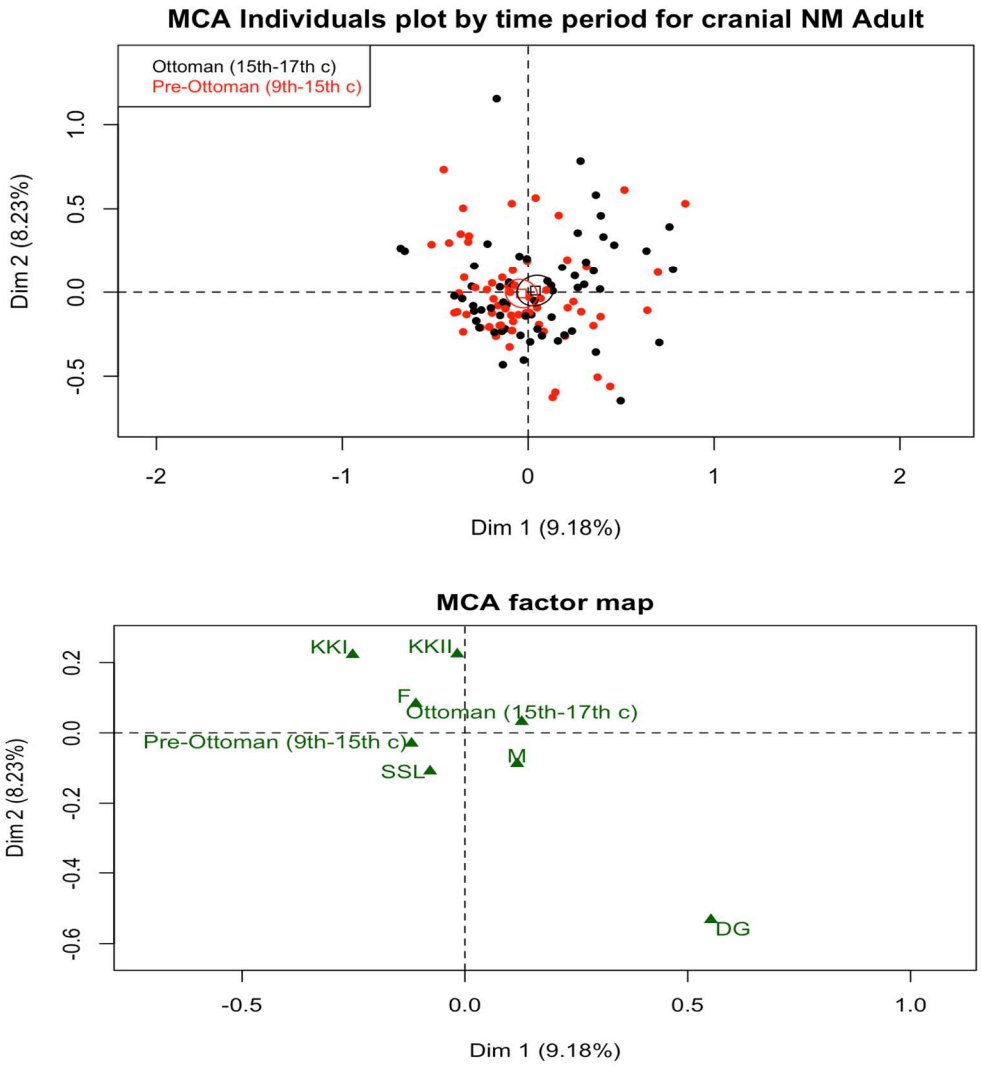

Figure C - 13: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for cranial non-metric – adult only sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

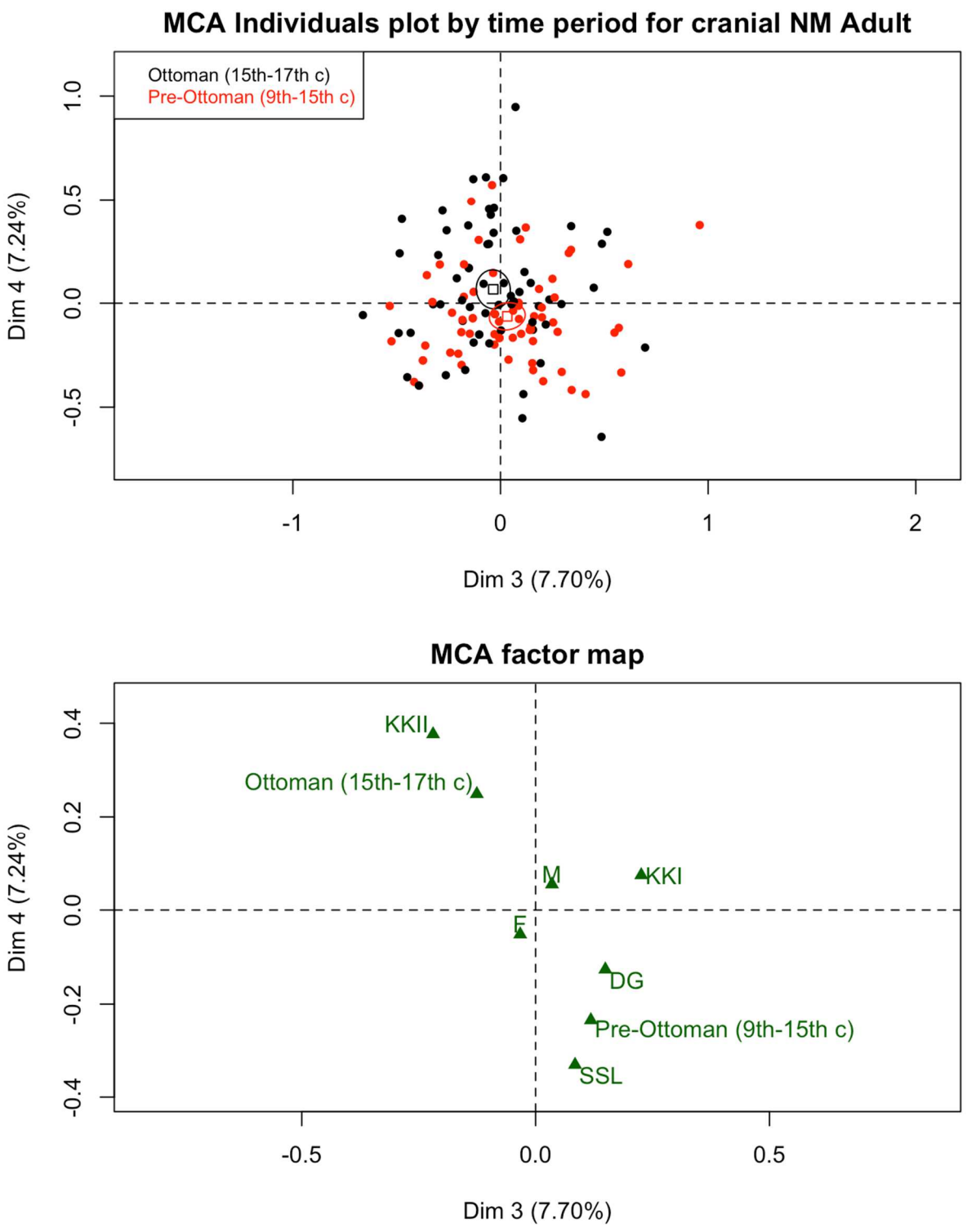

Figure C - 14: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for cranial non-metric – adult only sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

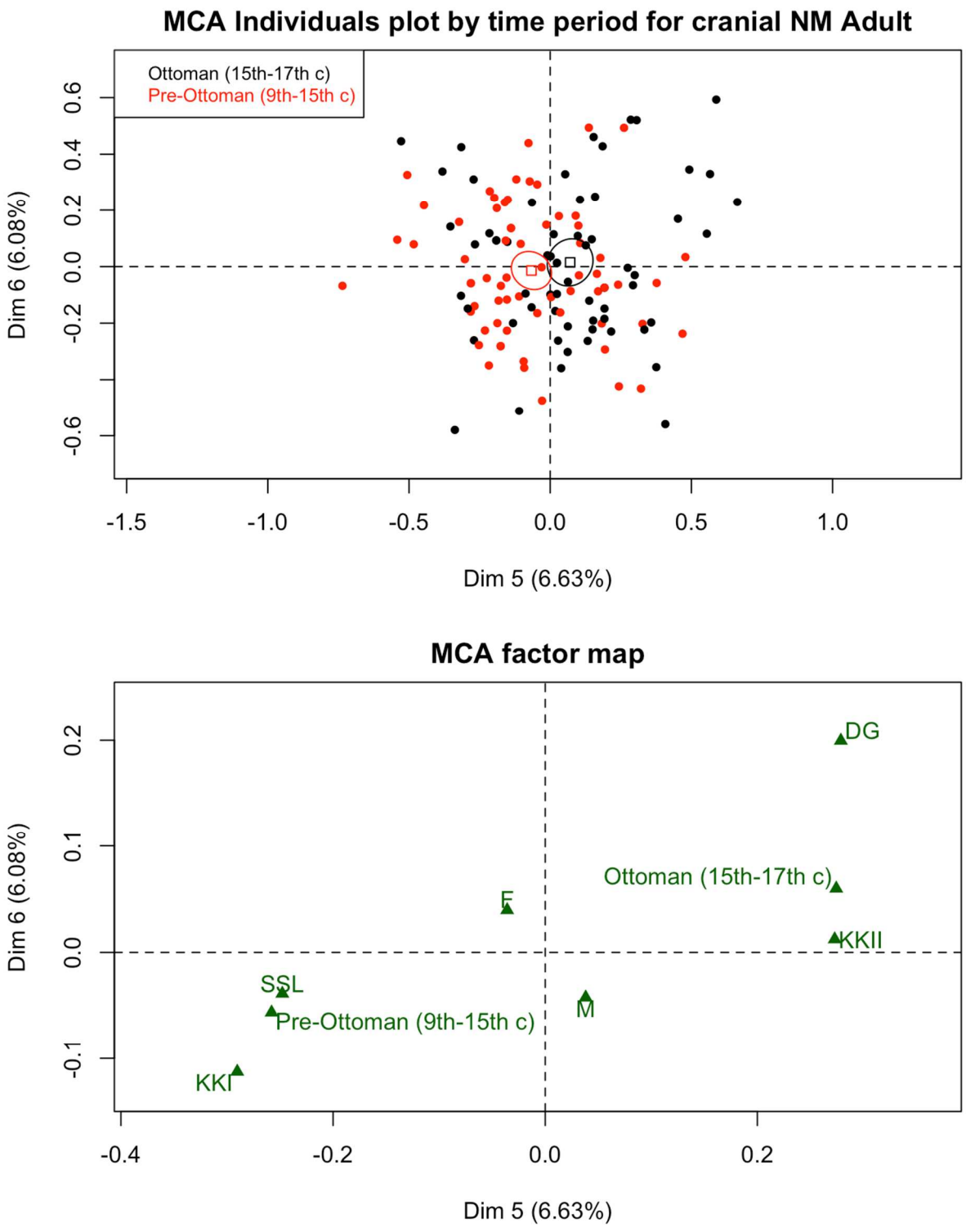

Figure C - 15: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for cranial non-metric – adult only sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

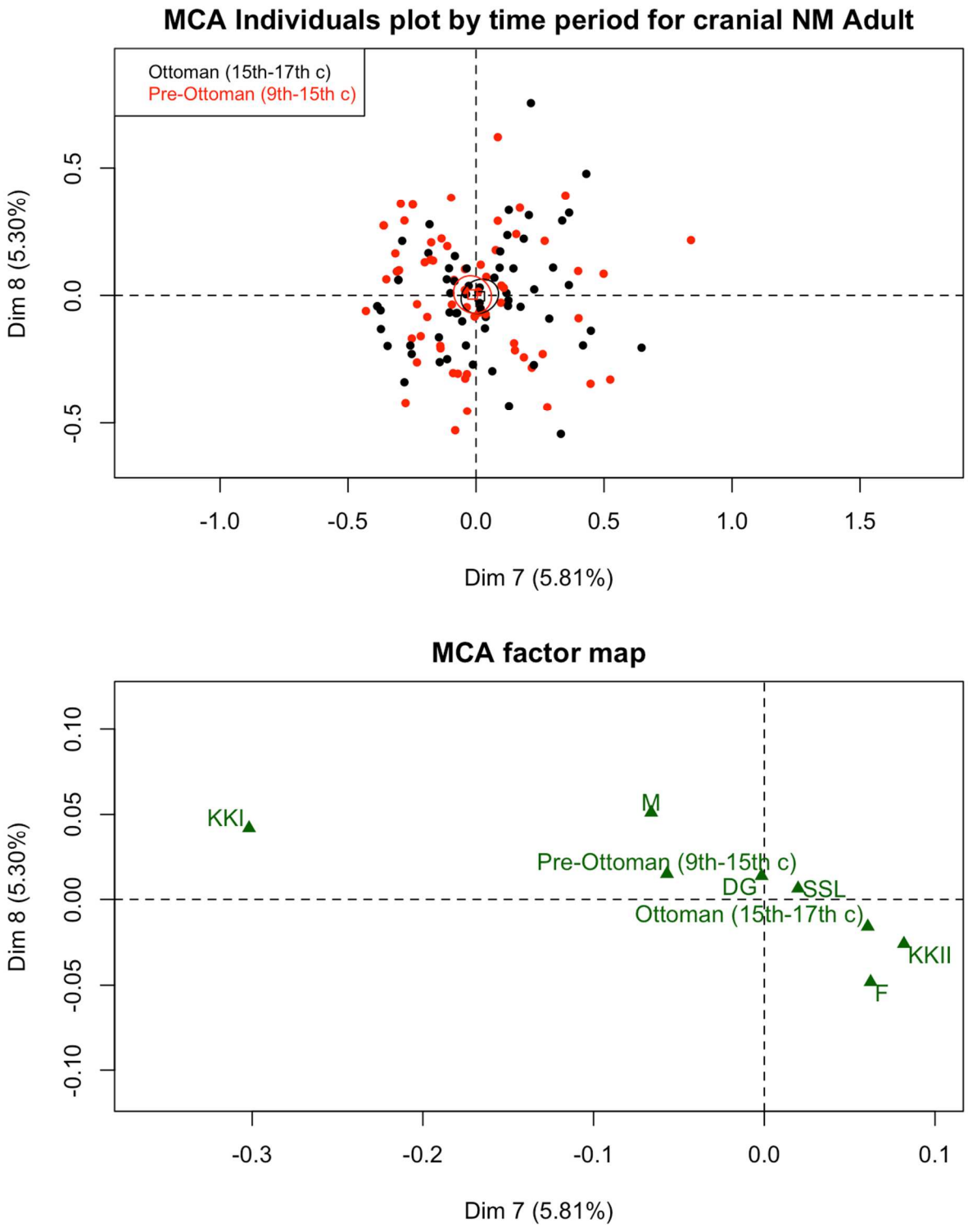

Figure C - 16: Upper: Dim 7 and Dim 8 individuals factor plots (MCA) for cranial non-metric – adult only sample (n=140), colored by time period. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

Dental metric – male sample (n=53)

The first four PCA dimensions of the dental metric – male sample had significant eigenvalues and represented 72% of the cumulative variance in the sample (Table 7-1). MANOVA analysis of the first four PCA dimensions did not identify significant group separation by time-period (Table 7-2). Therefore the descriptive discriminate analysis (DDA) and one-way analysis of variance of the PCA dimensions are presented here.

Results of the DDA analysis using the first four PCA dimensions by time period found no significant differences between individuals (Canon 1: F=1.3, p-value=0.28) (Figure C-17). There are no differences between time periods using the dental metric – male sample.

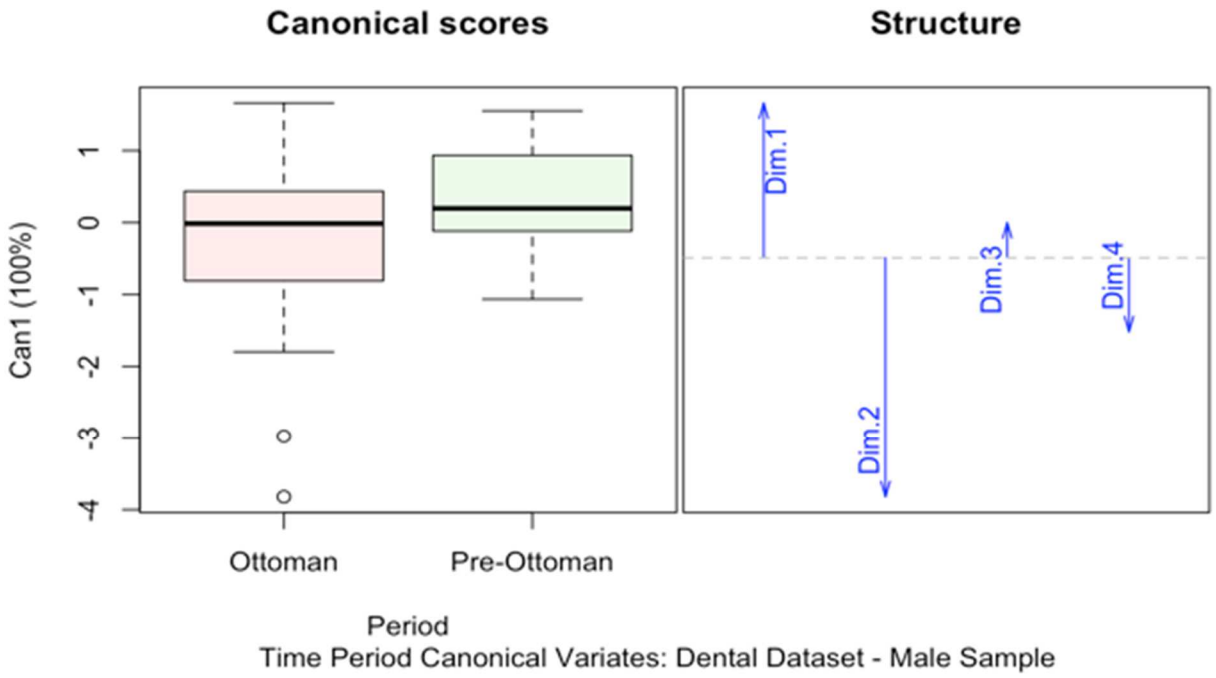

Figure C - 17: Canonical variate 1 by time period for dental metric dataset - male sample (n=53).

Figure C-18 presents the individuals factor plots of the first four PCA dimensions. Using a one-way analysis of variance, none of the first four PCA dimensions significantly separated individuals by time period. However, Dimension 2 did separate individuals by age (R^2=0.13, p=0.01): subadults were positively correlated, while adults were negatively correlated on Dimension 2. However, this age association is likely a result of small sample sizes, there are only five older adolescents included in the sample. Table C-2 presents the component loadings and eigenvalues for the PCA dimensions of the dental metric – male sample. Since none of the dimensions separated individuals by time period, elaboration on which variables contributed to the formation of each dimension has been omitted. However, variables that significantly contributed to the formation of each dimension are highlighted in gray in Table C-2.

Table C - 2: PCA component loadings and eigenvalues of the dental metric - male sample (n=53).

	PC1	PC2	PC3	PC4	PC5
MD Crown UM2	0.11	0.25	0.07	0.44	0.54
MD Crown LC	2.66	0.80	-1.99	0.03	-0.12
MD Crown LM1	1.86	0.05	0.86	0.75	0.56
BL Crown UC	1.46	-0.57	-0.43	-0.24	0.27
BL Crown UM2	1.21	0.01	0.52	-0.37	-0.11
BL Crown LI2	0.85	-0.53	-0.32	0.33	-0.27
BL Crown LC	0.64	-0.37	-0.01	0.07	0.17
BL Crown LP3	4.26	-0.07	0.07	-0.32	0.22
BL Crown LM2	2.28	0.99	0.70	-0.02	0.05
MD CEJ UC	1.84	-0.74	0.17	0.11	-0.65
MD CEJ UM1	1.06	0.38	0.75	-0.01	-1.23
MD CEJ LI2	0.82	0.76	-0.48	-0.11	-0.25
MD CEJ LC	0.79	0.26	-0.35	0.10	-0.01
MD CEJ LP4	0.36	0.51	-0.36	-0.10	-0.23
MD CEJ LM1	3.45	2.14	0.03	0.00	0.20
BL CEJ UI2	2.01	-1.24	-0.68	-1.34	0.91
BL CEJ UP3	1.44	0.13	-0.24	-0.98	0.76
BL CEJ UM2	0.89	0.38	1.08	-0.36	-0.32
BL CEJ LI2	0.65	-0.99	0.01	0.37	-0.16
BL CEJ LM1	0.62	0.10	0.14	0.66	-0.09
Eigenvalue	9.60	2.43	1.32	1.11	0.96
% Variance	0.48	0.12	0.07	0.06	0.05
Cumulative %	0.48	0.60	0.67	0.72	0.77

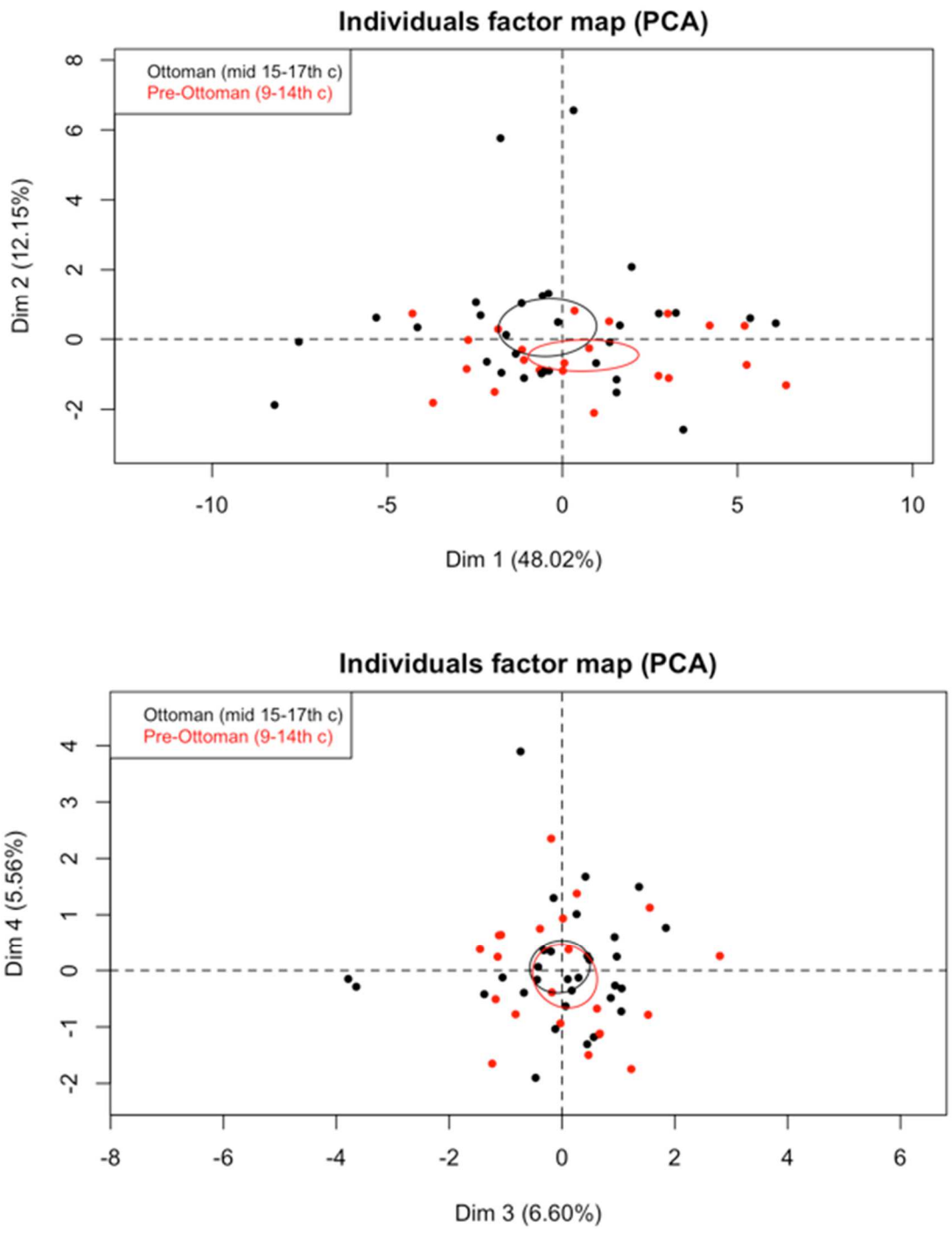

Figure C - 18: Upper: Dim 1 and Dim 2 of individuals factor plot (PCA) for the dental metric - male sample (n=53), colored by time period. Lower: Dim 3 and Dim 4 of individuals factor plot (PCA) for the dental metric - male sample (n=53), colored by time period.

Cranial metric – male sample (n=58)

Results of the cranial metric – male sample multivariate statistical analyses are presented in Chapter 7: Results. MANOVA, DDA and PCA analyses identified significant separation of individuals based on time period. One-way analysis of variance found Dimension 3 and Dimension 4 did not separate individuals by time period, therefore the individual factor plots for these dimensions are presented here in Figure C-19.

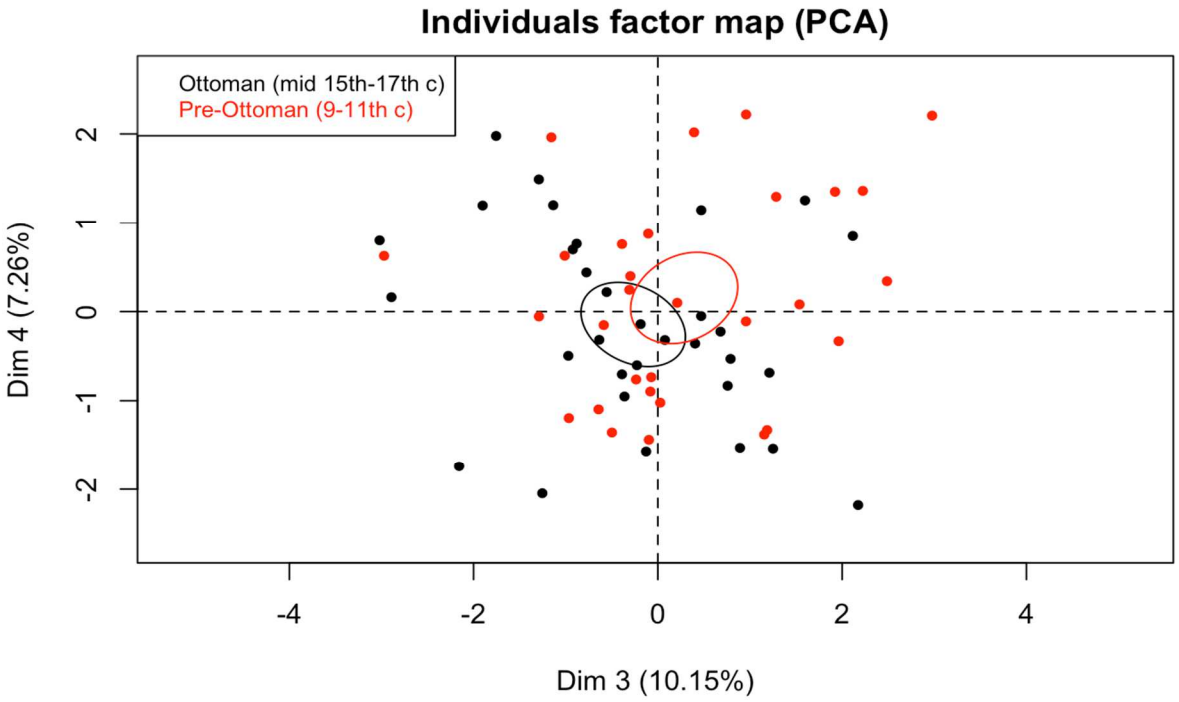

Figure C - 19: Dim 3 and Dim 4 individuals factor plot (PCA) for the cranial metric - male sample (n=62), colored by time period.

Dental non-metric – male sample (n=53)

The first seven MCA dimensions of the dental non-metric – male sample (n=53) had significant eigenvalues and represented 73.9% of the cumulative variance in the sample (Table 7-1). For the dental non-metric – male sample none of the MANOVA by time period results were

significant (Table 7-2). Therefore, the dental non-metric – male sample does not differ by time period and the null hypothesis cannot be disproven.

The results of the DDA analysis using the first seven MCA dimensions by time period found no significant differences between individuals (Canon 1: F=1.73, p-value=0.13) (Figure C-20). Dimension 1, Dimension 2, and Dimension 7 had the largest standard coefficients and therefore contributed most to the formation of Canon 1.

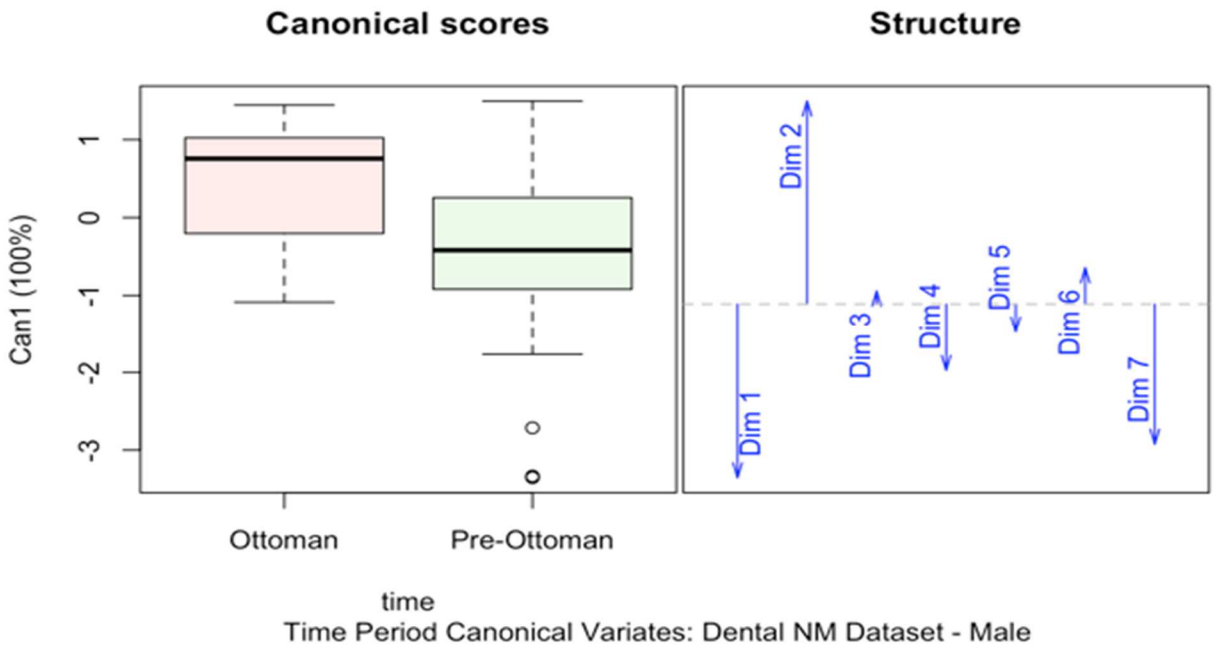

Figure C - 20: Canonical variate 1 by time period for dental non-metric dataset - male sample (n=53).

The component loadings and eigenvalues for the first seven MCA dimensions are presented in Table C-3. Using one-way analysis of variance analysis, the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table C-3.

Table C - 3: MCA component loadings and eigenvalues for dental non-metric dataset - male sample (n=53).

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7
UI1 Double Shoveling - A	-0.04	-0.03	-0.01	-0.55	0.04	-0.08	0.14
UI1 Double Shoveling - P	0.95	0.74	0.33	14.12	-0.95	1.95	-3.67
LC Double Root - A	0.07	-0.10	-0.02	0.01	-0.04	0.38	-0.42
LC Double Root - P	-1.83	2.45	0.40	-0.20	0.91	-9.59	10.76
UI1 Radical Number - 2+ Radicals	-0.69	1.36	0.54	0.30	-1.26	0.62	-1.20
UI1 Radical Number - One Radical	0.83	-1.65	-0.66	-0.36	1.52	-0.75	1.45
UP4 Mesial Accessory Ridges - A	-0.28	-0.17	0.24	0.08	0.02	-0.08	-0.01
UP4 Mesial Accessory Ridges - P	7.17	4.41	-6.05	-2.12	-0.44	1.99	0.33
LP4 Multiple Lingual Cusps - A	0.34	0.17	0.06	1.71	1.99	-2.06	-0.67
LP4 Multiple Lingual Cusps - P	-0.26	-0.13	-0.05	-1.31	-1.53	1.58	0.52
UM2 Carabelli's - A	-0.52	0.16	-0.11	-0.30	0.28	-0.01	-0.09
UM2 Carabelli's - P	6.38	-1.95	1.31	3.72	-3.45	0.18	1.13
UM2 Metacone Cusp 3 - A	8.43	5.92	-0.78	-3.37	1.34	-0.44	-2.54
UM2 Metacone Cusp 3 - P	-0.33	-0.23	0.03	0.13	-0.05	0.02	0.10
UM3 Mesial Paracone Tubercle - A	-0.24	0.41	-0.29	-0.04	0.28	0.07	-0.22
UM3 Mesial Paracone Tubercle - P	3.94	-6.82	4.82	0.68	-4.67	-1.18	3.66
UM2 Parastyle - A	-0.29	-0.13	0.26	0.10	-0.05	-0.04	-0.11
UM2 Parastyle - P	7.52	3.33	-6.63	-2.50	1.36	0.96	2.72
LM3 Congenital Absence - Congenital Absence	-0.14	-3.51	-0.01	-2.12	7.37	2.14	-4.18
LM3 Congenital Absence - Tooth Present	0.01	0.29	0.00	0.17	-0.60	-0.17	0.34
UM3 Hypocone Cusp 4 - A	-0.66	-0.04	-0.59	0.52	0.45	0.69	0.92
UM3 Hypocone Cusp 4 - P	2.02	0.11	1.82	-1.59	-1.37	-2.11	-2.84
UM3 Metaconule Cusp 5 - A	-0.71	0.02	-0.70	-0.33	-0.81	-0.62	-0.28
UM3 Metaconule Cusp 5 - P	2.17	-0.05	2.16	1.01	2.50	1.90	0.85
UM2 Root Number - 1-2 Roots	-0.11	3.51	4.80	-1.22	1.06	-2.51	-0.45
UM2 Root Number - 3+ Roots	0.02	-0.62	-0.85	0.22	-0.19	0.45	0.08
UM2 Cusp Number - 3 Cusps	-0.74	6.13	11.99	-1.66	3.81	12.74	9.24
UM2 Cusp Number - 4+ Cusps	0.01	-0.12	-0.23	0.03	-0.07	-0.24	-0.18
LM2 Groove Pattern - Non-Y	-0.06	0.77	-0.30	0.44	-0.01	0.02	0.29
LM2 Groove Pattern - Y	0.30	-3.75	1.47	-2.17	0.03	-0.10	-1.44
Eigenvalue	0.18	0.13	0.10	0.09	0.09	0.08	0.07
% Variance	17.74	12.78	10.38	9.37	8.58	7.91	7.15
Cumulative %	17.74	30.52	40.89	50.26	58.80	66.80	73.90

Individual factor plots for the first six MCA dimensions are presented in Figure C-21 and Figure C-22. Dimension 1, Dimension 3, Dimension 4, Dimension 5, Dimension 6 and Dimension 7 did not separate individuals by time period (Figure C-21 and Figure C-22), therefore the component loadings of the significantly contributing variables for each of these dimensions are not examined here but are still highlighted in Table C-3. Dimension 2 did separate individuals by time period.

Dimension 2 accounted for 12.78% of the sample variance and separated individuals by time period (R^2=0.0866, p-value=0.0305) (Figure C-21): pre-Ottoman individuals were negatively correlated, while Ottoman individuals were positively correlated on Dimension 2. Dimension 2 was characterized by a positively correlated LM2 groove pattern-non-Y and the UM3 mesial paracone tubercle-absence, while a LM2 groove pattern-Y and UM3 mesial paracone tubercle-presence are negatively correlated (Table C-3). Ottoman individuals had higher frequencies of LM2 groove pattern- non-Y, and UM3 mesial paracone tubercle-absence: making them positively correlated on Dimension 2. Pre-Ottoman individuals had higher frequencies of the LM2 groove pattern-Y and UM3 mesial paracone tubercle-presence: making them negatively correlated on Dimension 2.

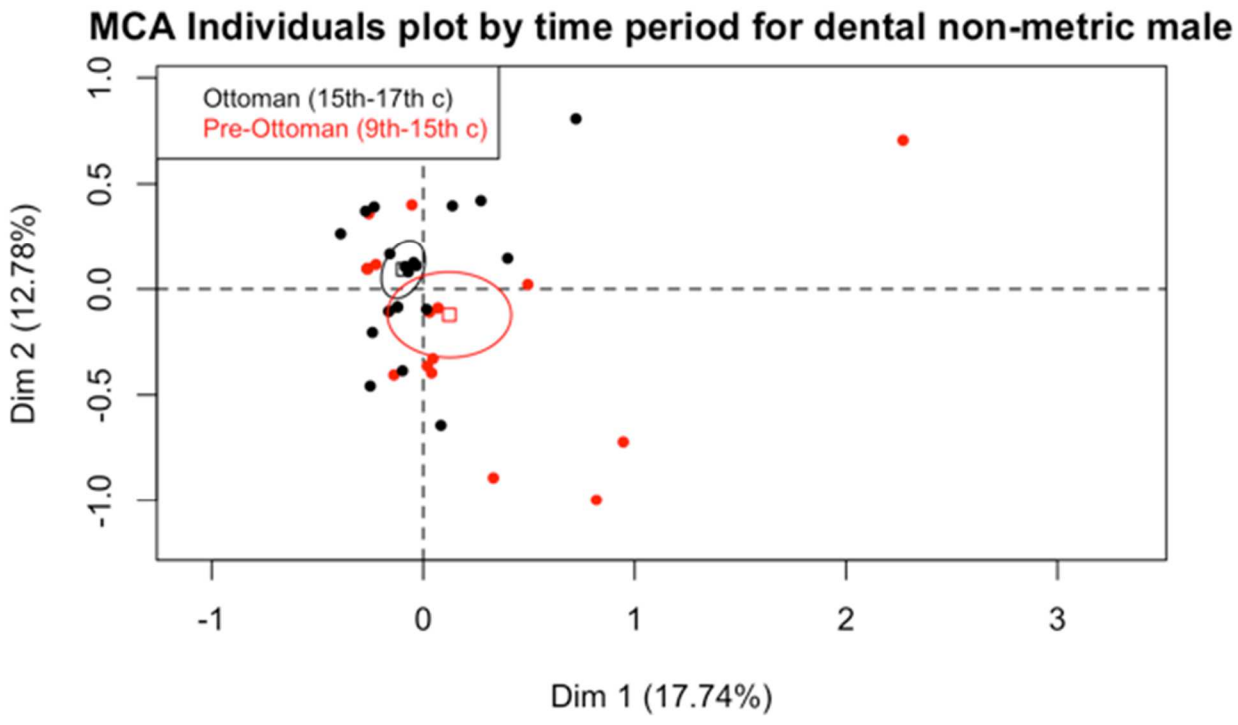

Figure C - 21: Dim 1 and Dim 2 individuals factor plots (MCA) for the dental non-metric - male sample (n=53), colored by time period.

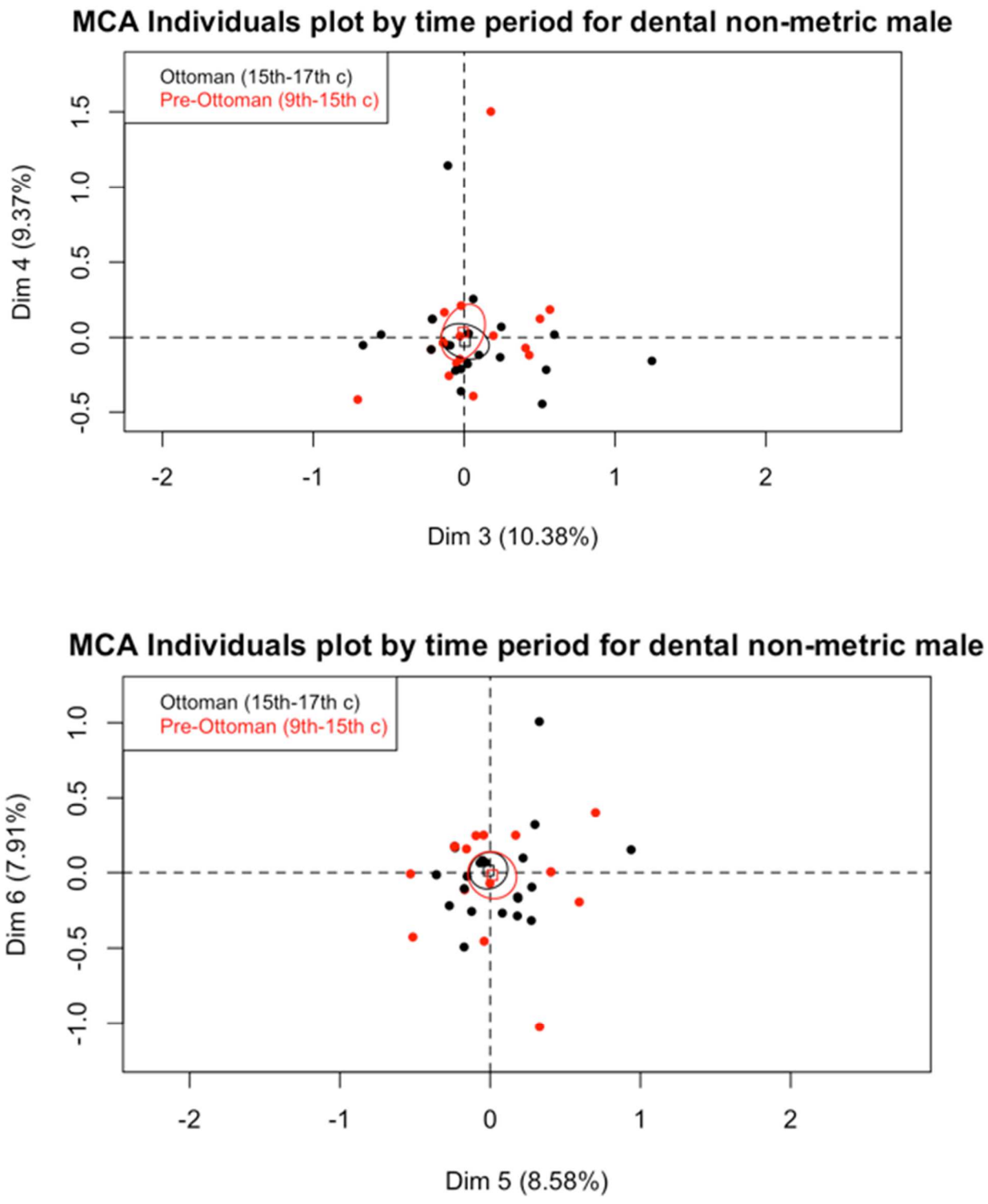

Figure C - 22: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for the dental non-metric - male sample (n=53), colored by time period. Lower: Dim 5 and Dim 6 individuals factor plots (MCA) for the dental non-metric - male sample (n=53), colored by time period.

Cranial non-metric – male sample (n=68)

The first eight MCA dimensions of the cranial non-metric – male sample (n=68) had significant eigenvalues and represented 64.42% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – male sample none of the MANOVA by time period results were significant (Table 7-2). Therefore, the cranial non-metric – male sample does not differ by time period and the null hypothesis cannot be disproven.

Results of the DDA analysis of the first eight MCA dimensions and time period identified no significant correlations with Canon 1 (Figure D-23). There are no identified differences between male individuals from the Ottoman and pre-Ottoman periods.

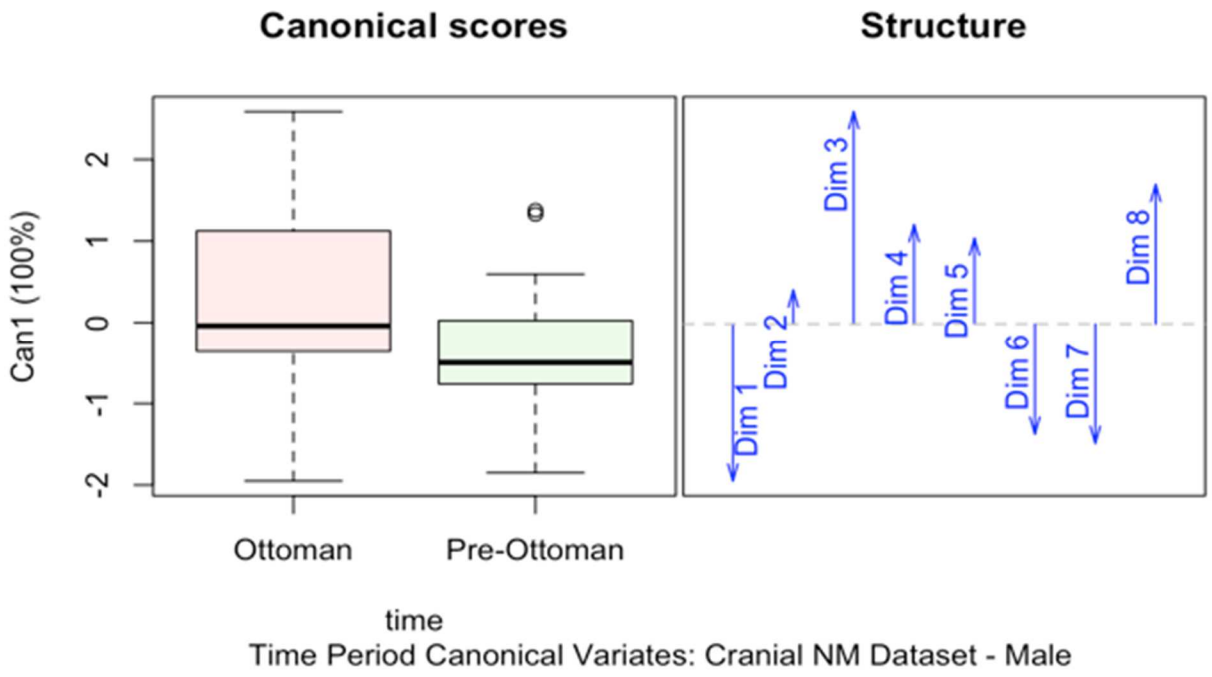

Figure C - 23: Canonical variate 1 by time period for the cranial non-metric - male sample (n=68).

The component loadings and eigenvalues for the first eight MCA dimensions are presented in Table C-4. Using one-way analysis of variance, the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table C-4. None of

the eight significant dimensions separated individuals by time period (Figure C-24 and Figure C-25). Therefore, discussions of the component loadings of each dimension have been omitted. Age does not separate individuals on any of the dimensions.

Table C - 4: MCA component loadings and eigenvalues for cranial non-metric dataset - male sample (n=68).

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8
Metopic Suture - A	0.33	-0.05	-0.42	0.07	-0.07	-0.29	-0.08	-0.12
Metopic Suture - P	-10.92	1.83	15.40	-2.71	0.86	3.92	1.03	1.53
Supranasal Suture - A	-2.67	3.19	2.55	-0.09	0.42	1.70	1.24	4.34
Supranasal Suture - P	1.26	-1.52	-1.16	0.04	-0.19	-0.72	-0.51	-1.68
Frontal Grooves - A	0.21	0.15	-0.90	-0.38	-0.36	0.54	0.20	-0.60
Frontal Grooves - P	-3.06	-0.70	4.34	1.72	1.68	-2.54	-0.96	3.03
Medial Supraorbital Foramen - A	-1.95	3.32	-2.18	-0.37	-5.50	0.98	-0.91	-1.26
Medial Supraorbital Foramen - P	0.73	-1.31	0.81	0.14	1.87	-0.96	0.91	1.38
Lateral Supraorbital Foramen - A	-2.14	0.19	-1.53	0.37	-1.25	0.99	0.29	0.11
Lateral Supraorbital Foramen - P	2.11	-0.19	1.58	-0.39	1.39	-1.08	-0.32	-0.12
Parietal Foramen - A	1.42	-4.77	0.19	1.79	-2.06	2.06	2.86	0.11
Parietal Foramen - P	-0.39	1.22	-0.14	-1.35	1.70	-1.83	-0.82	-0.03
Occipital Mastoid Ossicle - A	-0.52	-0.61	-0.04	-1.15	-0.17	-0.46	0.21	0.64
Occipital Mastoid Ossicle - P	3.20	4.01	0.24	7.52	1.05	2.69	-1.27	-3.75
Occipital Foramen - A	1.82	2.53	-2.31	-1.91	-1.16	-0.43	5.35	2.02
Occipital Foramen - P	-0.66	-1.00	0.98	0.26	0.17	0.06	-0.73	-0.28
Ossicle at Asterion-A	-1.17	0.24	-0.42	-1.40	1.52	0.22	1.03	-0.23
Ossicle at Asterion-P	3.93	-0.79	1.26	4.44	-4.60	-0.63	-2.81	1.83
Condylar Canal - A	-0.09	0.10	-0.64	0.30	0.32	-0.23	-0.21	0.27
Condylar Canal - P	1.17	-1.29	7.91	-3.80	-4.13	3.08	2.88	-3.68
Pharyngeal Tubercle - A	-9.96	9.53	-0.03	2.16	-0.33	2.39	-2.55	0.58
Pharyngeal Tubercle - P	0.79	-0.72	0.00	-0.15	0.07	-0.48	0.57	-0.14
Basilar Sphenoid Bridge - A	-0.47	-0.48	0.28	-0.01	-0.41	-0.62	0.24	-0.57
Basilar Sphenoid Bridge - P	3.88	4.03	-2.39	0.11	3.70	5.64	-2.06	4.60
Flexure of Superior Sagittal Sulcus - Other	7.21	-0.39	-0.56	0.48	-0.09	2.26	-0.31	3.07
Flexure of Superior Sagittal Sulcus - Right	-1.98	0.32	0.45	-0.43	0.09	-0.69	0.10	-0.92
Biasterionic Suture - A	-0.91	-1.67	-0.77	0.02	0.12	0.82	0.17	0.27
Biasterionic Suture - P	2.80	5.10	2.37	-0.06	-0.33	-2.38	-0.46	-0.73
Mastoid Foramen - Extrasutural	0.08	2.07	0.56	1.87	-0.32	-1.49	1.16	-0.80
Mastoid Foramen - In Suture	-0.14	-3.79	-0.33	-1.16	0.18	0.88	-0.71	0.49
Parietal Notch Bone - A	-1.20	-0.98	-0.97	1.71	0.34	-0.43	-0.40	0.18
Parietal Notch Bone - P	3.27	2.49	2.59	-4.36	-0.85	0.99	2.71	-1.25
Accessory Mental Foramen - A	-0.80	0.41	-1.37	1.29	1.41	-0.82	2.27	0.29
Accessory Mental Foramen - P	0.80	-0.38	1.30	-1.26	-1.38	0.86	-2.34	-0.30
Mylohyoid Bridge - A	-0.40	-0.19	0.36	0.18	-0.39	-0.25	0.05	0.26
Mylohyoid Bridge - P	5.00	2.31	-4.13	-5.98	13.07	9.22	-2.06	-3.27
Retromolar Foramen - A	0.12	0.81	-1.11	-1.58	-1.54	-1.53	-0.69	1.42
Retromolar Foramen - P	-0.17	-1.15	1.66	2.34	2.32	2.20	0.93	-2.01
Eigenvalue	0.11	0.10	0.10	0.08	0.07	0.07	0.06	0.05
% Variance	11.46	9.77	9.68	8.38	7.19	6.81	5.82	5.30
Cumulative %	11.46	21.23	30.91	39.29	46.48	53.29	59.11	64.41

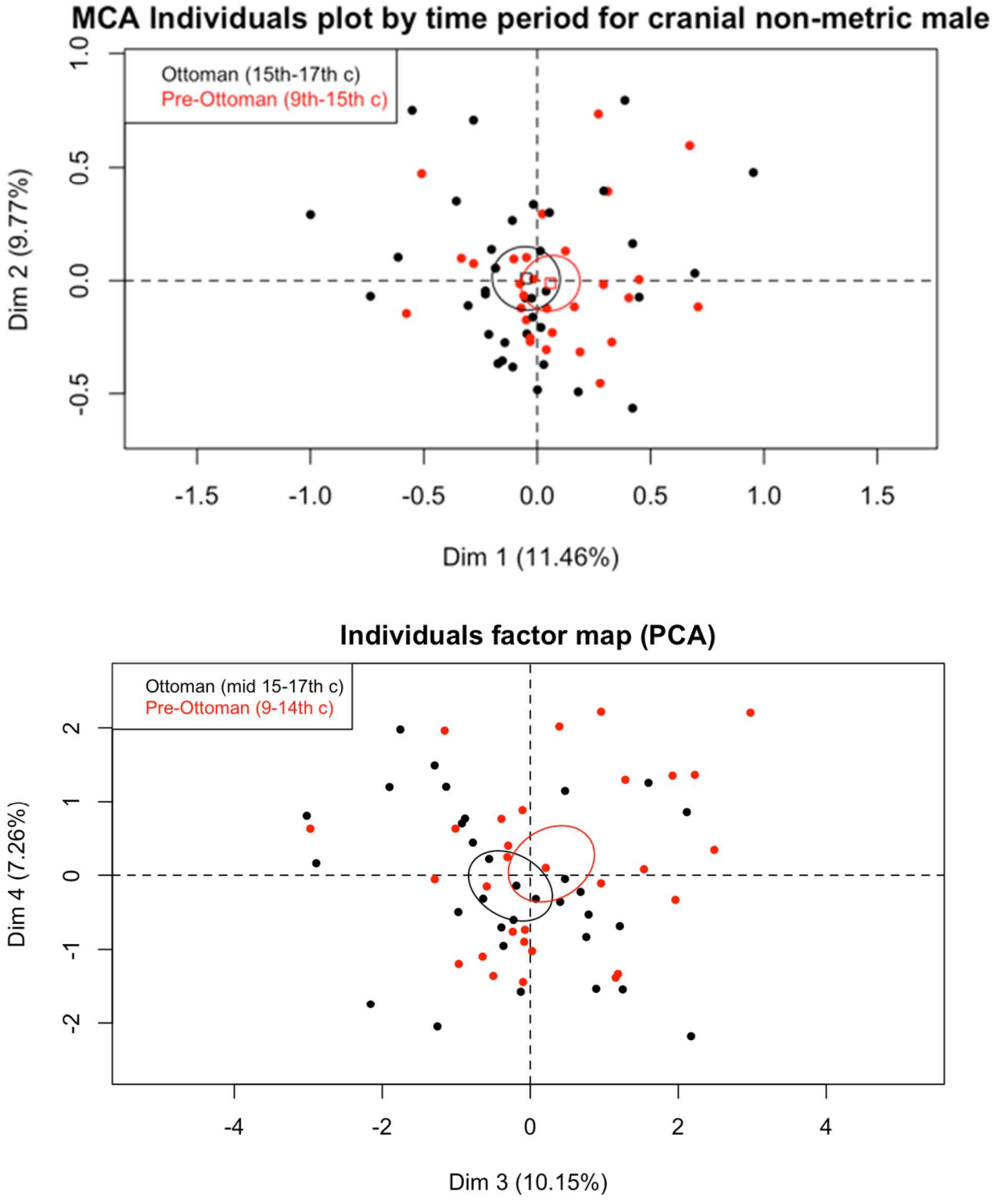

Figure C - 24: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the cranial non-metric - male sample (n=68), colored by time period. Lower: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - male sample (n=68), colored by time period.

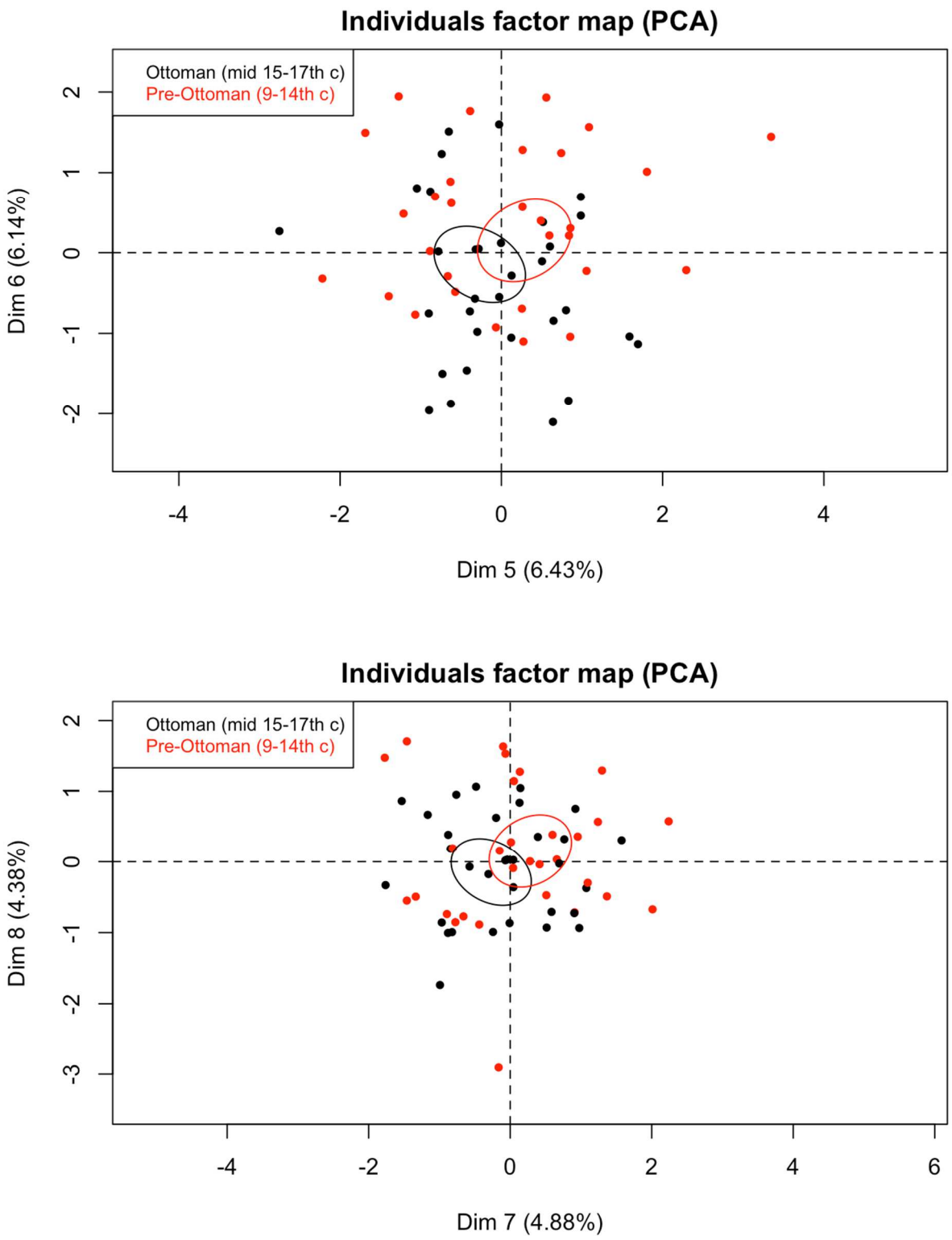

Figure C - 25: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the cranial non-metric - male sample (n=68), colored by time period. Lower: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - male sample (n=68), colored by time period.

Dental metric – female sample (n=58)

Results of the dental metric – female sample multivariate statistical analyses are presented in Chapter 7: Results. One-way analysis of variance found Dimension 1, Dimension 2, and Dimension 5 to not separate individuals by time period, therefore the individual factor plots for these dimensions are presented here in Figure C-23.

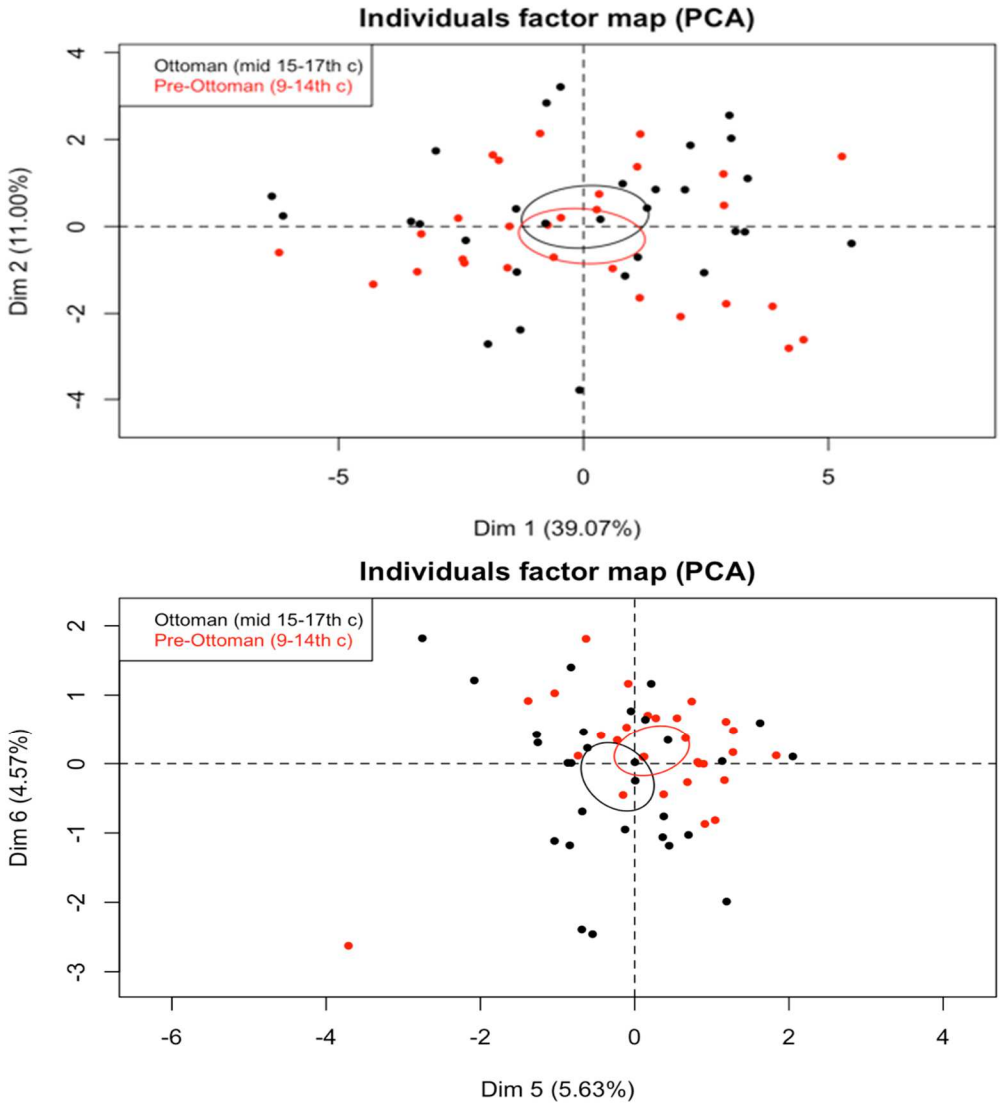

Figure C - 26: Upper: Dim 1 and Dim 2 individuals factor plot (PCA) for the dental metric - female sample (n=58), colored by time period. Lower: Dim 5 and Dim 6 individuals factor plot (PCA) for the dental metric - female sample (n=58), colored by time period.

Cranial metric – female sample (n=70)

Results of the cranial metric – female sample multivariate statistical analyses are presented in Chapter 7: Results. One-way analysis of variance found Dimension 2, Dimension 3, Dimension 4, Dimension 5 and Dimension 6 to not separate individuals by time period, therefore the individual factor plots for Dimension 3 through Dimension 6 are presented in Figure C-24.

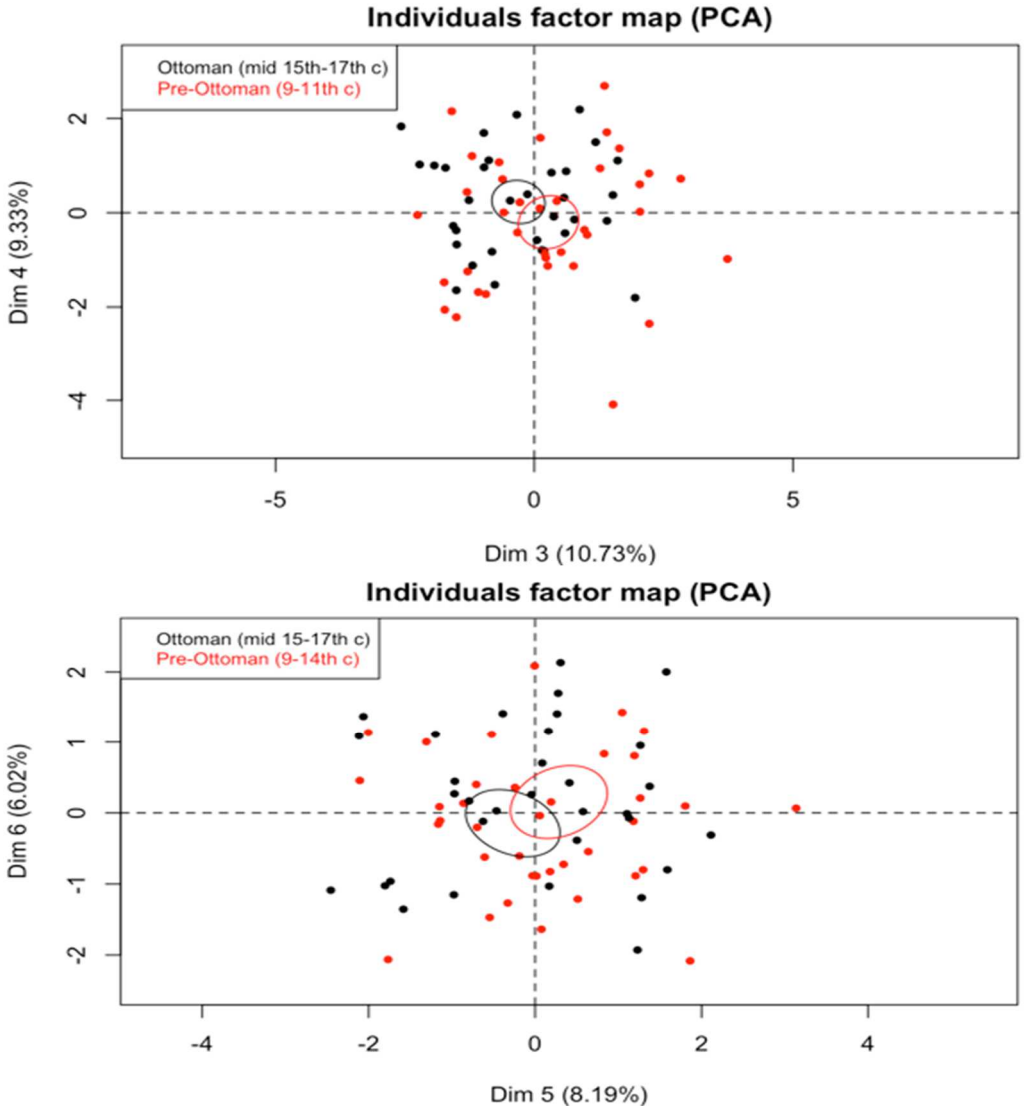

Figure C - 27: Dim 3 and Dim 4 individuals factor plot (PCA) for the cranial metric - female sample (n=70), colored by time period. Lower: Dim 5 and Dim 6 individuals factor plot (PCA) for the cranial metric - female sample (n=70), colored by time period.

Dental non-metric – female sample (n=58)

Results of the dental non-metric – female sample multivariate statistical analyses are presented in Chapter 7: Results. One-way analysis of variance found Dimension 2 through Dimension 6 to not separate individuals by time period, therefore the individual factor plots for Dimension 3 through 6 are presented here in Figure C-28.

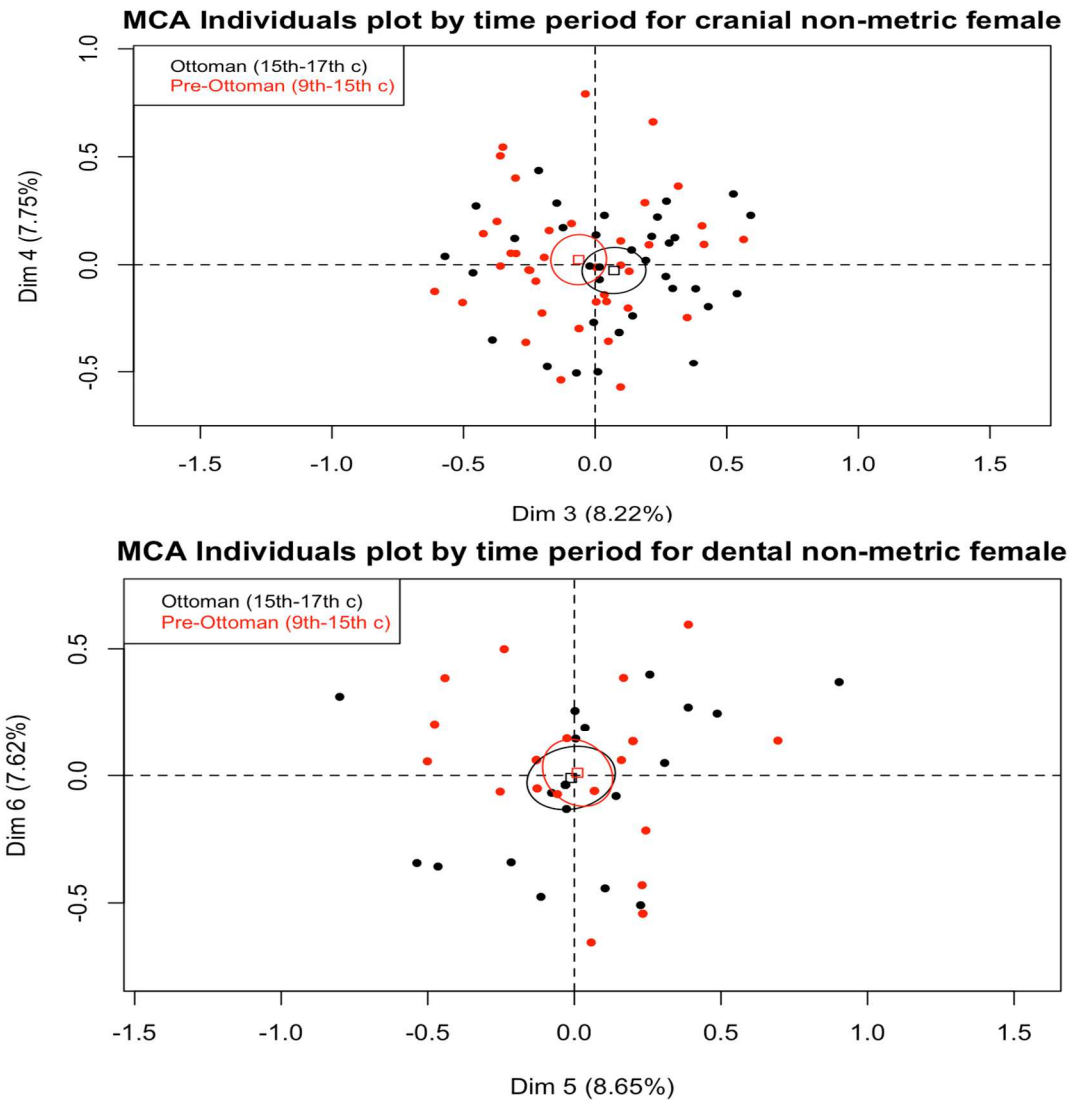

Figure C - 28: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for the dental non-metric - female sample (n=58), colored by time period. Lower: Dim 7 and Dim 8 individuals factor plots (MCA) for the dental non-metric - female sample (n=58), colored by time period.

Cranial non-metric – female sample (n=75)

The first eight MCA dimensions of the cranial non-metric – female sample (n=75) had significant eigenvalues and represented 62.43% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – female sample none of the MANOVA by time period results were significant (Table 7-2). Therefore, the cranial non-metric – female sample does not differ by time period and the null hypothesis cannot be disproven. Results of the DDA analysis of the first eight MCA dimensions and time period identified no significant correlations with Canon 1 (Figure C-23). There are no identified differences between female individuals from the Ottoman and pre-Ottoman groups using DDA.

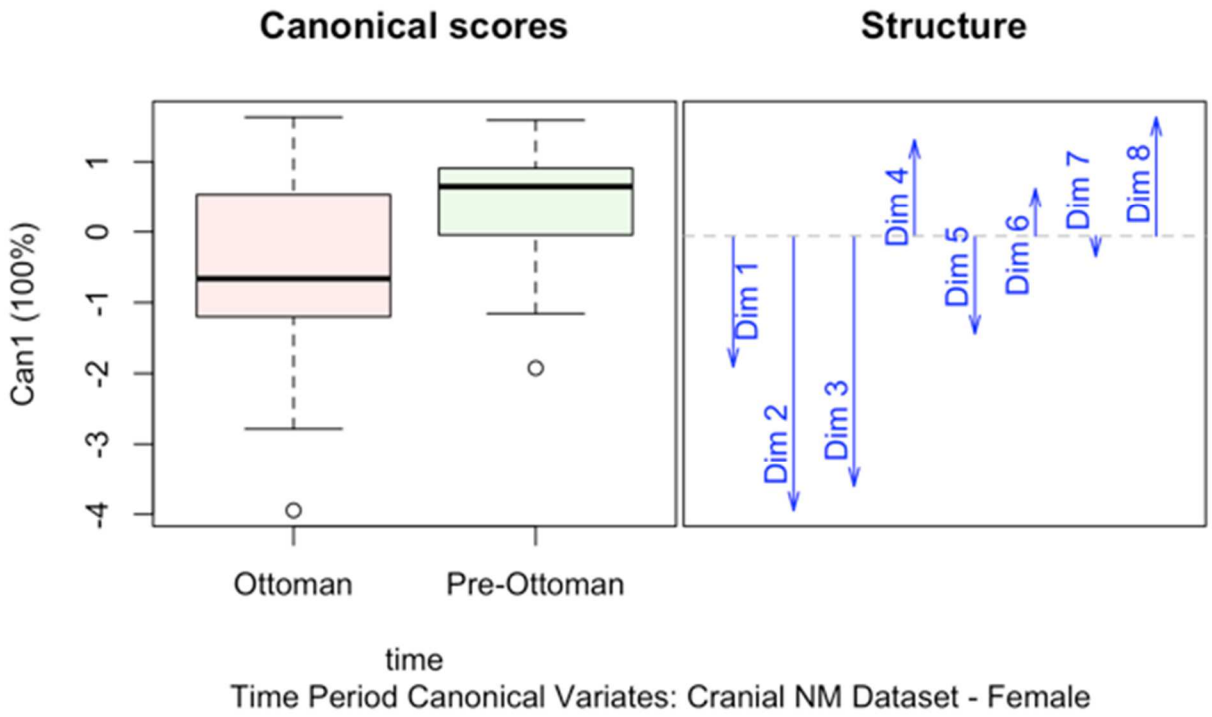

Figure C - 29: Canonical variate 1 by time period for the cranial non-metric - female sample (n=75).

The component loadings and eigenvalues for the first eight components are presented in Table C-5. Using factor analysis the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table C-5. Individual factor plots for the first eight MCA dimensions are presented in Figure C-30 and Figure C-31. Dimension 1, Dimensions 4, Dimension 5, Dimension 6, Dimension 7, and Dimension 8 did not separate individuals by time period (Figure C-30 and Figure C-31). Age did not separate individuals on any of the significant dimensions. Dimension 2 and Dimension 3 separated individuals by time period.

Dimension 2 separated individuals by time period (R^2=0.0655, p-value=0.0267) (Figure C-30): Ottoman females were positively correlated, while pre-Ottoman females were negatively correlated on Dimension 2. Dimension 2 was characterized by the positive correlation of the presence of the accessory mental foramen, parietal notch bone, basilar sphenoid bridging, ossicle at asterion, biasterionic suture, and metopic suture; while the absence of these traits were negatively correlated on Dimension 2 (Table C-5). Therefore, Ottoman females had higher frequencies of the presence of accessory mental foramen, parietal notch bone, basilar-sphenoid bridging, ossicle at asteroid, biasterionic suture, and metopic suture: while pre-Ottoman females had higher frequencies of the absence of these traits.

Dimension 3 also separated individuals by time period (R^2=0.0544, p-value=0.0440) (Figure C-30): Ottoman females were positively correlated while pre-Ottoman females were negatively correlated with Dimension 3. Dimension 3 was characterized by positively correlated right-flexure of the superior sagittal sulcus, medial supraorbital foramen-absence, lateral supraorbital foramen-presence and mastoid foramen-in suture; the opposite of these traits are negatively correlated (non-right-flexure of the superior sagittal sulcus, medial supraorbital foramen-presence, lateral supraorbital foramen-absence and mastoid foramen-extrasutural)

(Table C-5). Therefore, Ottoman females had higher frequencies of right-flexure of superior sagittal sulcus, medial supraorbital foramen-absence, lateral supraorbital foramen-presence and mastoid foramen-in suture: while, pre-Ottoman females had higher frequencies of the opposite of these traits.

Table C - 5: MCA component loadings and eigenvalues for the cranial non-metric - female sample (n=75).

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8
Metopic Suture - A	0.45	-0.44	-0.30	0.34	-0.25	-0.16	-0.02	-0.53
Metopic Suture - P	-7.72	7.60	5.11	-5.88	1.70	1.19	0.17	3.90
Supranasal Suture - A	-3.38	-0.55	-0.02	-0.94	1.20	0.10	0.75	0.00
Supranasal Suture - P	2.42	0.42	0.01	0.66	-0.85	-0.07	-0.51	0.00
Frontal Grooves - A	-0.38	0.14	-0.40	0.00	-0.57	-0.47	0.24	-0.56
Frontal Grooves - P	7.65	-1.11	3.39	0.03	4.86	3.85	-1.96	4.74
Medial Supraorbital Foramen - A	0.70	-3.73	4.85	2.71	-2.17	-1.11	-0.09	2.49
Medial Supraorbital Foramen - P	-0.23	1.25	-1.52	-0.88	0.69	0.94	0.08	-2.08
Lateral Supraorbital Foramen - A	-0.97	-1.02	-1.24	0.06	0.54	-0.70	-0.71	0.16
Lateral Supraorbital Foramen - P	2.18	2.30	2.70	-0.14	-1.21	1.48	1.60	-0.33
Parietal Foramen - A	-0.02	3.88	-0.17	2.82	2.09	0.35	4.06	1.40
Parietal Foramen - P	0.00	-0.81	0.09	-1.57	-1.14	-0.20	-0.90	-0.33
Occipital Mastoid Ossicle - A	0.55	-0.06	0.23	0.65	0.04	-0.13	-0.71	-0.15
Occipital Mastoid Ossicle - P	-3.86	0.45	-1.55	-4.74	-0.29	0.84	4.78	0.94
Occipital Foramen - A	2.74	-0.75	-1.20	-1.97	1.22	-3.02	-1.91	3.59
Occipital Foramen - P	-1.29	0.35	0.57	0.37	-0.24	0.61	0.38	-0.70
Ossicle at Asterion-A	0.14	-1.11	-0.47	1.61	-1.35	0.36	-0.10	0.28
Ossicle at Asterion-P	-0.47	3.62	1.50	-5.21	4.05	-1.13	0.30	-2.31
Condylar Canal - A	-0.64	-0.11	0.07	0.34	0.47	-0.35	0.03	0.03
Condylar Canal - P	5.98	1.06	-0.71	-3.43	-4.60	3.41	-0.33	-0.25
Pharyngeal Tubercle - A	7.70	-0.05	6.93	5.16	3.20	1.37	2.30	-3.97
Pharyngeal Tubercle - P	-0.74	0.00	-0.65	-0.47	-0.78	-0.33	-0.55	0.99
Basilar Sphenoid Bridge - A	0.54	-0.74	-0.63	-0.40	0.61	0.20	0.30	-0.24
Basilar Sphenoid Bridge - P	-3.05	4.04	3.43	2.29	-3.25	-1.16	-1.57	1.23
Flexure of Superior Sagittal Sulcus - Other	2.61	-0.76	-2.92	0.64	1.80	1.27	-0.31	-0.51
Flexure of Superior Sagittal Sulcus - Right	-0.59	0.45	1.75	-0.38	-1.10	-0.30	0.08	0.13
Biasterionic Suture - A	-0.58	-0.82	-0.28	0.31	0.45	1.54	-0.32	0.41
Biasterionic Suture - P	2.94	3.89	1.41	-1.44	-2.08	-7.25	1.38	-1.89
Mastoid Foramen - Extrasutural	1.47	1.35	-1.60	-0.99	0.19	0.22	0.78	2.00
Mastoid Foramen - In Suture	-2.46	-2.32	1.08	0.71	-0.14	-0.16	-0.55	-1.40
Parietal Notch Bone - A	0.22	-1.19	-0.12	-0.83	-0.56	-0.99	0.88	0.05
Parietal Notch Bone - P	-0.78	4.14	0.42	2.71	1.93	3.32	-7.88	-0.40
Accessory Mental Foramen - A	-0.07	-1.45	0.79	-0.59	-0.22	0.57	1.12	0.26
Accessory Mental Foramen - P	0.12	2.53	-1.39	1.00	0.36	-0.99	-1.83	-0.46
Mylohyoid Bridge - A	-0.02	-0.49	0.71	-0.51	-0.21	0.47	-0.18	-0.16
Mylohyoid Bridge - P	0.10	3.21	-4.57	8.70	3.66	-7.99	3.12	1.11
Retromolar Foramen - A	0.30	-0.76	1.01	-0.66	1.59	-1.67	-0.59	-0.75
Retromolar Foramen - P	-0.54	1.37	-1.86	1.14	-2.95	2.88	1.00	1.28
Eigenvalue	0.10	0.09	0.08	0.07	0.07	0.07	0.06	0.06
% Variance	10.84	9.27	8.22	7.75	7.16	7.00	6.26	5.93
Cumulative %	10.80	20.10	28.30	36.10	43.20	50.20	56.51	62.43

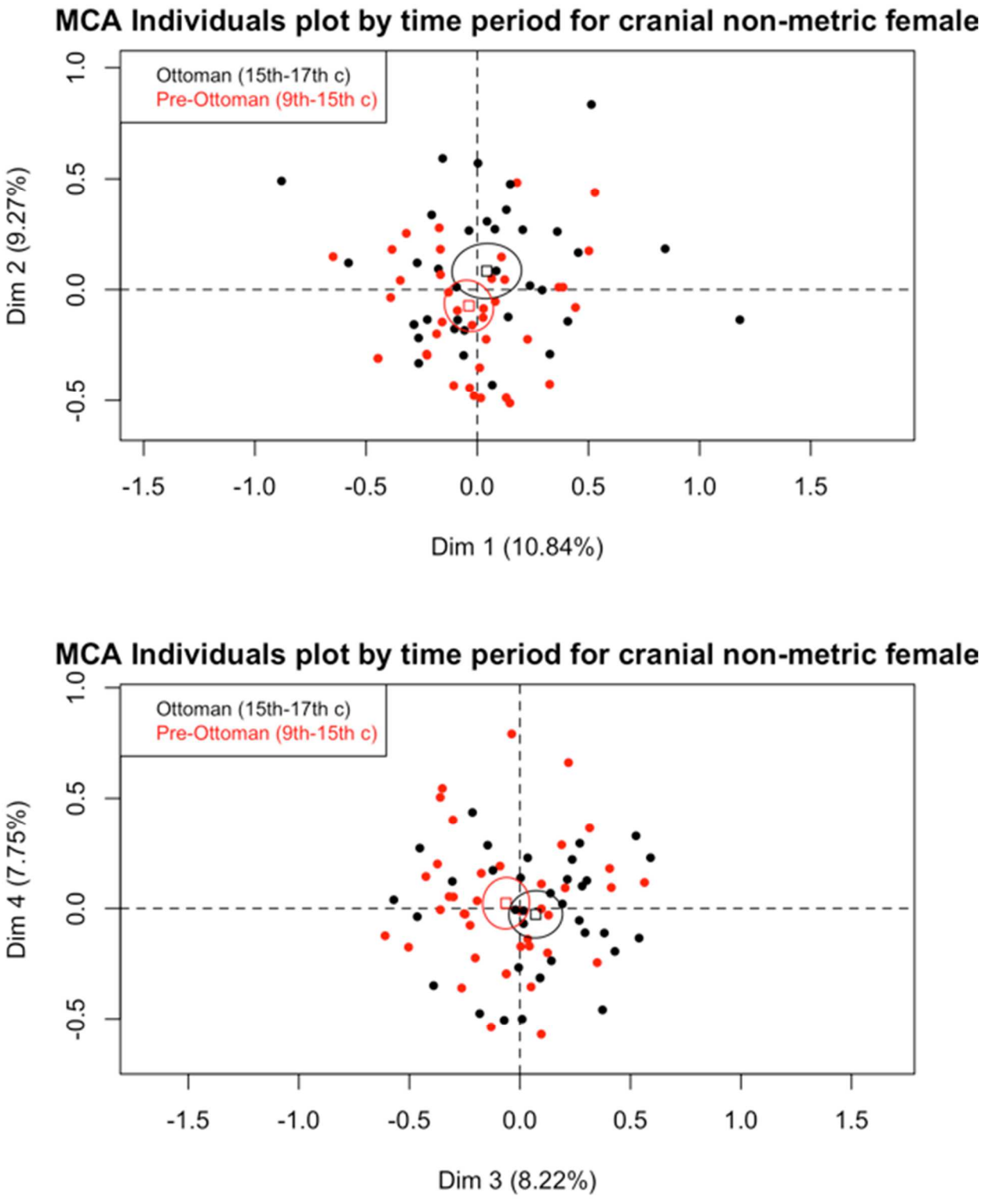

Figure C - 30: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the cranial non-metric - female sample (n=75), colored by time period. Lower: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - female sample (n=75), colored by time period.

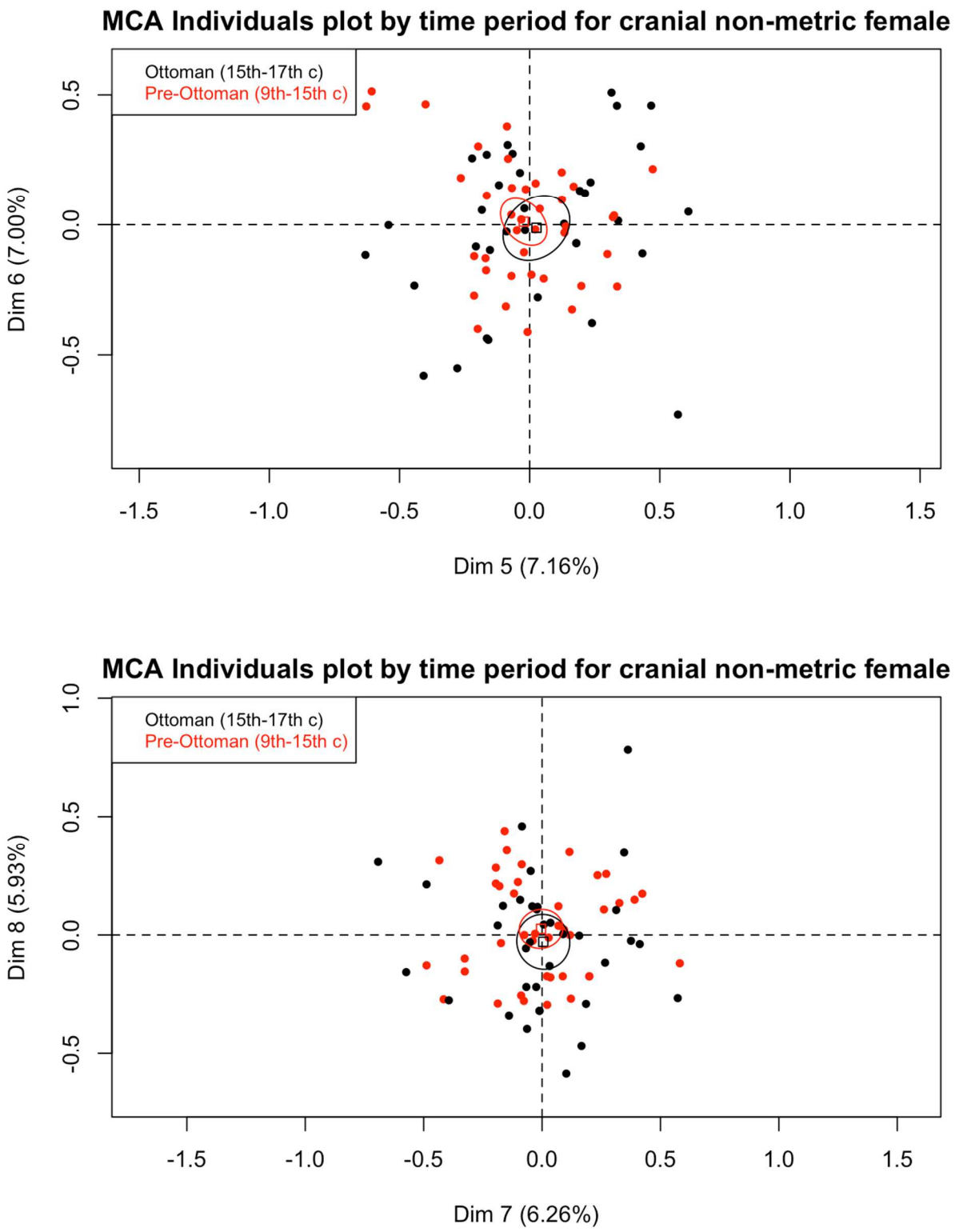

Figure C - 31: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the cranial non-metric - female sample (n=75), colored by time period. Lower: Dim 7 and Dim 8 individuals factor plots (MCA) for the cranial non-metric - female sample (n=75), colored by time period.

Dental metric – indeterminate sample (n=28)

Interpretations of the indeterminate data are tentative at best, due to the small sample size. The first six PCA dimensions of the dental metric - indeterminate sample (n=28) had significant eigenvalues and represented 78.5% of the cumulative variance in the sample (Table 7-1). For the dental metric – indeterminate sample none of the MANOVA by time period results were significant (Table 7-2). Therefore, the dental metric – indeterminate sample does not differ by time period and the null hypothesis cannot be disproven. no DDA was performed for the dental metric – indeterminate sample, due to small sample size and the lack of significant differences from the MANOVA analysis.

The PCA of the dental metric – indeterminate sample was explored by time period. Figure C-32 and Figure C-33 present the individuals factor plots for the first six PCA dimensions. A one-way analysis of variance of the first six PCA dimensions found none separated individuals by time period. Since none of the dimensions separated individuals by time period, a discussion of the component loadings for each dimension has been omitted here, however Table C-6 contains the component loadings and eigenvalues for the PCA dimensions. Variables that significantly contribute to the formation of each dimension are highlighted in gray in Table C-6.

Table C - 6: PCA component loadings and eigenvalues of the dental metric - indeterminate sample (n=28).

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
MD Crown UM2	0.06	-0.09	0.31	0.58	0.04	0.05	0.20
MD Crown LC	3.44	-1.31	-5.43	0.12	0.01	0.00	0.03
MD Crown LM1	1.79	-0.38	-1.13	-0.62	4.61	1.52	0.00
BL Crown UC	1.40	0.37	0.59	0.03	-0.80	-0.94	-0.95
BL Crown UM2	0.71	0.14	0.32	0.76	0.56	0.46	-1.17
BL Crown LI2	0.72	-0.16	-0.46	0.26	-0.28	-0.42	0.12
BL Crown LC	0.54	-0.01	0.12	-0.16	0.05	-0.62	-0.15
BL Crown LP3	5.38	0.08	-0.34	-0.24	0.12	0.07	-0.44
BL Crown LM2	2.53	-0.42	1.93	-2.00	0.17	0.11	0.18
MD CEJ UC	2.05	-0.01	0.41	0.52	-1.21	-1.08	-1.02
MD CEJ UM1	1.26	0.02	0.55	-0.51	0.34	0.91	-0.19
MD CEJ LI2	0.53	0.81	-0.41	0.63	0.13	0.24	0.20
MD CEJ LC	0.76	0.12	0.12	-0.02	-0.19	-0.25	0.32
MD CEJ LP4	0.27	0.55	-0.23	-0.08	-0.07	0.06	0.31
MD CEJ LM1	5.71	5.51	0.12	-0.17	0.05	-0.07	0.13
BL CEJ UI2	1.58	-1.18	-1.39	1.12	-5.55	0.16	-0.06
BL CEJ UP3	0.78	0.39	1.28	-0.87	-1.97	1.94	-0.47
BL CEJ UM2	0.91	-0.76	0.53	0.07	0.42	-0.13	-0.58
BL CEJ LI2	0.56	-0.72	-0.32	-0.40	-0.27	0.00	0.16
BL CEJ LM1	0.53	-0.31	-0.10	-0.08	0.05	0.17	0.62
Eigenvalue	7.83	2.23	1.88	1.47	1.26	1.01	0.95
% Variance	0.39	0.11	0.09	0.07	0.06	0.05	0.05
Cumulative %	0.39	0.50	0.60	0.67	0.73	0.78	0.83

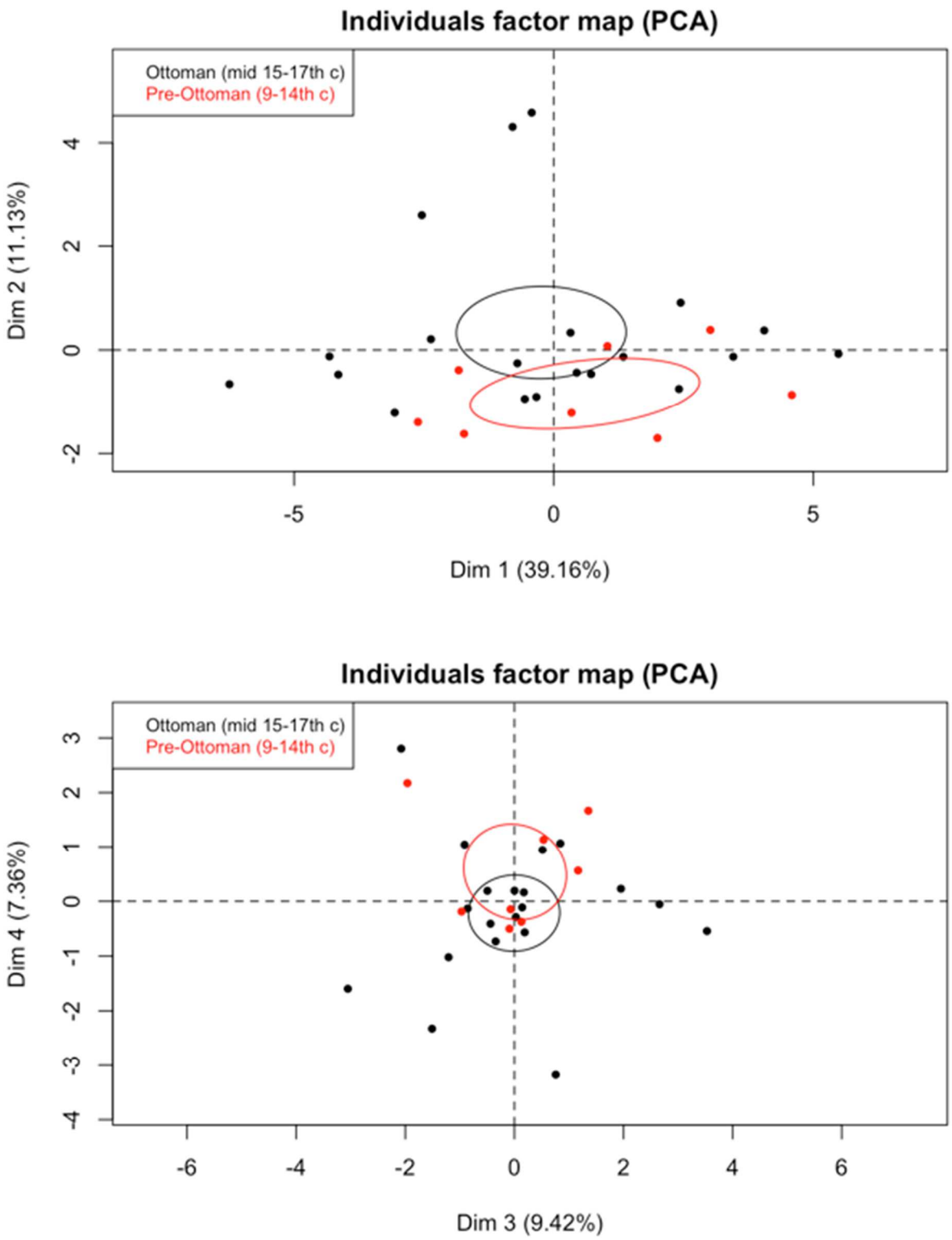

Figure C - 32: Upper: Dim 1 and Dim 2 individuals factor plot (PCA) for the dental metric - indeterminate sample (n=28), colored by time period. Lower: Dim 3 and Dim 4 individuals factor plot (PCA) for the dental metric - indeterminate sample (n=28), colored by time period.

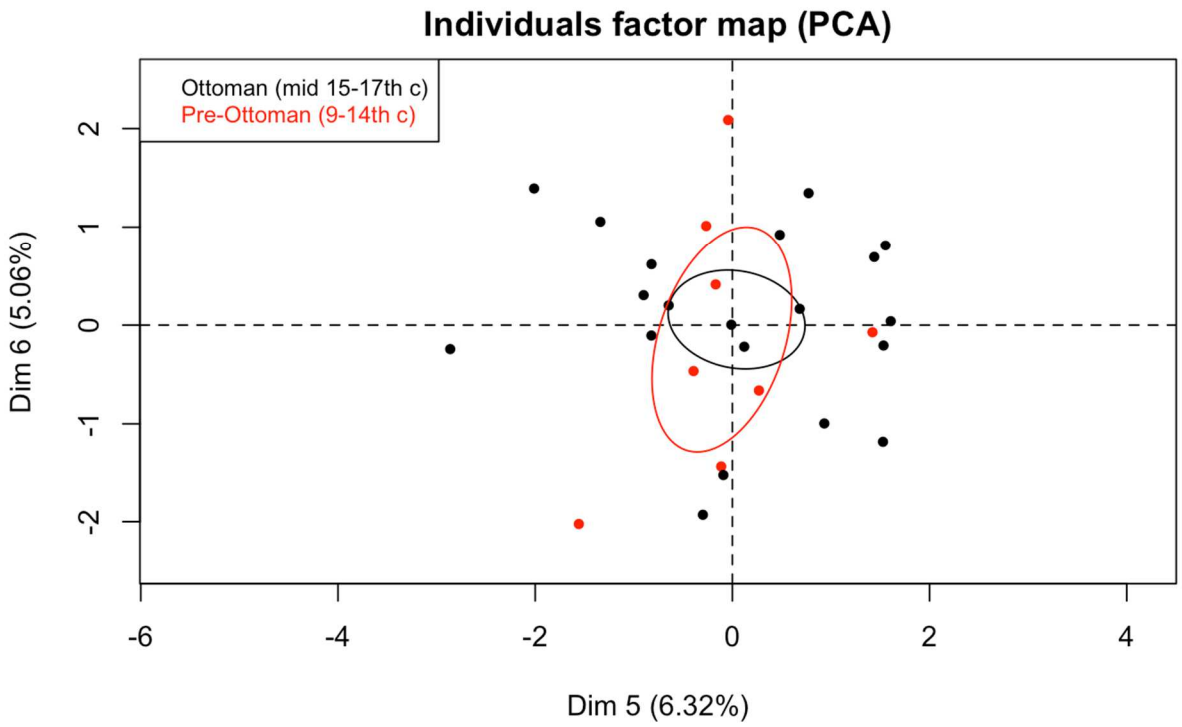

Figure C - 33: Dim 5 and Dim 6 individuals factor plot (PCA) for the dental metric - indeterminate sample (n=28), colored by time period.

Dental non-metric – indeterminate sample (n=29)

Results of the dental non-metric – indeterminate sample multivariate statistical analyses are presented in Chapter 7: Results. One-way analysis of variance found Dimension 2 through Dimension 6 to not separate individuals by time period, therefore the individual factor plots for Dimension 3 through 6 are presented here in Figure C-31.

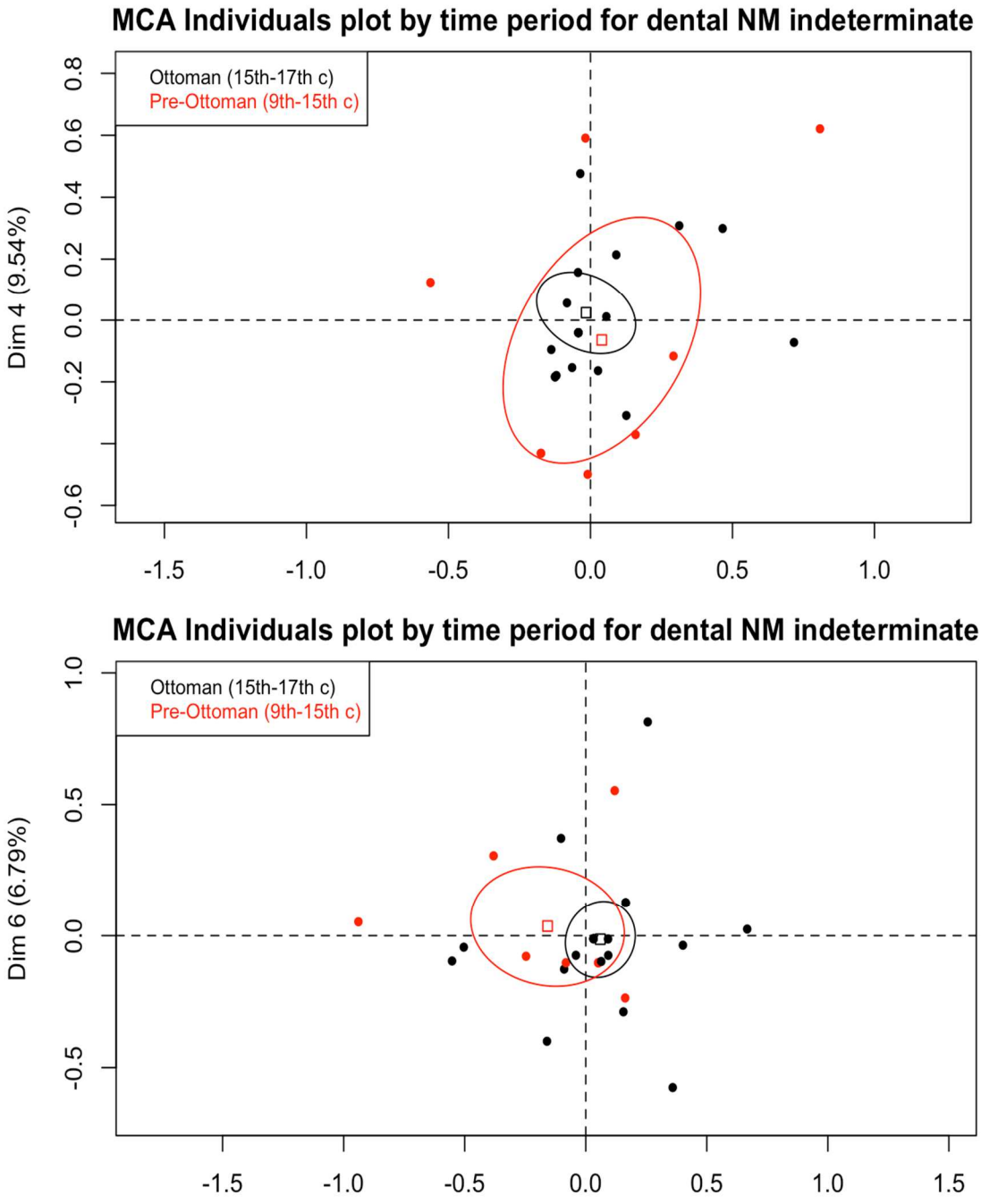

Figure C - 34: Upper: Dim 3 and Dim 4 individuals factor plot (MCA) for the dental non-metric - indeterminate sample (n=28), colored by time period. Lower: Dim 5 and Dim 6 individuals factor plot (MCA) for the dental non-metric - indeterminate sample (n=28), colored by time period.

Cranial non-metric – indeterminate sample (n=102)

The first seven MCA dimensions of the cranial non-metric – indeterminate sample (n=102) had significant eigenvalues and represented 60.06% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – indeterminate sample none of the MANOVA by time period results were significant (Table 7-2). Therefore, the cranial non-metric – indeterminate sample does not differ by time period and the null hypothesis cannot be disproven.

Results of the DDA analysis of the first seven MCA dimensions and time period identified no significant correlations with Canon 1 (Figure C-35). There are no identified differences between indeterminate individuals form the Ottoman and pre-Ottoman groups.

Individual factor plots for the first eight MCA dimensions are presented in Figure C-36 and Figure C-37. Examination of the individual factor plots using factor analysis found no separation of individuals by time period on any of the dimensions (Figure C-36 and Figure C-37). Therefore, discussion of the component loadings for each dimension has been omitted here, but the component loadings and eigenvalues for the first seven MCA dimensions are presented in Table C-7. Using one-way analysis of variance the variables that contributed significantly to the formation of each dimension are highlighted in gray in Table C-7.

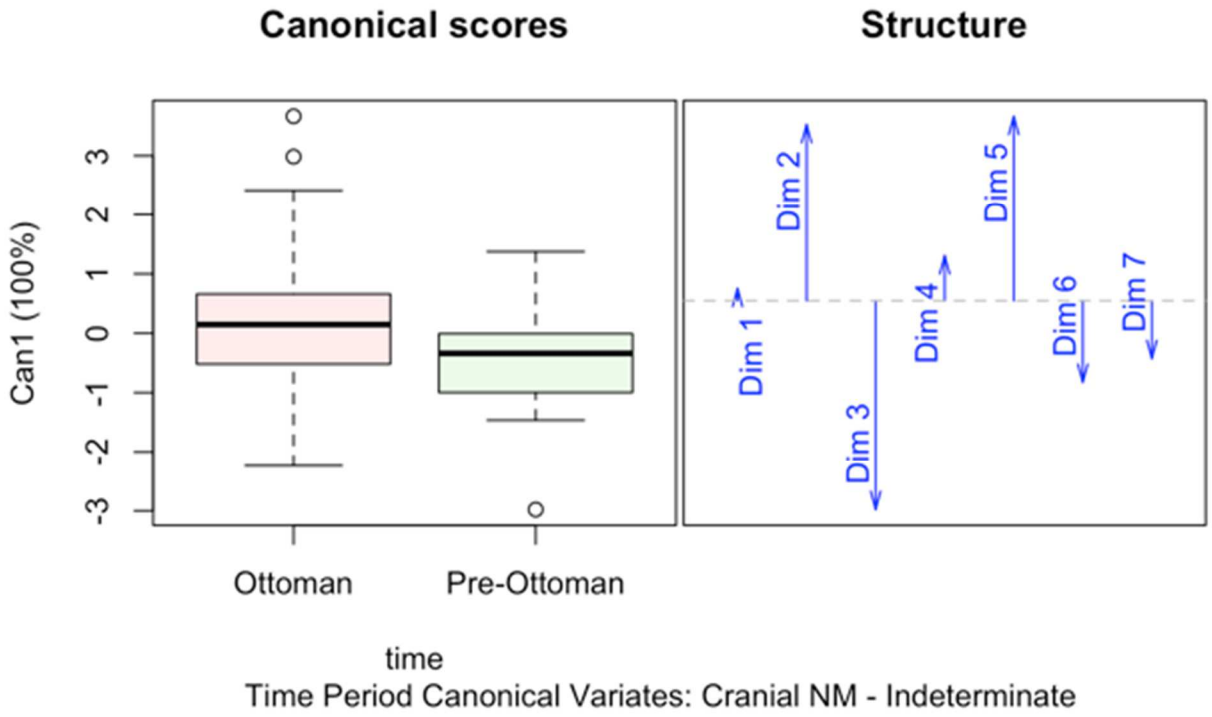

Figure C - 35: Canonical variate 1 by time period for the cranial non-metric - indeterminate sample (n=102).

Table C - 7: MCA component loadings and eigenvalues for cranial non-metric dataset - indeterminate sample (n=102).

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7
Metopic Suture - A	-0.18	-0.36	-0.30	0.06	0.36	0.20	-0.30
Metopic Suture - P	5.94	10.93	8.95	-1.74	-3.65	-1.97	3.08
Supranasal Suture - A	-0.01	4.74	1.40	0.38	1.44	-3.22	1.35
Supranasal Suture - P	0.00	-2.14	-0.64	-0.17	-0.63	1.42	-0.58
Frontal Grooves - A	-0.19	0.06	0.36	0.50	-0.78	0.56	0.54
Frontal Grooves - P	3.10	-0.32	-2.02	-2.87	4.82	-3.45	-3.50
Medial Supraorbital Foramen - A	-0.37	-0.27	4.90	0.74	-2.76	-0.18	-0.98
Medial Supraorbital Foramen - P	0.19	0.14	-2.55	-0.38	1.40	0.28	1.43
Lateral Supraorbital Foramen - A	-1.10	0.43	1.07	0.65	1.43	2.13	-1.43
Lateral Supraorbital Foramen - P	1.36	-0.58	-1.41	-0.90	-2.05	-2.89	1.90
Parietal Foramen - A	0.44	2.74	-2.32	3.09	2.20	-0.10	2.56
Parietal Foramen - P	-0.09	-0.59	1.52	-1.92	-1.31	0.06	-0.52
Occipital Mastoid Ossicle - A	-0.76	0.09	-0.12	-0.19	0.04	0.04	0.08
Occipital Mastoid Ossicle - P	12.62	-1.61	1.94	3.02	-0.69	-0.63	-1.17
Occipital Foramen - A	-1.49	-0.77	-1.68	2.44	-1.63	2.88	0.93
Occipital Foramen - P	1.03	0.51	1.11	-0.56	0.37	-0.68	-0.23
Ossicle at Asterion-A	-1.28	-0.11	-0.23	-0.43	-0.08	0.21	0.79
Ossicle at Asterion-P	9.73	0.85	1.67	3.15	0.57	-1.52	-5.75
Condylar Canal - A	-0.17	0.54	-0.20	0.20	-0.30	0.03	0.07
Condylar Canal - P	1.98	-6.44	2.40	-2.59	3.88	-0.46	-1.02
Pharyngeal Tubercle - A	-1.19	-0.29	0.38	2.80	0.59	-0.72	-0.25
Pharyngeal Tubercle - P	2.40	0.59	-0.76	-5.54	-3.54	4.12	1.38
Basilar Sphenoid Bridge - A	-0.58	-0.02	0.43	-0.39	0.37	-0.14	0.31
Basilar Sphenoid Bridge - P	7.64	0.32	-5.95	5.50	-4.96	1.83	-4.12
Flexure of Superior Sagittal Sulcus - Other	3.37	-2.17	-0.39	0.96	-0.19	-1.45	0.59
Flexure of Superior Sagittal Sulcus - Right	-1.38	2.71	0.46	-1.08	0.22	0.56	-0.23
Biasterionic Suture - A	-0.49	0.03	-0.17	0.47	-0.89	-0.35	-0.94
Biasterionic Suture - P	4.03	-0.20	1.29	-3.66	6.57	2.57	6.99
Mastoid Foramen - Extrasutural	1.80	2.59	-1.83	0.16	0.93	1.61	-2.01
Mastoid Foramen - In Suture	-1.70	-2.41	0.59	-0.05	-0.31	-0.58	0.72
Parietal Notch Bone - A	-1.04	-0.27	-0.82	-0.64	-0.04	-0.40	-0.20
Parietal Notch Bone - P	7.19	1.82	5.43	4.25	0.23	2.62	3.99
Accessory Mental Foramen - A	-0.88	1.50	1.72	1.10	0.79	-0.25	-0.28
Accessory Mental Foramen - P	0.79	-1.40	-1.72	-1.10	-0.82	0.27	0.28
Mylohyoid Bridge - A	-0.33	0.36	-0.43	-0.01	-0.12	-0.15	-0.08
Mylohyoid Bridge - P	13.40	-14.27	16.97	0.62	13.33	16.13	8.05
Retromolar Foramen - A	-0.52	-1.08	0.39	0.78	-0.14	-0.32	-0.01
Retromolar Foramen - P	2.29	5.00	-1.86	-3.49	0.64	1.45	0.04
Eigenvalue	0.13	0.11	0.09	0.07	0.07	0.06	0.05
% Variance	13.28	11.09	9.12	7.77	7.34	6.09	5.37
Cumulative %	13.30	24.40	33.50	41.30	48.60	54.70	60.06

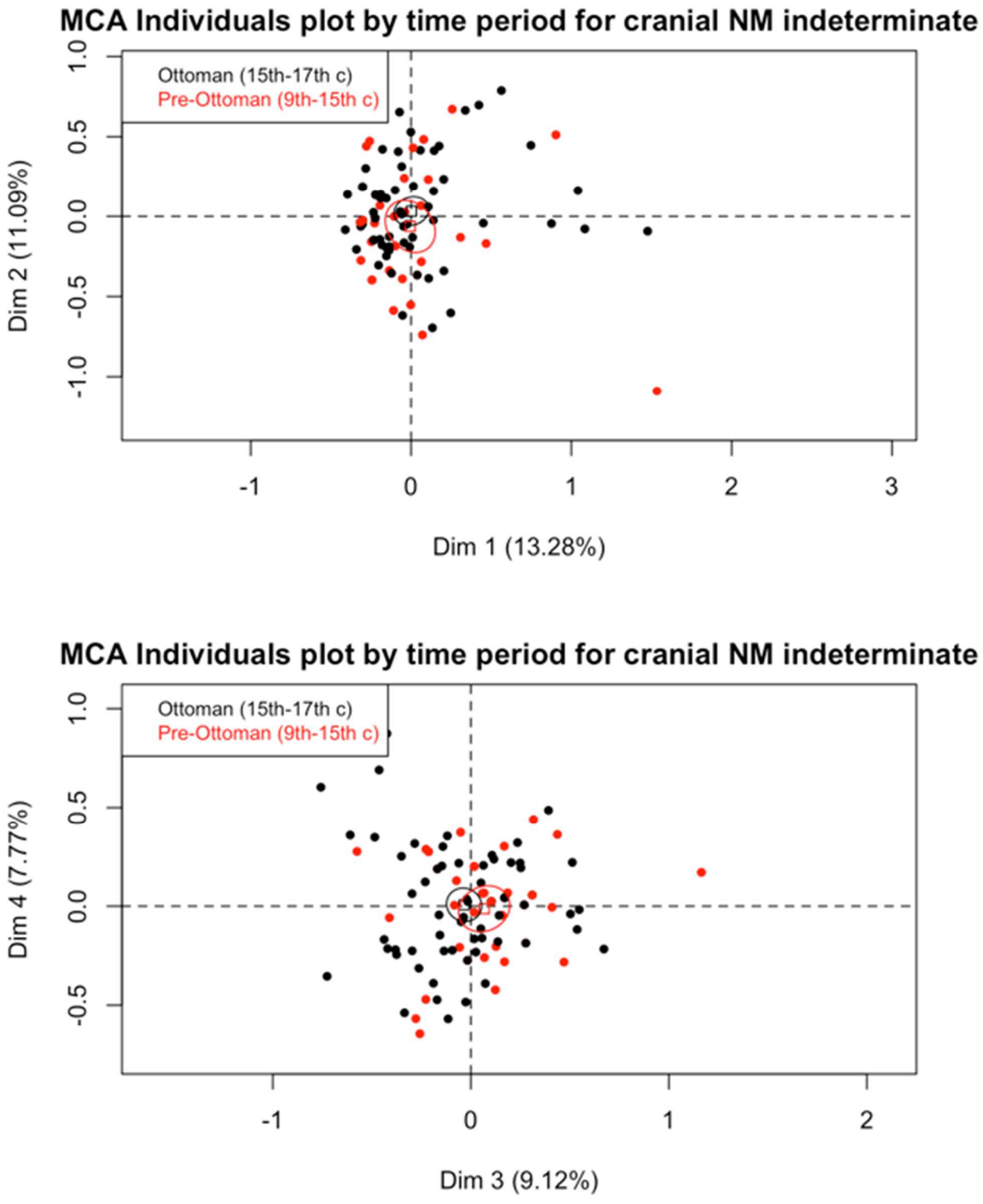

Figure C - 36: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the cranial non-metric - indeterminate sample (n=102), colored by time period. Lower: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - indeterminate sample (n=102), colored by time period.

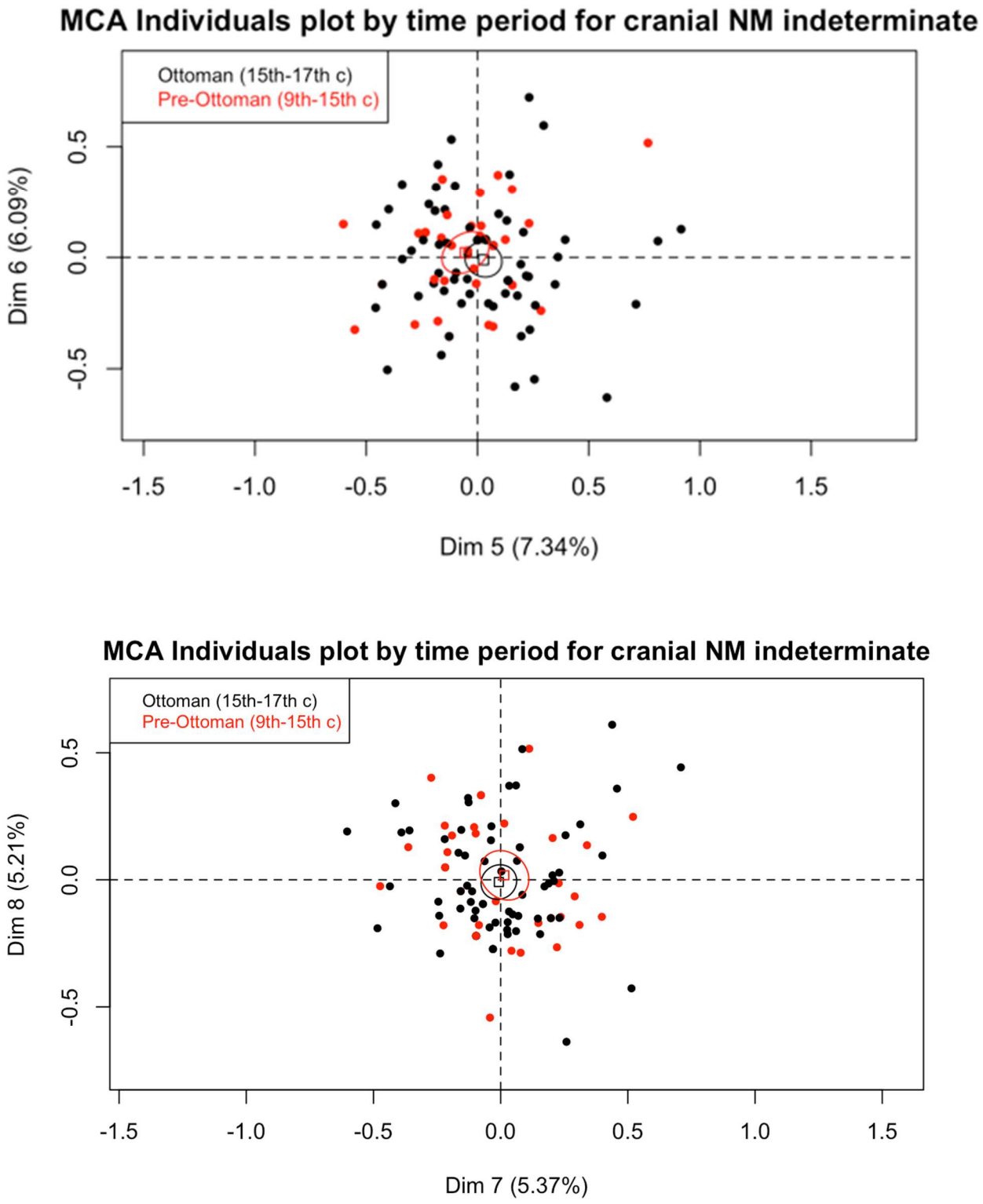

Figure C - 37: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the cranial non-metric - indeterminate sample (n=102), colored by time period. Lower: Dim 7 and Dim 8 individuals factor plots (MCA) for the cranial non-metric - indeterminate sample (n=102), colored by time period.

APPENDIX D

RESULTS OF THE BIODISTANCE ANALYSES BY SITE NAME

Site name comparisons were not included in the results chapter because they did not directly address the project hypotheses. In addition, sample sizes are small once divided by site name, and especially so once further divided by sex. Therefore, the results of all site name comparisons are provided here as an appendix and provide additional information concerning relationships between sites. Unless stated otherwise, the statistical analyses presented in this chapter used the reduced and imputed dataset. Summary statistics of the final datasets can be found in Appendix A. The demographic breakdowns of each dataset can be found in Appendix B.

For each data set, the principal components analysis for the metric data or multiple correspondence analysis for non-metric data was run and significant eigenvalues were identified (see Table 7-1). Dimensions with significant eigenvalues were then subjected to a MANOVA test (Table D-1). Significant MANOVA tests were followed-up with descriptive discriminate analysis (DDA) to identify if the dimensions could successfully separate individuals based on site name. The basic question of concern was whether the PCA and MCA dimensions could be used to identify group membership. The groups in question are the sites, Šibenik-Sv. Lovre, Koprivno-Križ I, Koprivno-Križ II, and Drinovci-Greblje. In addition, the PCA/MCA results were explored using the *dimdesc* function of the *FactoMineR* package which performed a one-way analysis of variance test to identify variables (including supplementary variables such as site name) that significantly correlated with each dimension (Le et al. 2008). The R^2 and *p*-values are

provided for any significant correlations between individuals and site name. Lastly, the total sample non-metric datasets were also subjected to mean measure of divergence (MMD) and multidimensional scaling (MDS). Due to sample size differences between groups (see demographics of datasets in Appendix B), only the total sample datasets could be used with confidence and therefore no comparisons using the male only or female only samples are presented. Multidimensional scaling (MDS) was performed only by site name for the cranial and dental non-metric – total samples, because the time period comparisons only had two groups, and MDS requires at least three groups to make a comparison. The lower the stress value, the better the rank order correlation between similarity scores and distances between pairs of points (Drennan, 2009). The stress value indicates how accurate the picture is, the general rule of thumb is that a stress value of about 0.1500 or lower is associated with interpretable configurations and is usually achieved within three dimensions (Drennan, 2009).

The follow-up analyses for the samples are organized by sample and data-type, and are presented in the following sections. The total sample comparisons are presented first, followed by the male-only, female-only and indeterminate-only samples.

Table D - 1: MANOVA results by site name.

Time Period	Dim. used	n	Pillai	F	p-value	Wilks	F	p-value	Hotelling-Lawley	F	p-value	Roy	F	p-value
Total Sample														
Dent Metric	4	139	0.10	1.21	0.28	0.90	1.21	0.28	0.11	1.2	0.28	0.07	2.43	0.05
Cr. Metric	6	132	0.43	3.47	0.00	0.62	3.58	0.00	0.54	3.66	0.00	0.33	6.86	0.00
Dent NM	8	140	0.48	3.14	0.00	0.57	3.38	0.00	0.68	3.63	0.00	0.54	8.84	0.00
Cr. NM	8	245	0.26	2.79	0.00	0.76	2.82	0.00	0.29	2.85	0.00	0.17	4.90	0.00
Cr. NM Adult	8	130	0.33	1.87	0.01	0.70	1.90	0.01	0.39	1.92	0.01	0.24	3.60	0.00
Male Sample														
Dent Metric	4	53	0.26	1.11	0.35	0.75	1.15	0.32	0.32	1.19	0.30	0.29	3.43	0.02
Cr. Metric	6	62	0.83	3.51	0.00	0.35	3.78	0.00	1.38	3.96	0.00	0.86	7.86	0.00
Dent NM	7	53	0.71	1.98	0.01	0.44	1.99	0.01	1.00	1.99	0.01	0.56	3.59	0.00
Cr. NM	8	68	0.49	1.44	0.10	0.56	1.51	0.07	0.68	1.58	0.05	0.52	3.84	0.00
Female Sample														
Dent Metric	5	58	0.49	2.03	0.02	0.56	2.13	0.01	0.69	2.22	0.01	0.53	5.48	0.00
Cr. Metric	6	70	0.40	1.63	0.06	0.64	1.66	0.05	0.51	1.68	0.05	0.36	3.73	0.00
Dent NM	7	58	0.60	1.80	0.02	0.49	1.87	0.02	0.87	1.92	0.01	0.60	4.30	0.00
Cr. NM	8	75	0.47	1.52	0.06	0.59	1.53	0.06	0.59	1.54	0.06	0.35	2.87	0.01
Indeterminate Sample														
Dent Metric	6	28	0.60	0.88	0.61	0.82	0.82	0.67	0.78	0.78	0.73	0.40	1.4	0.26
Dent NM	6	29	1.27	2.68	0.00	0.08	4.53	0.00	7.43	7.71	0.00	6.93	25.4	0.00
Cr. NM	7	102	0.28	1.41	0.11	0.73	1.44	0.10	0.34	1.47	0.09	0.25	3.40	0.00

Total Sample Comparisons

The dental metric, cranial metric, dental non-metric, and cranial non-metric results for the total sample are presented in this section. In addition, the cranial non-metric results using an adult only sample are presented.

Dental metric – total sample (n=139)

The first four components of the dental metric – total sample (n=139) had significant eigenvalues and represented 64.5% of the cumulative variance in the sample (Table 7-1). For the dental metric – total sample none of the MANOVA by site name results were significant (Table D-1). The dental metric – total sample does not differ by site name and the null hypothesis cannot be disproven. Results of the DDA analysis using the first four PCA dimensions by site

name identified no significant differences between individuals when grouped by site name (Canon 1: F=1.205, p-value=0.28) (Figure D-1).

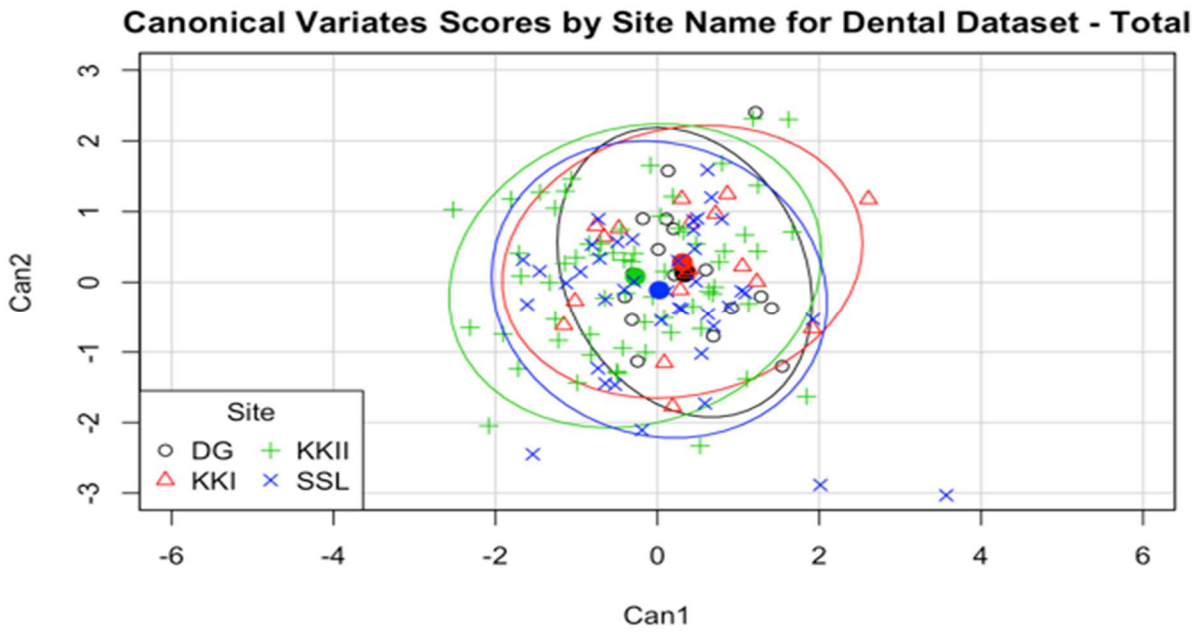

Figure D - 1: Canonical variants 1 and 2 by site name for the dental metric - total sample (n=139).

The PCA of the dental metric – total sample was explored using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each PCA dimension (Husson, et al. 2011). The component loadings and eigenvalues are presented in Table C-1 of Appendix C. Individual factor plots of the first four PCA dimensions are presented in Figure D-2 and Figure D-3. Using a one-way analysis of variance the dental metric – total sample was explored by site name. None of the first four PCA dimensions separated individuals by site name. Therefore discussion of the variables that characterize each of these components has been omitted (see Table C-1 for component loadings).

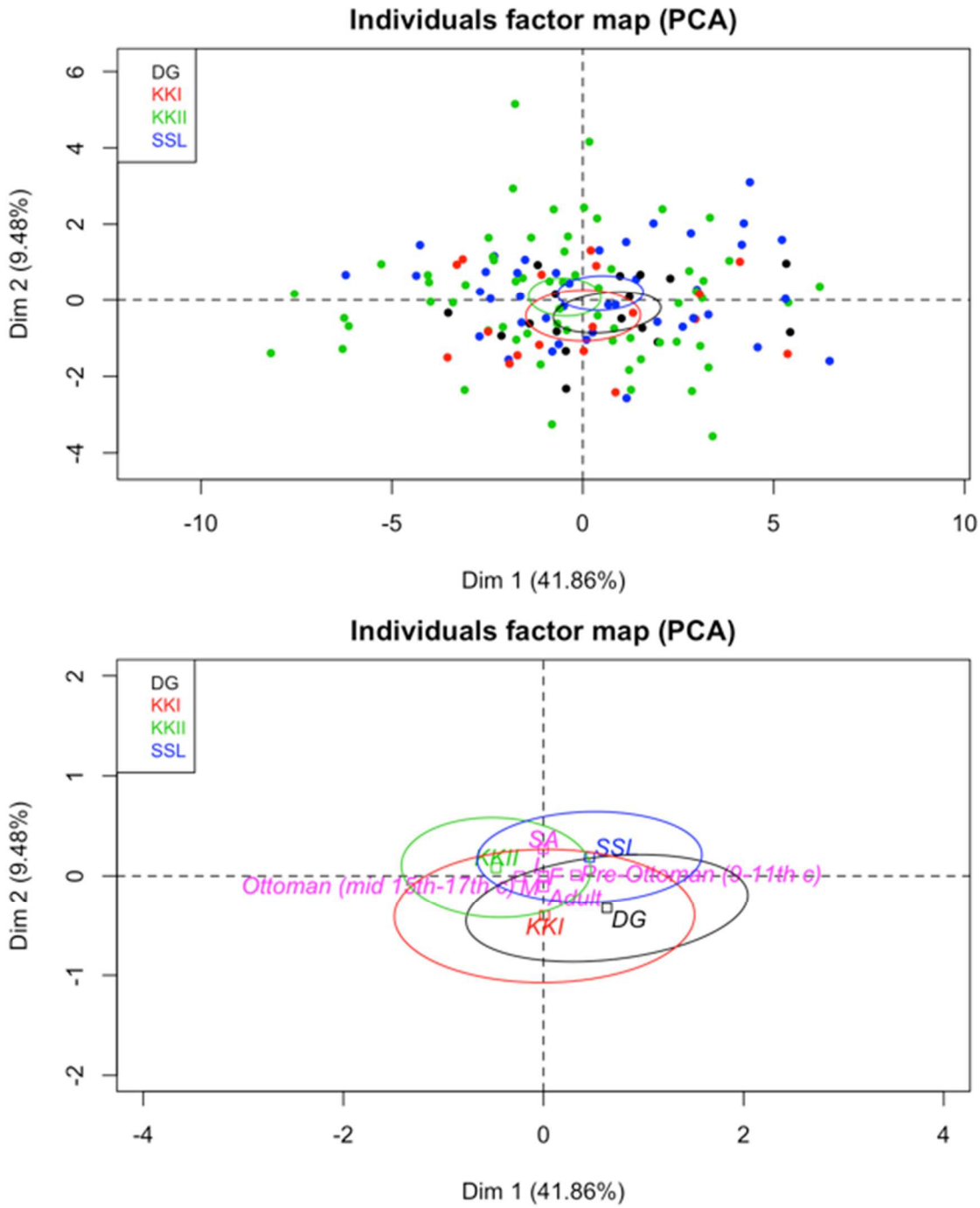

Figure D - 2: Upper: Dim 1 and Dim 2 individuals factor plot (PCA) for the dental metric dataset - total sample (n=139), colored by site name. Lower: individual data points are removed and barycenters of the individuals belonging to each site name are retained.

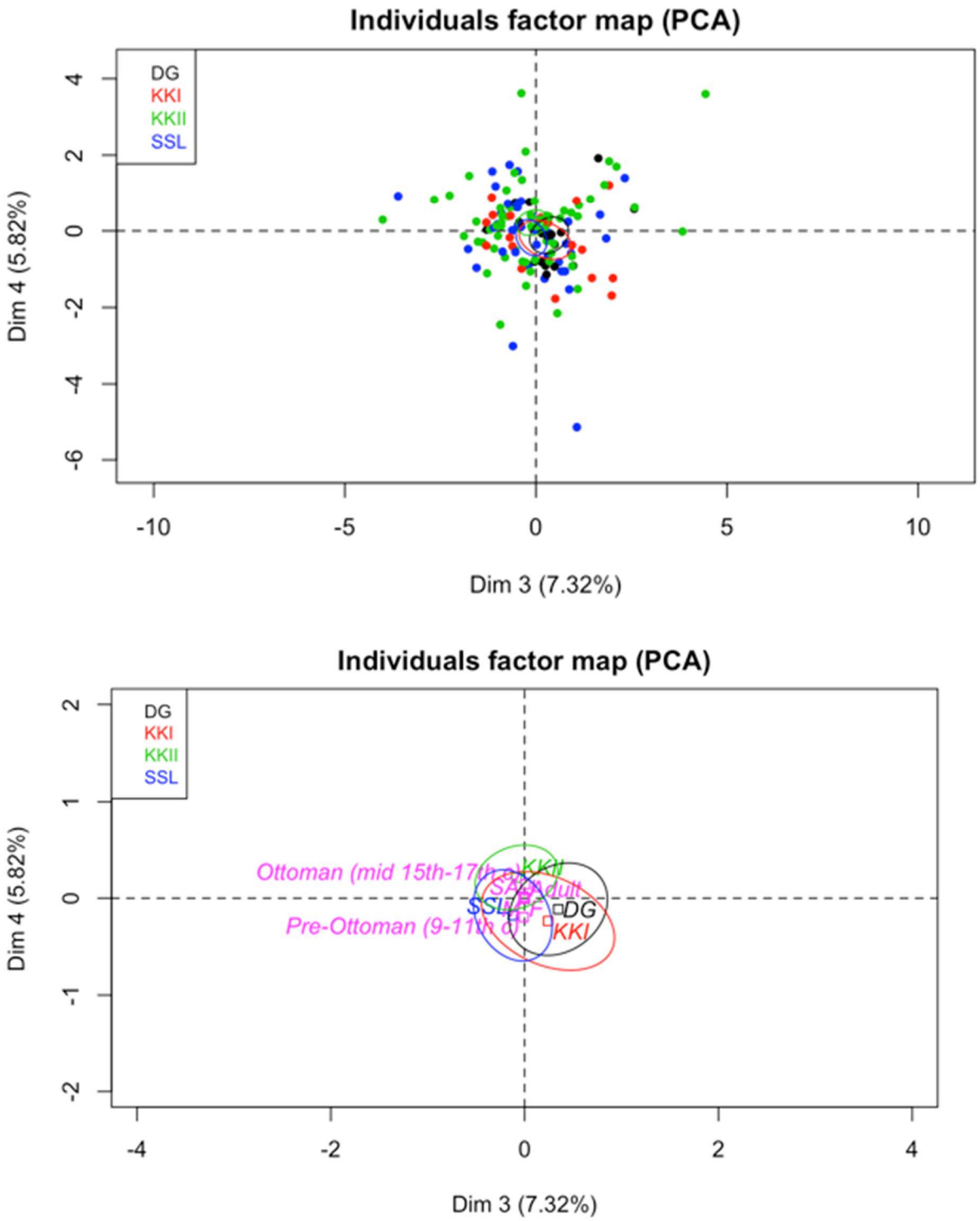

Figure D - 3: Upper: Dim 3 and Dim 4 individuals factor plot (PCA) for the dental metric dataset - total sample (n=139), colored by site name. Lower: individual data points are removed and barycenters of the individuals belonging to each site name are retained.

Cranial metric – total sample (n=132)

The first six dimensions of the cranial metric dataset-total sample (n=132) had significant eigenvalues and represented 69% of the cumulative variance in the sample (Table 7-1). For the cranial metric – total sample all four of the MANOVA by site name significance tests were significant (Table D-1). Therefore, differences between sites were identified using the cranial metric – total sample.

Results of the DDA analysis of the first six principal components and site name identified a significant correlation with Canon 1 (Canon 1: F=3.58, *p*-value=1.7e-06) and with Canon 2 (Canon 2: F=2.54, *p*-value=0.0061) (Figure D-4). The third canon was not significant.

Canon 1 represented 60.86% of the sample variation. For Canon 1, Dimension 1, Dimension 4 and Dimension 6 are negatively correlated, while Dimension 2, Dimension 3 and Dimension 5 are positively correlated (see Table 7-3 for component loadings of PCA dimensions). Dimension 2, Dimension 3 and Dimension 5 have the largest standard coefficients on Canon 1 and therefore contribute most to the formation of Canon 1. The site Šibenik-Sv. Lovre is the only site positively correlated with Canon 1; the other three sites are negatively correlated. Šibenik-Sv. Lovre is the oldest site included in the pre-Ottoman sample and is therefore more temporally separated from the other sites. While Koprivno-Križ I, which is also included in the pre-Ottoman sample, is closer to the conflict/Ottoman-controlled period than the Šibenik-Sv. Lovre site and therefore we may expect to see it more closely align with the Ottoman period sites.

Canon 2 represents 35.27% of the sample variation. For Canon 2, Dimension 2, Dimension 5 and Dimension 6 are negatively correlated, while Dimension 1, Dimension 3, and Dimension 4 are positively correlated. Dimension 1, Dimension 4, and Dimension 6 had the

largest standard coefficients on Canon 1 and therefore contributed most to the formation of Canon 2. Canon 2 separates Drinovci-Greblje (positive) from the other three sites. Drinovci-Greblje is consistently different from the other sites in the proceeding analyses. There is the possibility that this is a reflection of the low sample size from Drinovci-Greblje, but if it is true, then the Drinovci-Greblje people are different from the other samples including the other Ottoman period sample, Koprivno-Križ II, and may warrant further investigation/excavation of the site in the future.

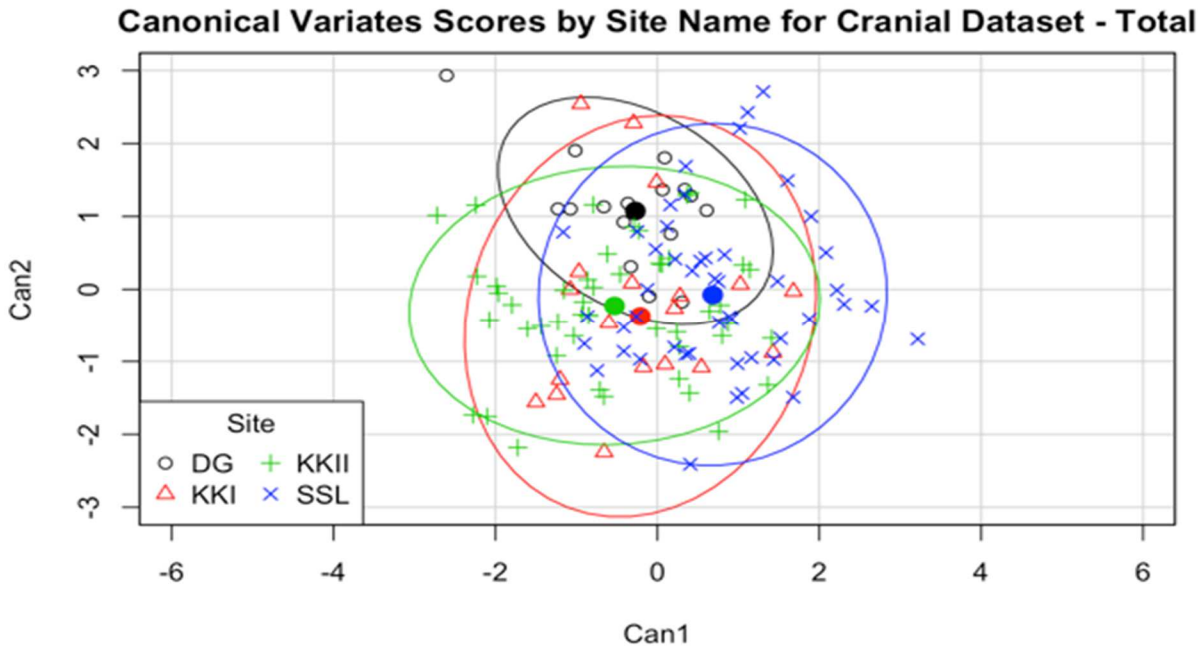

Figure D - 4: Canonical variants 1 and 2 by site name for the cranial metric - total sample (n=132).

The PCA of the cranial metric – total sample was explored using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each PCA dimension (Husson, et al. 2011). The component loadings and eigenvalues of the cranial metric – total sample PCA analysis are

presented in Table 7-3. Since DDA identified Dimension 2, Dimension 3, and Dimension 5 to significantly contribute to group identification by site name, the variable contributions for these three components are presented here.

Dimension 5 represented 7% of the sample variance and separated mandibular and cranial breadth measurements (negative), from nasal and orbital height and parietal chord measurements (positive).

The PCA of the total cranial sample was explored by site name using one-way analysis of variance. Figure D-5 through Figure D-7 present the individuals factor plots for the first six PCA dimensions. Dimension 2 accounted for 13.2% of the sample variance and separated individuals by site name ($R^2 = 0.9$, p-value = 0.01) (Figure D-5): the site Šibenik-Sv. Lovre was positively correlated, while the site Drinovci-Greblje is negatively correlated on Dimension 2. Dimension 2 separated measurements of the orbit (negative) from mandibular measurements (positive) (Table 7-3). Šibenik-Sv. Lovre individuals had larger mandibular measurements, making them positively correlated with Dimension 2. Drinovci-Greblje individuals had larger orbital measurements, making them negatively correlated with Dimension 2.

PC3 accounted for 10% of the sample variance and separated individuals by site name (R^2=0.14, p-value=0.00) (Figure D-6): the Šibenik-Sv. Lovre site is positively correlated, while Koprivno-Križ II is negatively correlated on Dimension 3. Dimension 3 separated measurements of the cranial vault and base (positive) from measurements of the nose and forehead (negative). Therefore, Šibenik-Sv. Lovre individuals had larger cranial vault and base measures, making them positively correlated with Dimension 3. While Koprivno-Križ II individuals had larger nose and forehead measurements, making them negatively correlated with Dimension 3.

Dimension 5 accounts for 7% of the sample variance and shows separation of individuals by site name (R^2=0.07, *p*-value=0.03) (Figure D-7): the Šibenik-Sv. Lovre site is positively correlated, while Koprivno-Križ II site is negatively correlated on PC5. The Šibenik-Sv. Lovre individuals had larger nasal and orbital height and parietal chord measurements, making them positively correlated with Dimension 5. The Koprivno-Križ II individuals had larger mandibular and cranial breadth measurements, making them more negatively correlated with Dimension 5.

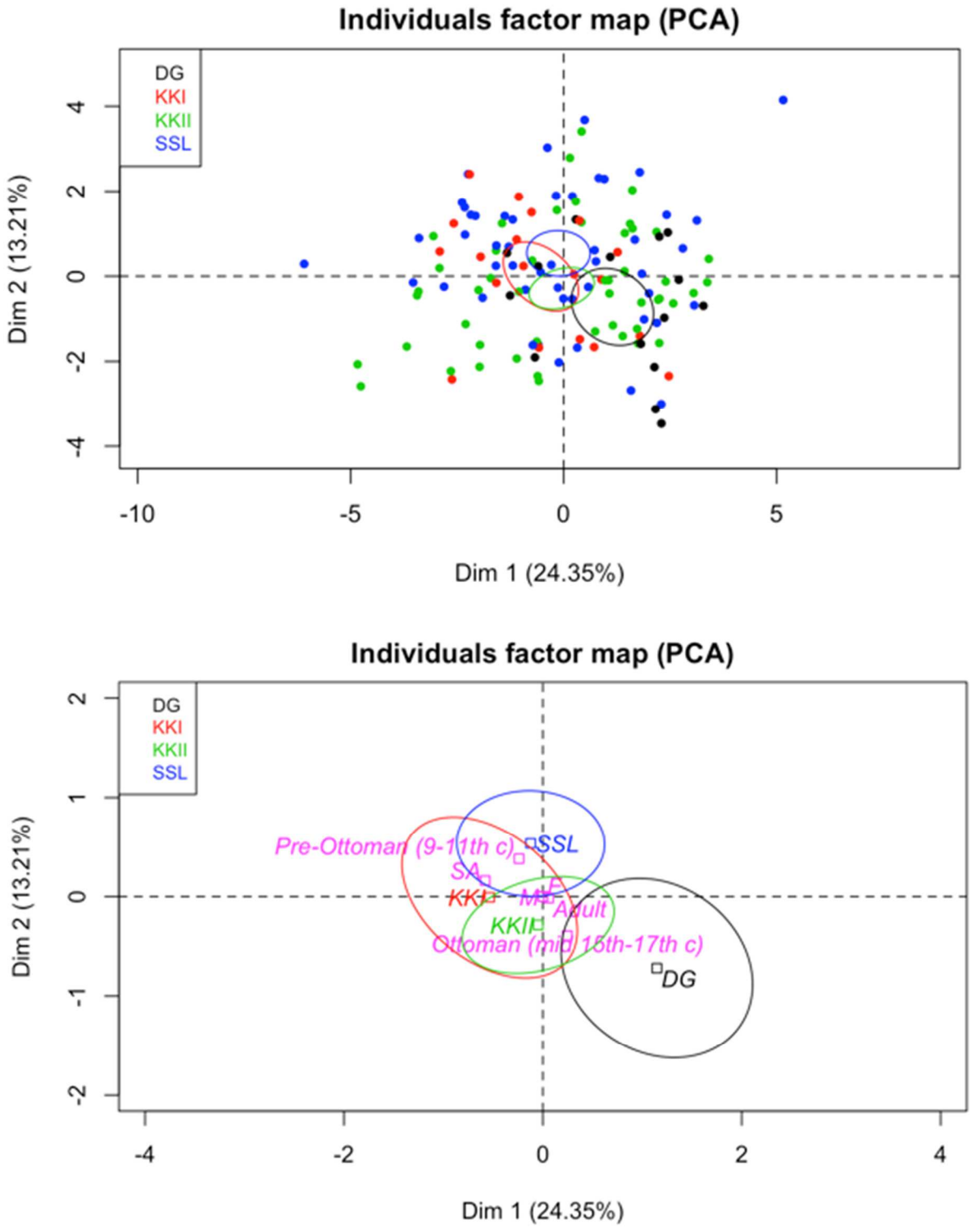

Figure D - 5: Upper: Dim 1 and Dim 2 individuals factor plot (PCA) for the cranial metric – total sample (n=132), colored by site name. Lower: individual data points are removed and barycenters of the individuals belonging to each site name are retained.

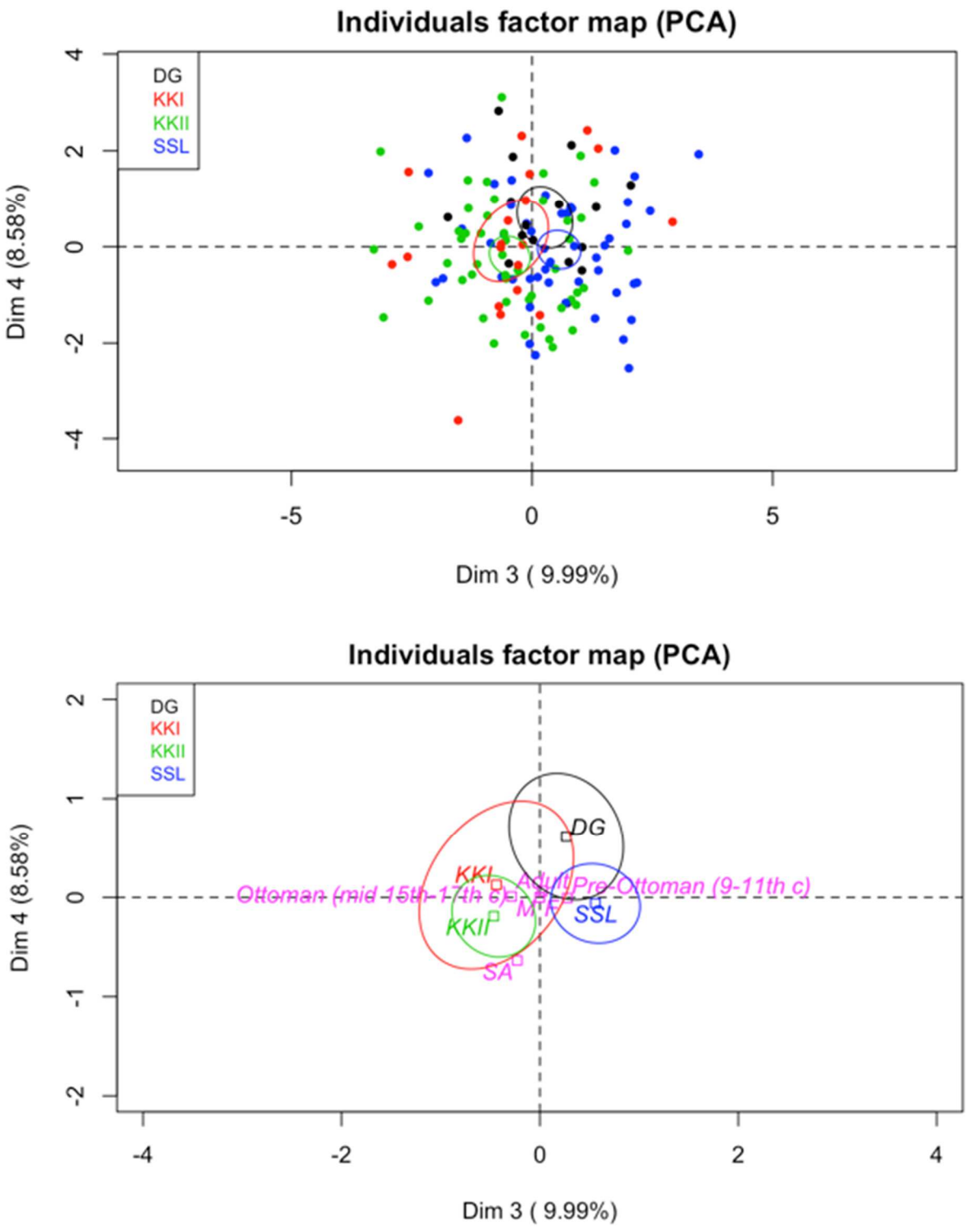

Figure D - 6: Upper: Dim 3 and Dim 4 individuals factor plot (PCA) for the cranial metric – total sample (n=132), colored by site name. Lower: individual data points are removed and barycenters of the individuals belonging to each site name are retained.

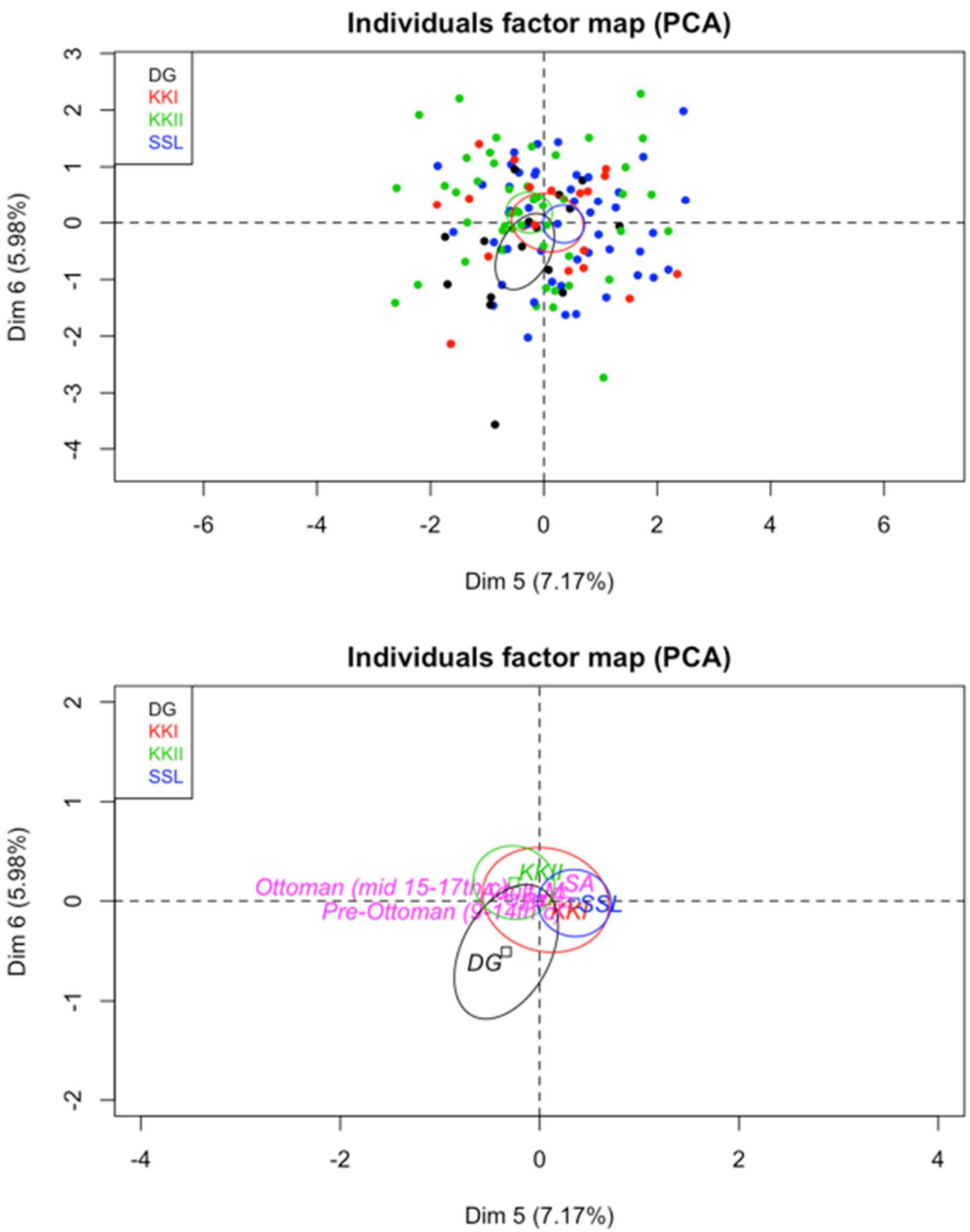

Figure D - 7: Upper: Dim 5 and Dim 6 individuals factor plot (PCA) for the cranial metric – total sample (n=132), colored by site name. Lower: individual data points are removed and barycenters of the individuals belonging to each site name are retained.

Dental non-metric – total sample (n=140)

For the dental non-metric – total sample (n=140) the first eight eigenvalues were significant and represented 72.19% of the cumulative variance in the sample (Table 7-1). For the dental non-metric – total sample all four of the MANOVA significance tests were significant (Table D-1). Therefore, differences between sites are identified using the dental non-metric – total sample.

Results of the DDA analysis using the first eight MCA dimensions by site name identified significant differences between individuals when grouped by site name on Canon 1 (Canon 1: F=3.38, p-value=0.00), but not for the other canons (Figure D-8). Šibenik Sv. Lovre and Koprivno-Križ I were negatively correlated, while Koprivno-Križ II and Drinovci-Greblje were positively correlated with Canon 1. Dimension 1, Dimension 3 and Dimension 6 were negatively correlated, while Dimension 2, Dimension 4, Dimension 5, Dimension 7 and Dimension 8 were positively correlated on Cannon 1 (see Table 7-4 for component loadings). Dimension 1 and Dimension 2 had the largest standard deviation coefficients and therefore contributed most to the formation of Canon 1.

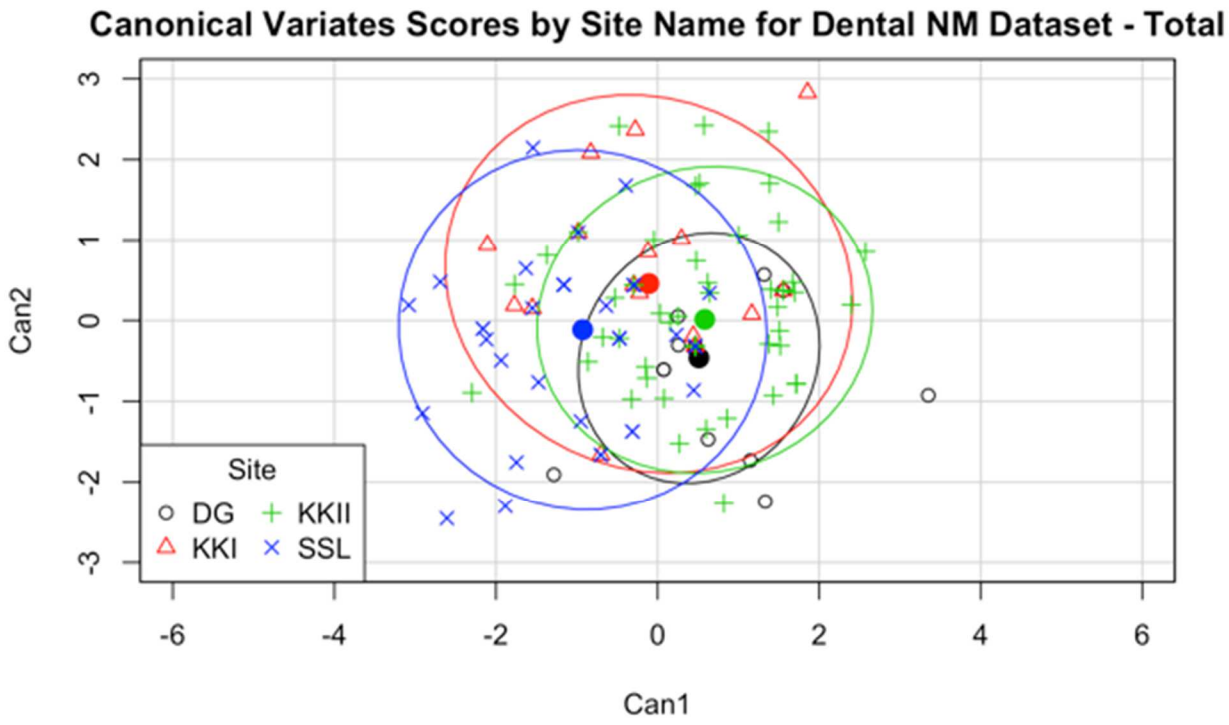

Figure D - 8: Canonical variants 1 and 2 by site name for the dental non-metric - total sample (n=140).

The MCA of the dental non-metric – total sample was explored using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each MCA dimension (Husson, et al. 2011). The first eight MCA dimensions represented a cumulative 72.19% of the total sample variance. The variables that contribute significantly to the formation of each dimension are highlighted in gray in Table 7-4. Individual factor plots for the first eight MCA dimensions are presented in Figure D-9 through Figure D-12. Dimension 1 and Dimension 2 separated individuals by site name (Figure D-9). Dimensions three through eight did not separate individuals by site name (Figure D-10 through Figure D-12).

Dimension 1 to accounted for 15.69% of the sample variance and separated individuals by site name (R^2=0.2359, p-value=0.00) (Figure D-9): individuals from Šibenik-Sv. Lovre were

positively correlated, while individuals from Koprivno-Križ II were negatively correlated on Dimension 1. The component loadings of Dimension 1 identified the presence of UM2 Carabelli's trait, UM3 hypocone, UM3 mesial paracone tubercle, and UM3 metaconule to be positively correlated, and the absence of these traits to be negatively correlated (Table 7-4). Therefore, the individuals from the Šibenik-Sv. Lovre site had higher frequencies of Carabelli's trait, hypocones, mesial paracone tubercles and metaconules, while individuals from the Koprivno-Križ II site had lower frequencies of these traits. Resulting in the individuals from Šibenik-Sv. Lovre being positively correlated, while individuals from Koprivno-Križ II are negatively correlated on Dimension 1.

Dimension 2 accounts for 10.34% of the sample variance and also separated individuals by site name (R^2=0.1008, p-value=0.0023) (Figure D-9): individuals from the Koprivno-Križ II site were positively correlated, while individuals from the Šibenik-Sv. Lovre site were negatively correlated on Dimension 2. The component loadings of Dimension 2 identified the presence of UP4 mesial accessory ridges, the presence of UM2 parastyle, and the absence of the UM2 metacone to be positively correlated, while the absence of UP4 mesial accessory ridges, the absence of UM2 parastyle and the presence of the UM2 metacone were negatively correlated (Table 7-4). Therefore, the individuals from the Koprivno-Križ II site had higher frequencies of UP4 mesial accessory ridges presence, UM2 parastyle presence, and UM2 metacone absence. Individuals from the Šibenik-Sv. Lovre site had lower frequencies of these traits. These results show a positive correlation of individuals from the Koprivno-Križ II site, and the negative correlation of individuals from the Šibenik-Sv. Lovre site on Dimension 2.

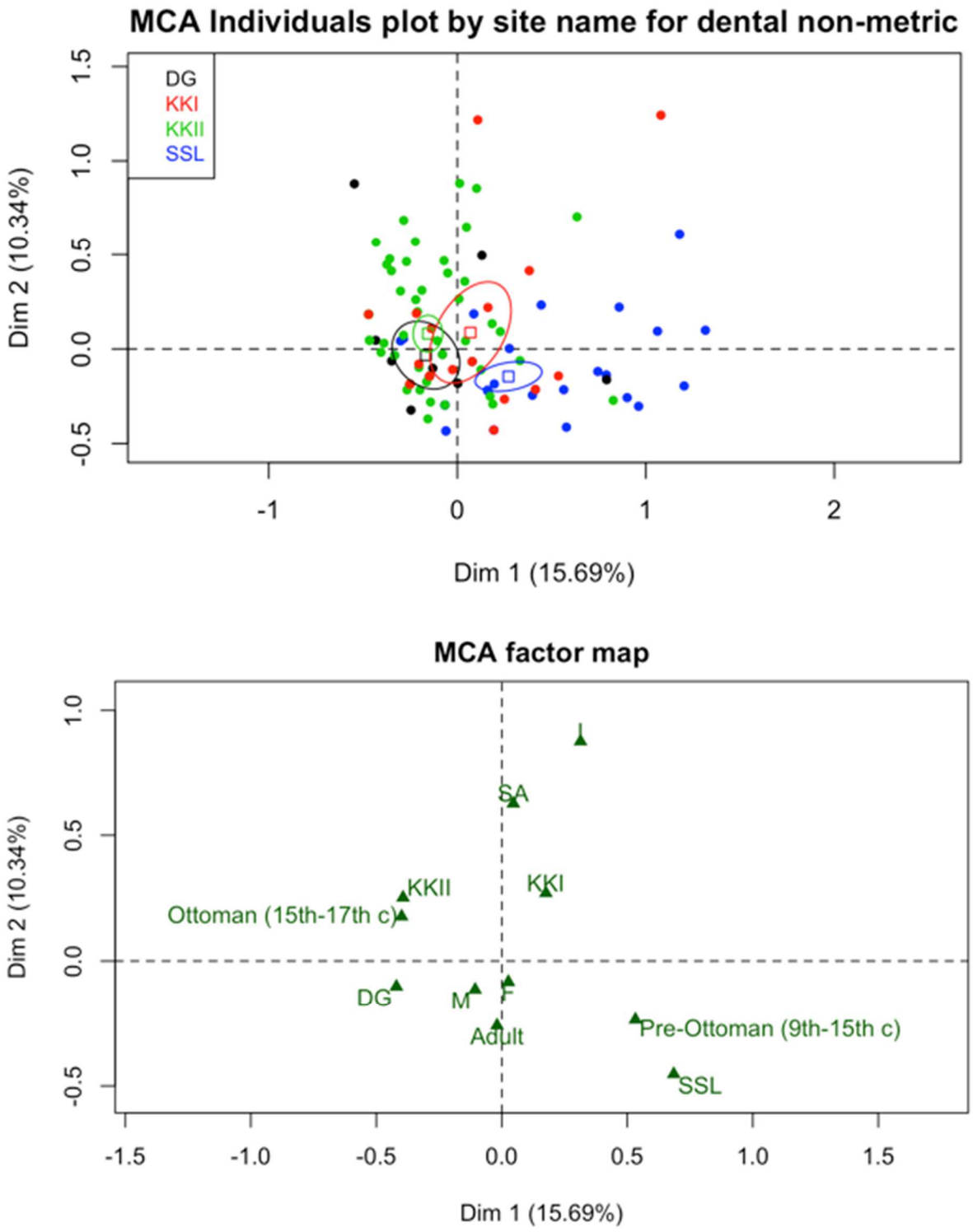

Figure D - 9: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the dental non-metric - total sample (n=140), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

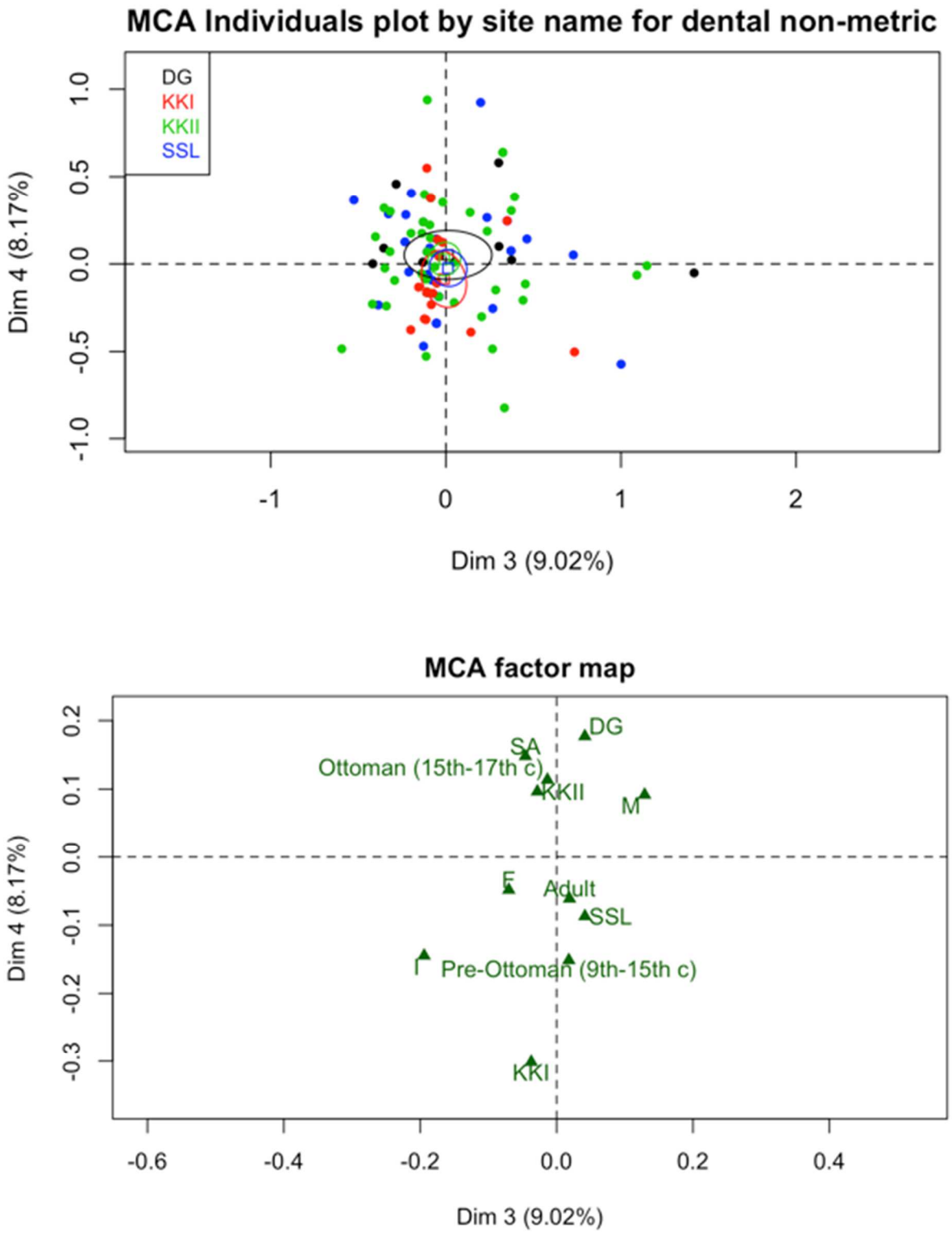

Figure D - 10: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for the dental non-metric - total sample (n=140), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

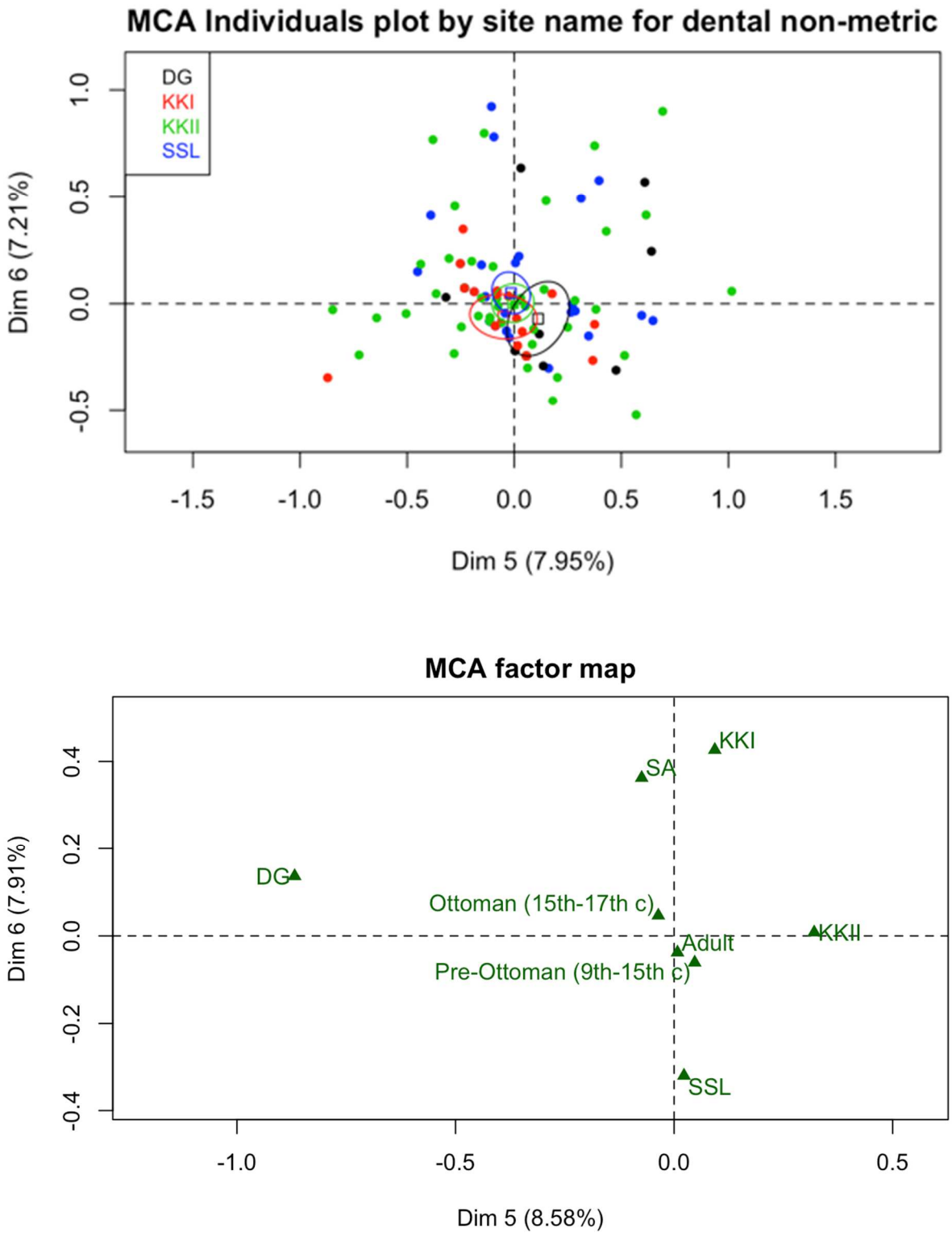

Figure D - 11: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the dental non-metric - total sample (n=140), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

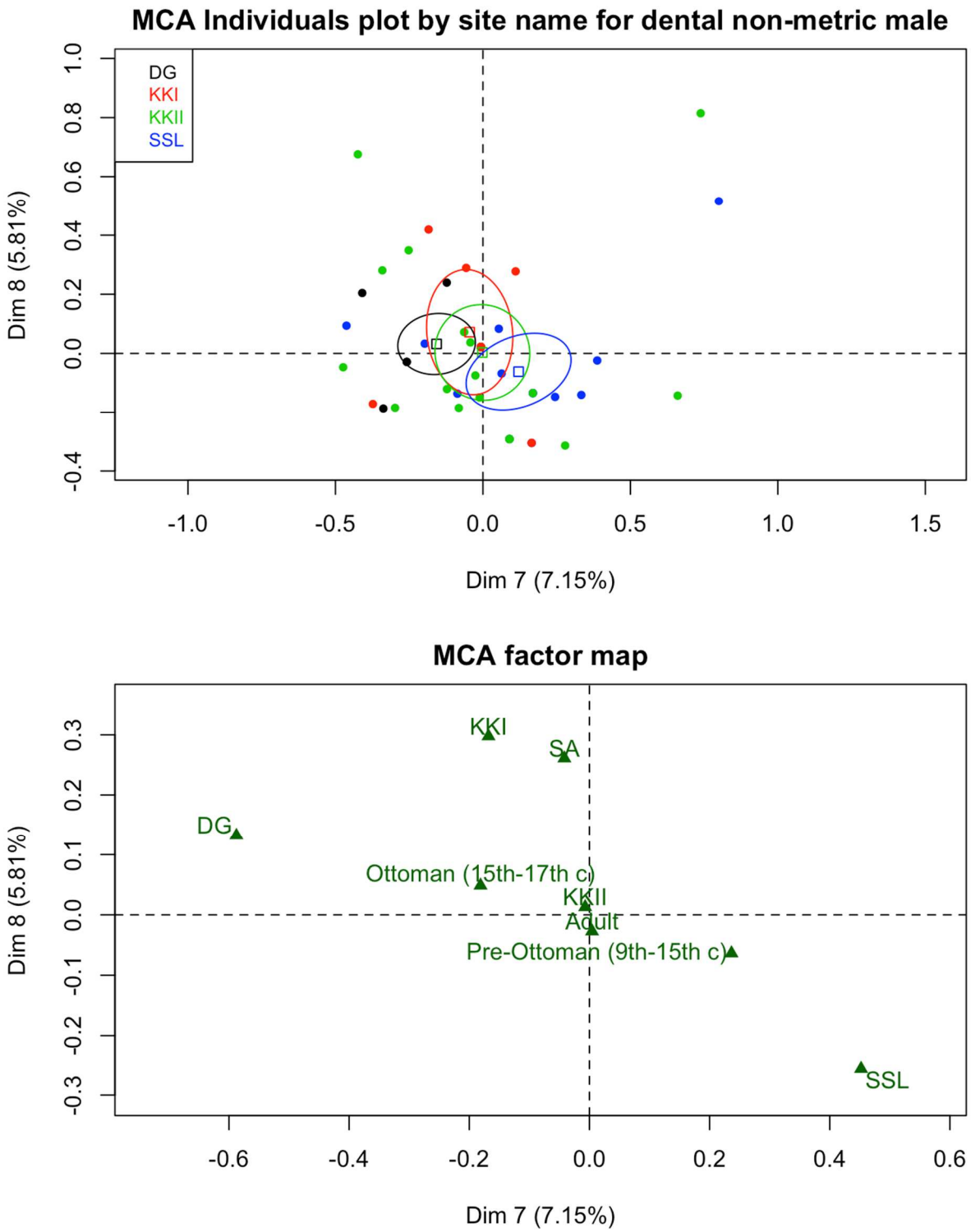

Figure D - 12: Upper: Dim 7 and Dim 8 individuals factor plots (MCA) for the dental non-metric - total sample (n=140), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

The site name results of the MMD analysis for the total sample – dental non-metric dataset are presented in Table D-2. After removal of traits with a negative overall measure of divergence (MD), only five traits remained for the MMD analysis. Frequency counts for these traits by site name are presented in Table D-3. With only five traits used to produce the distances in Table D-2, any significant results must be treated with caution and corroborated with additional evidence. Significant differences resulted between the Drinovci-Greblje site and all other sites, as well as between the Šibenik-Sv. Lovre site and the Koprivno-Križ II site. These results are consistent with those of the total sample dental metric, cranial non-metric, and dental non-metric PCA and MCA analyses. Drinovci-Greblje is characteristically different from the other sites included in this study; however Drinovci-Greblje has a smaller total sample-size, which may account for why it appears to be so different. Šibenik-Sv. Lovre is the larger pre-Ottoman period site, and has been consistently different using the other analytical techniques from the large Ottoman period site, Koprivno-Križ II. Therefore, the significant difference between Šibenik-Sv. Lovre and Koprivno-Križ II here is likely a true difference.

Figure D-13 presents the results of the multi-dimensional scaling (MDS) for the dental non-metric – total sample. According to the dental non-metric MMD values, all four sites are distinct from one another (Table D-2, Figure D-13). The two pre-Ottoman sites (KKI and SSL) are more negatively correlated on the x-axis compared to the two Ottoman period sites (DG and KKII). In addition, the Drinovci-Greblje site is the most extreme in that it is located farthest from the origin point, 0.

Table D - 2: MMD values (upper triangular part) and associated SD values (lower triangular part), for the dental non-metric - total sample site name comparisons.

	DG	KKI	KKII	SSL
DG		0.261*	0.168*	0.503*
KKI	0.092		-0.048	0.045
KKII	0.064	0.062		0.191*
SSL	0.074	0.072	0.044	

* marks a significant value.

Table D - 3: Number of individuals and relative frequencies for each active variable within each site, and overall measure of divergence for each active variable for the dental non-metric – total sample.

	UI1 Double Shoveling	UI2 Radical #	UM2 Metacone (Cusp 3)	UM3 Metaconule (Cusp 5)	LM1 Cusp #
N DG	14	14	12	13	12
N KKI	13	17	16	11	13
N KKII	42	48	51	24	41
N SSL	15	24	36	24	28
Frequency DG	0	1	0.92	0.08	0.17
Frequency KKI	0.31	0.82	0.88	0.46	0.23
Frequency KKII	0.14	0.88	0.88	0.46	0.34
Frequency SSL	0.33	0.75	1	0.54	0.04
Overall MD	1.379	0.531	0.040	1.205	0.323

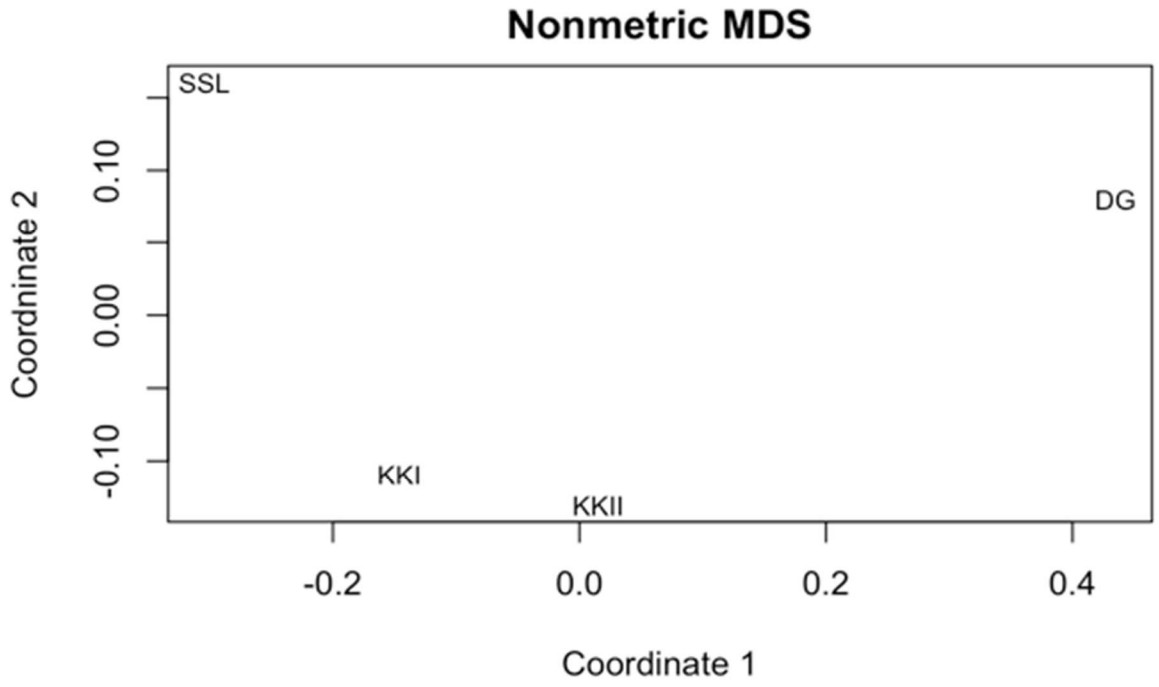

Figure D - 13: MDS plot using MMD distance values for dental non-metric dataset - total sample (stress level = 1.123e-14).

Cranial non-metric – total sample (n=245)

For the cranial non-metric – total sample (n=245) the first eight eigenvalues were significant and represented 56.35% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – total sample all four of the MANOVA significance tests were significant (Table D-1). Therefore, differences between sites are identified using the cranial non-metric – total sample.

Results of the DDA analysis of the first eight MCA dimensions and site name identified a significant correlation with Canon 1 (Canon 1: F=2.82, *p*-value=0.00) and with Canon 2 (Canon 2: F=2.11, *p*-value=0.01) (Figure D-14). The third canon is not significant.

The Šibenik-Sv. Lovre and Drinovci-Greblje sites are positively correlated, while both phases of the Koprivno-Križ site are negatively correlated with Canon 1 (Figure D-14). The Koprivno-Križ I sample is closer temporally and geographically to the Koprivno-Križ II sample, and therefore we may expect to see it more closely aligned with the large Ottoman period site, Koprivno-Križ II. Dimension 1, Dimension 4, Dimension 5, Dimension 6 and Dimension 7 are negatively correlated, while Dimension 2, Dimension 3 and Dimension 8 are positively correlated with Cannon 1 (see Table 7-7 for component loadings). Dimension 2 and Dimension 4 have the largest standard coefficients and therefore contribute most the formation of Canon 1.

Canon 2 separates Drinovci-Greblje and Koprivno-Križ II (negative) from the Šibenik-Sv. Lovre and Koprivno-Križ I sites (positive) (Figure D-14). Dimension 1, Dimension 2, Dimension 4, Dimension 5, and Dimension 8 are negatively correlated, while Dimension 3, Dimension 6 and Dimension 7 are positively correlated on Canon 2 (see Table 7-7 for component loadings). Dimension 3 and Dimension 7 have the largest standard coefficients and therefore contribute most to the formation of Canon 2.

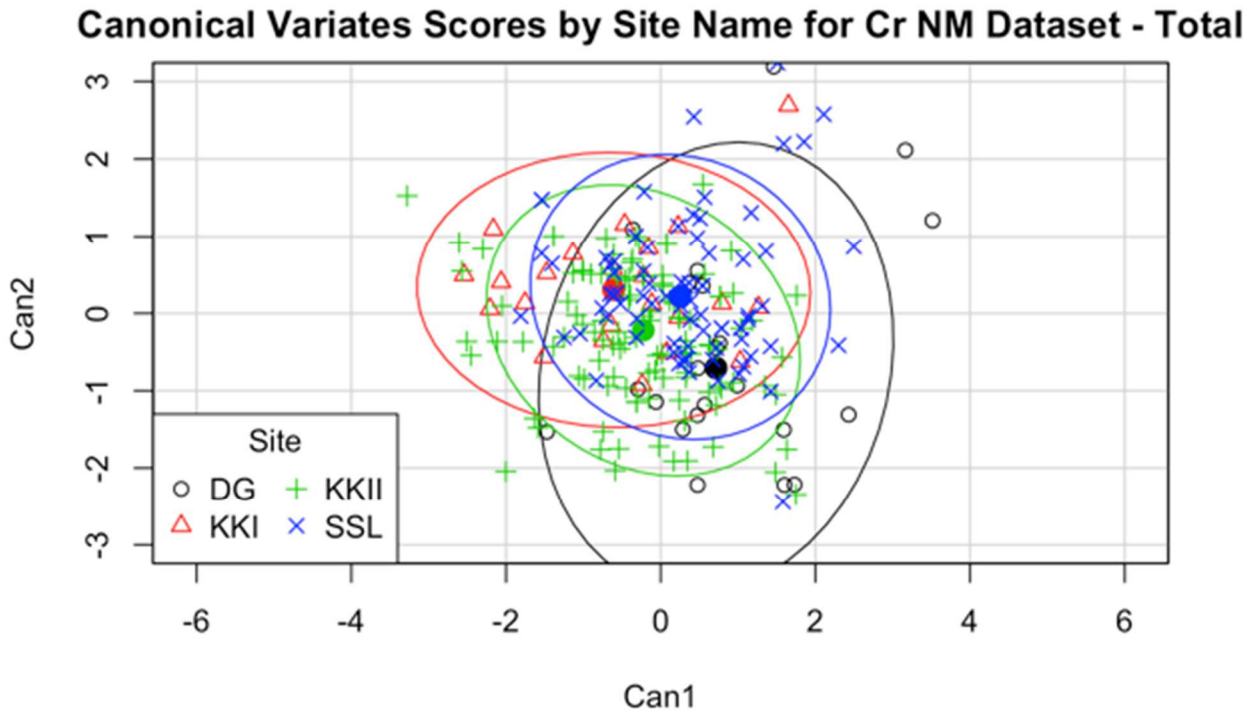

Figure D - 14: Canonical variants 1 and 2 by site name for the cranial non-metric - total sample (n=245).

The MCA of the cranial non-metric – total sample was explored using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each MCA dimension (Husson, et al. 2011). The component loadings and eigenvalues for the first eight components are presented in Table 7-7. Using one-way analysis of variance, the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table 7-7. Dimension 1, Dimension 4, Dimension 6, Dimension 7 and Dimension 8 did not separate individuals by site name (Figure D-15 through Figure D-18). Dimension 2, Dimension 3 and Dimension 5 separated individuals by site name (Figure D-15 through Figure D-17).

Dimension 2 separated individuals by site name (R^2=0.0858, p-value=0.0001) (Figure D-15): individuals from the Drinovci-Greblje site were positively correlated, while individuals from Koprivno-Križ I were negatively correlated with Dimension 2. Sex (R^2=0.0390, *p*-value=0.0081) (Figure D-15) also separates individuals on Dimension 2, with indeterminate individuals positively correlated, and female individuals negatively correlated. Age does not significantly separate individuals on Dimension 2. Dimension 2 is characterized most by the positive correlation of the supranasal suture-present, metopic suture-absent, and non-right flexure of the superior sagittal sulcus; and the negative correlation of the opposite of these traits: supranasal suture-absent, metopic suture-present, and right-flexure of the superior sagittal sulcus. Individuals from the Drinovci-Greblje site had higher frequencies of the supranasal suture-present, metopic suture-absent, and non-right flexure of the superior sagittal sulcus; making Drinovci-Greblje individuals positively correlated with Dimension 2. Individuals from Koprivno-Križ I had higher frequencies of supranasal suture-absent, metopic suture-present, and right flexure of the superior sagittal sulcus; making Koprivno-Križ I individuals negatively correlated with Dimension 2.

Dimension 3 separated individuals by site name (R^2=0.0.334, p-value=0.0422) (Figure D-16): individuals from the Koprivno-Križ II site were negatively correlated, while individuals from the Šibenik-Sv. Lovre site were positively correlated with Dimension 3. Age and sex did not significantly separate individuals on Dimension 3 (Figure D-16). Dimension three was characterized most by the positive correlation of frontal grooves-absent, mylohyoid bridging-present, and basilar-sphenoid bridging-present; and the negative correlation of the opposite of these traits, frontal grooves-present, mylohyoid bridging-absent, and basilar-sphenoid bridging-absent (Table 7-7). Therefore, individuals from the Šibenik-Sv. Lovre site had higher frequencies

for the frontal groove-presence, mylohyoid bridging-presence, and basilar-sphenoid bridging-presence: making Šibenik-Sv. Lovre individuals more positively correlated with Dimension 3. While individuals from the Koprivno-Križ II site had higher frequencies of frontal grooves-presence, mylohyoid bridging-absence, and basilar-sphenoid bridging-absence: making Koprivno-Križ II individuals more negatively correlated with Dimension 3.

Dimension 5 separated individuals by site name (R^2=0.0405, *p*-value=0.0188) (Figure D-17): Koprivno-Križ II was positively correlated while Šibenik-Sv. Lovre was negatively correlated. Age (R^2=0.0844, *p*-value=0.0000) and sex (R^2=0.0779, *p*-value=0.0001) also separated individuals on Dimension 5 (Figure D-17): indeterminate subadults were positively correlated while adults, both male and female, were negatively correlated with Dimension 5. Dimension 5 was characterized by the positive correlation of parietal foramen-absent, pharyngeal tubercle-absent, ossicle at asterion-present, mylohyoid bridging-absent and condylar canal-absent; and negative correlation of the opposite of these traits, parietal foramen-present, pharyngeal tubercle-present, ossicle at asterion-absent, mylohyoid bridging-present and condylar canal-present (Table 7-7). Individuals from the Koprivno-Križ II site had higher frequencies of parietal foramen-absence, pharyngeal tubercle-absence, ossicle at asterion-presence, mylohyoid bridging-absence and condylar canal-absence: making Koprivno-Križ II individuals positively correlated on Dimension 5. Individuals from the Šibenik-Sv. Lovre site had higher frequencies of parietal foramen-presence, pharyngeal tubercle-presence, ossicle at asterion-absence, mylohyoid bridging-presence and condylar canal-presence: making Šibenik-Sv. Lovre individuals negatively correlated on Dimension 5. However, the variables contributing to the formation of Dimension 5 could be interpreted as being affected by differential growth and therefore Dimension 5 may separate individuals more by age than by site name or sex. Therefore, an adult-

only sample was also tested to see if the significant separations by site name remained in the absence of subadult individuals.

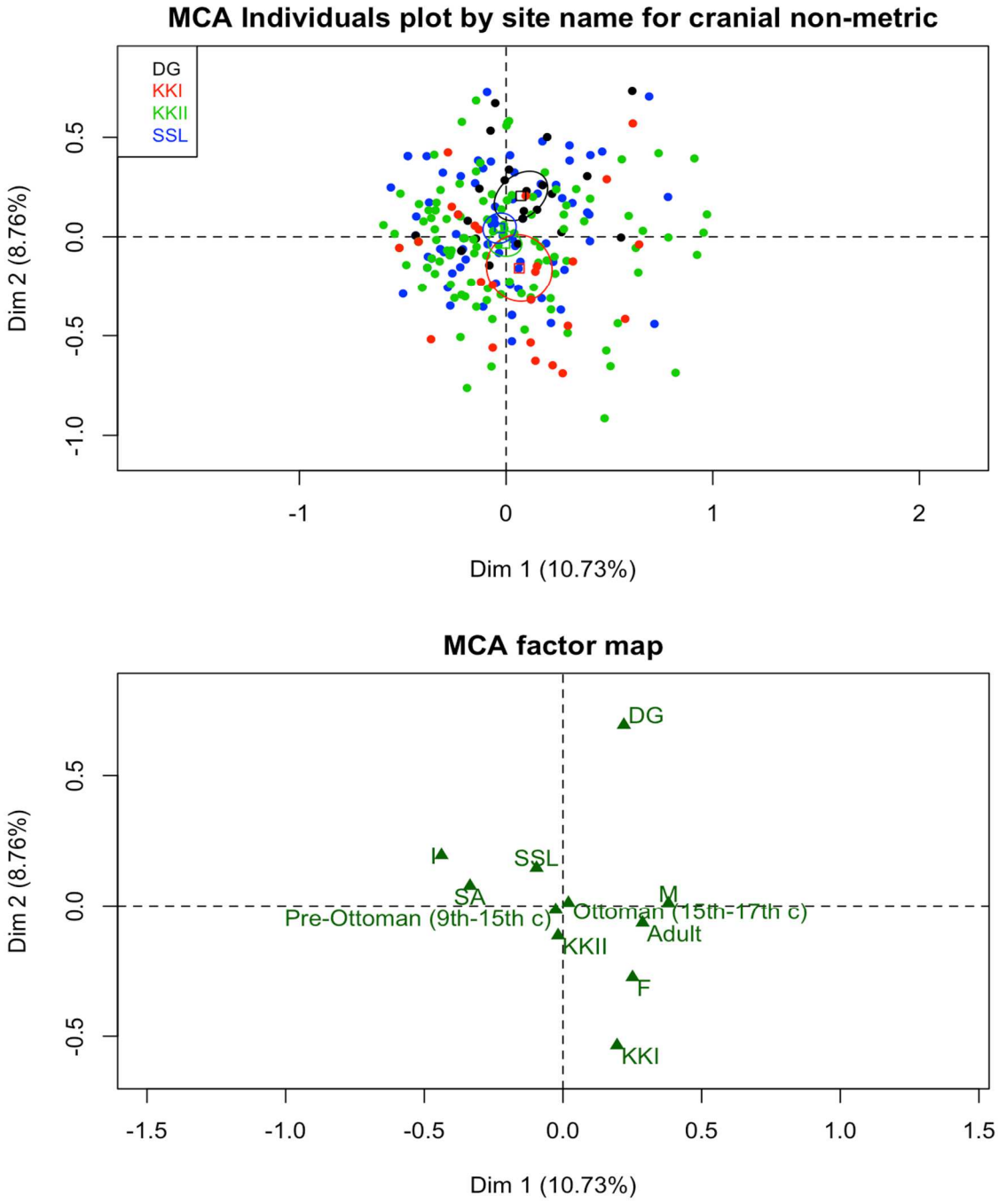

Figure D - 15: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the cranial non-metric - total sample (n=245), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

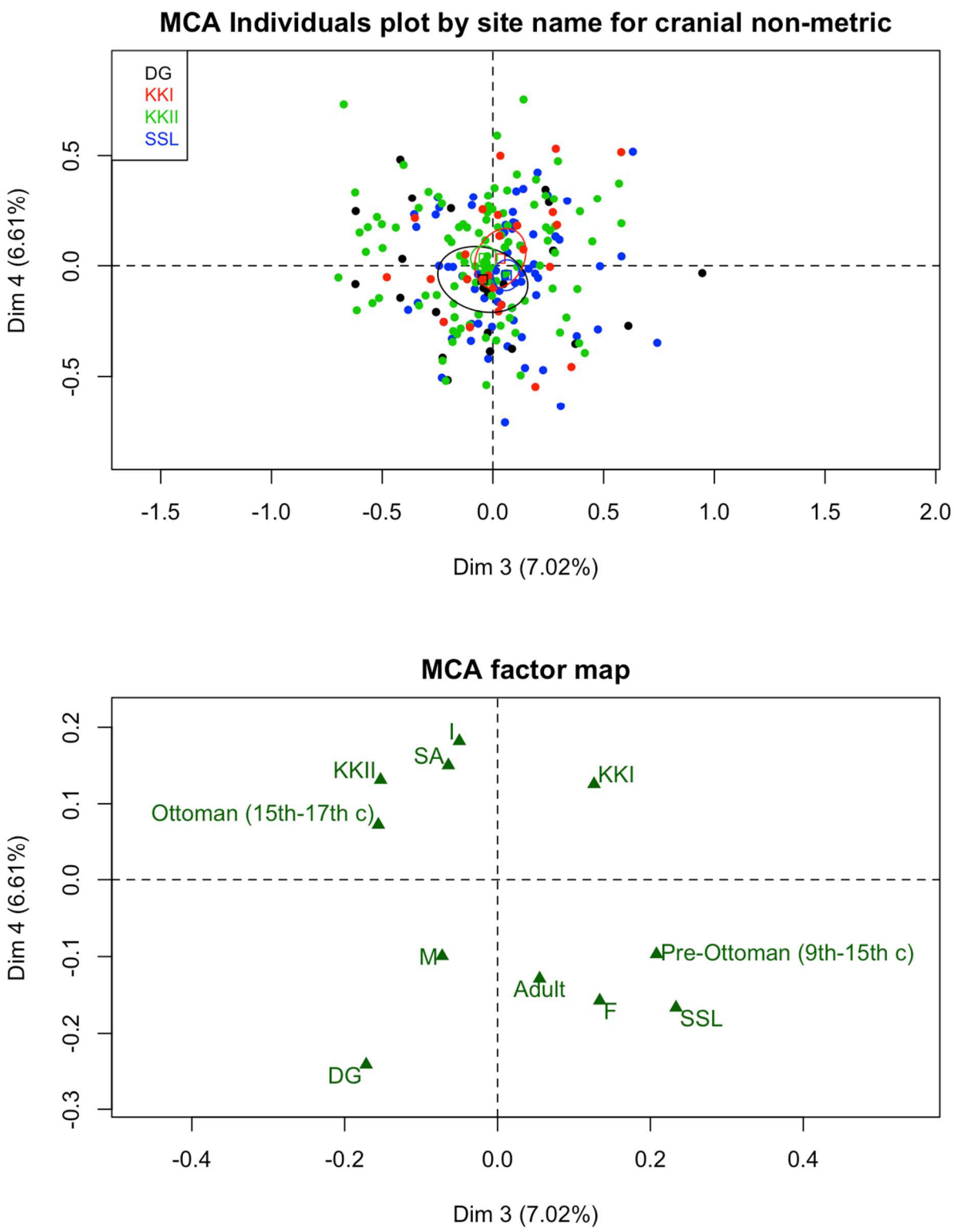

Figure D - 16: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - total sample (n=245), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

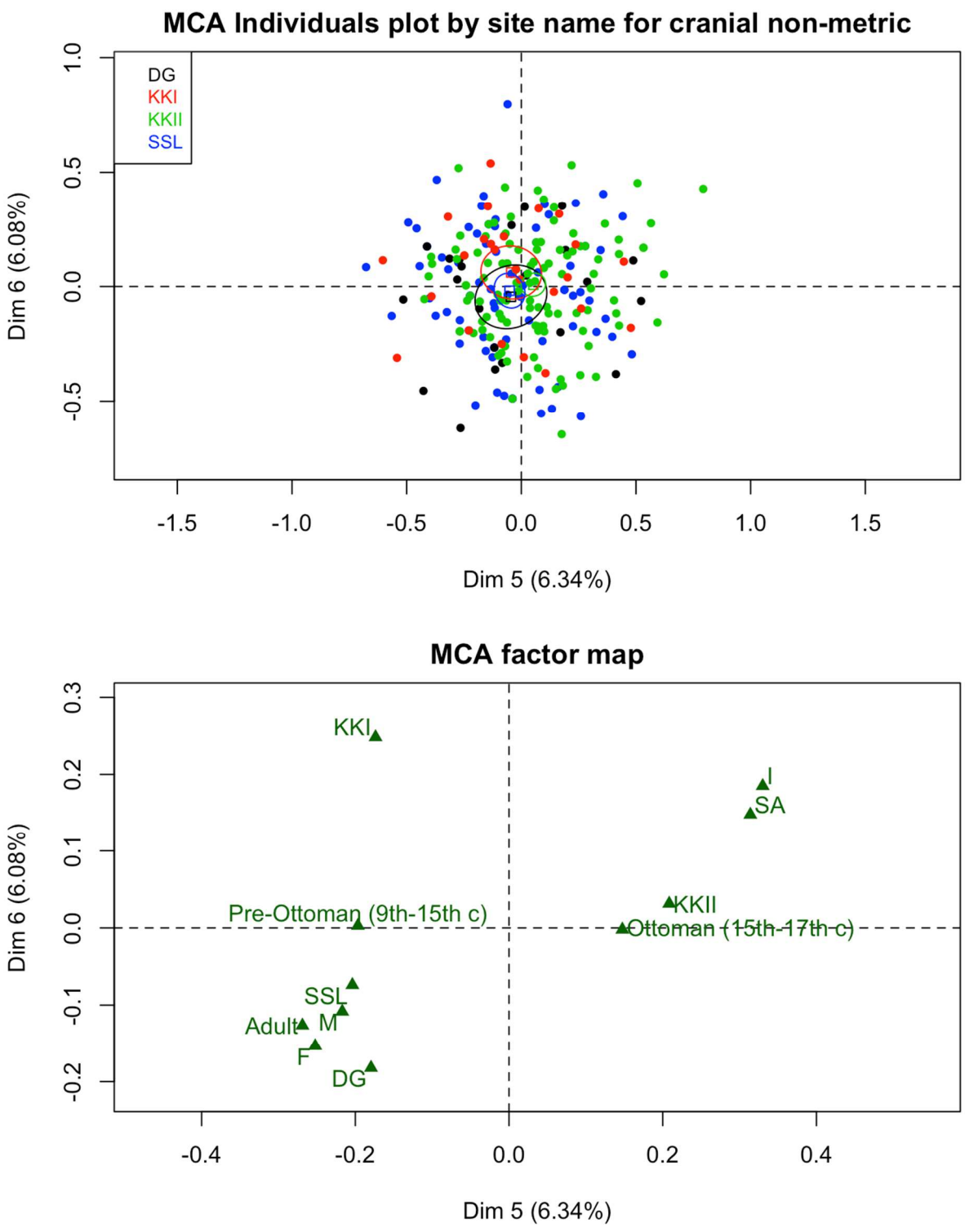

Figure D - 17: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the cranial non-metric - total sample (n=245), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

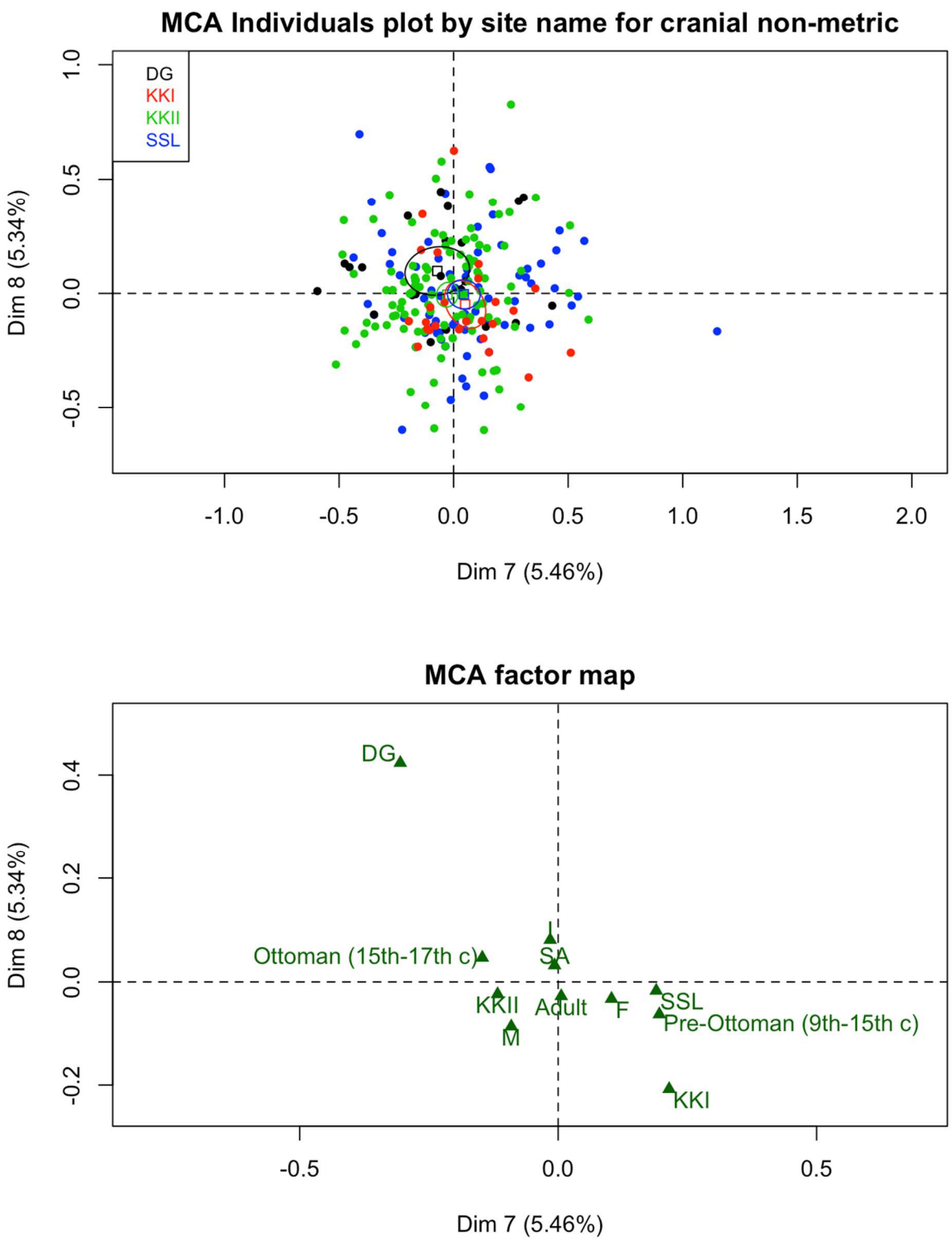

Figure D - 18: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - total sample (n=245), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

The site name results of the MMD analysis for the cranial non-metric – total sample are presented in Table D-4. After removal of traits with a negative overall measure of divergence (MD), only nine traits remained for the MMD analysis, frequency counts for these traits by site name are presented in Table D-5. A significant difference resulted between all site comparisons except for between the Šibenik-Sv. Lovre and Koprivno-Križ I sites. For the nine traits included, the Drinovci-Greblje and Koprivno-Križ II sites (both are from the Ottoman period) are significantly different from all other sites included in the analysis (including each other).

Figure D-19 presents the results of the MDS for the cranial non-metric – total sample. According to the cranial non-metric MMD values, results of the MDS place Šibenik-Sv. Lovre near Koprivno-Križ II (Figure D-19). This may be caused by larger sample-sizes that tend to reduce sample variability. For the cranial non-metric comparisons, the two pre-Ottoman sites (KKI and SSL) are more negatively correlated on the x-axis compared to the two Ottoman period sites (DG and KKII). In addition, the cranial non-metric comparisons identify the Drinovci-Greblje site as the most extreme in that it is located farthest from the origin point, 0.

Table D - 4: MMD values (upper right) and associated SD values (lower left), for the cranial non-metric - total sample site name comparisons.

	DG	KKI	KKII	SSL
DG		0.354*	0.185*	0.199*
KKI	0.042		0.052*	0.053
KKII	0.027	0.024		0.059*
SSL	0.029	0.027	0.012	

* marks a significant value.

Table D - 5: Number of individuals, frequencies of active variables within each site name, and overall measure of divergence of active variables, for the cranial non-metric – total sample.

	Metopic Suture	Supranasal Suture	Frontal Grooves	Medial Supraorbital Foramen	Lateral Supraorbital Foramen	Parietal Foramen	Occipito-Mastoid Ossicle	Occipital Foramen	Pharyngeal Tubercle
N DG	21	20	22	21	21	21	19	20	22
N KKI	25	25	24	25	25	24	21	23	21
N KKII	95	101	106	114	114	98	77	93	91
N SSL	67	64	71	73	75	66	58	72	64
Frequency DG	0.00	0.90	0.27	0.86	0.67	0.67	0.00	0.60	0.77
Frequency KKI	0.24	0.44	0.04	0.60	0.32	0.88	0.14	0.91	0.86
Frequency KKII	0.12	0.51	0.19	0.68	0.40	0.75	0.14	0.80	0.56
Frequency SSL	0.03	0.59	0.03	0.56	0.29	0.68	0.12	0.74	0.77
Overall MD	1.066	1.748	0.933	0.413	0.830	0.006	0.295	0.511	0.265

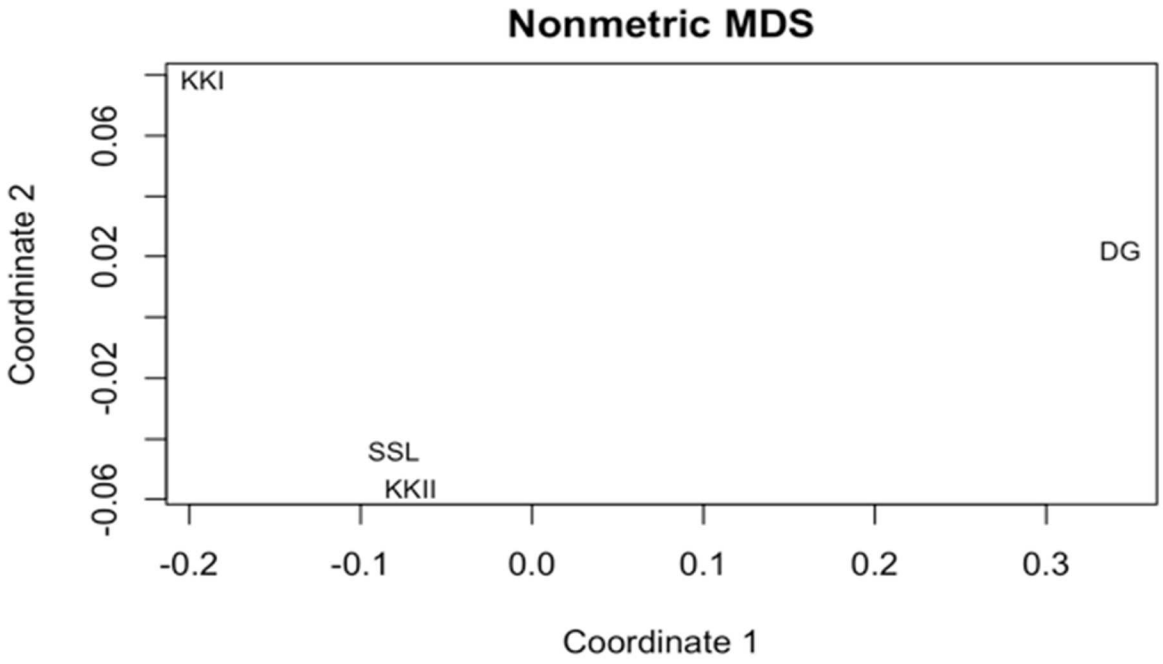

Figure D - 19: MDS plot using MMD distance values for the cranial non-metric - total sample (stress level=1.031e-14).

Cranial non-metric – adult only (n=140)

For the cranial non-metric – adult only sample (n=140) the first eight eigenvalues were significant and represented 56.18% of the cumulative variance in the sample (Table 7-1). For the

cranial non-metric – adult only sample all four of the MANOVA significance tests were significant (Table D-1). Therefore, differences between sites are identified using the cranial non-metric – adult only sample.

Results of the DDA analysis of the first eight MCA dimensions and site name identified a significant correlation with Canon 1 (Canon 1: F=1.898, *p*-value=0.0074) (Figure D-20): the Šibenik-Sv. Lovre, Koprivno-Križ I and Drinovci-Greblje sites were positively correlated, while the Koprivno-Križ II site was negatively correlated on Canon 1. Canon 2 and Canon 3 did not identify group separation by site name. Dimension 1, Dimension 3, and Dimension 8 are positively correlated, while Dimension 2, Dimension 4, Dimension 5, Dimension 6 and Dimension 7 are negatively correlated on Canon 1. Dimension 4 and Dimension 5 have the largest standard coefficients (followed by Dimension 2 and Dimension 3) and therefore contribute most to the formation of Canon 1 (Figure D-20).

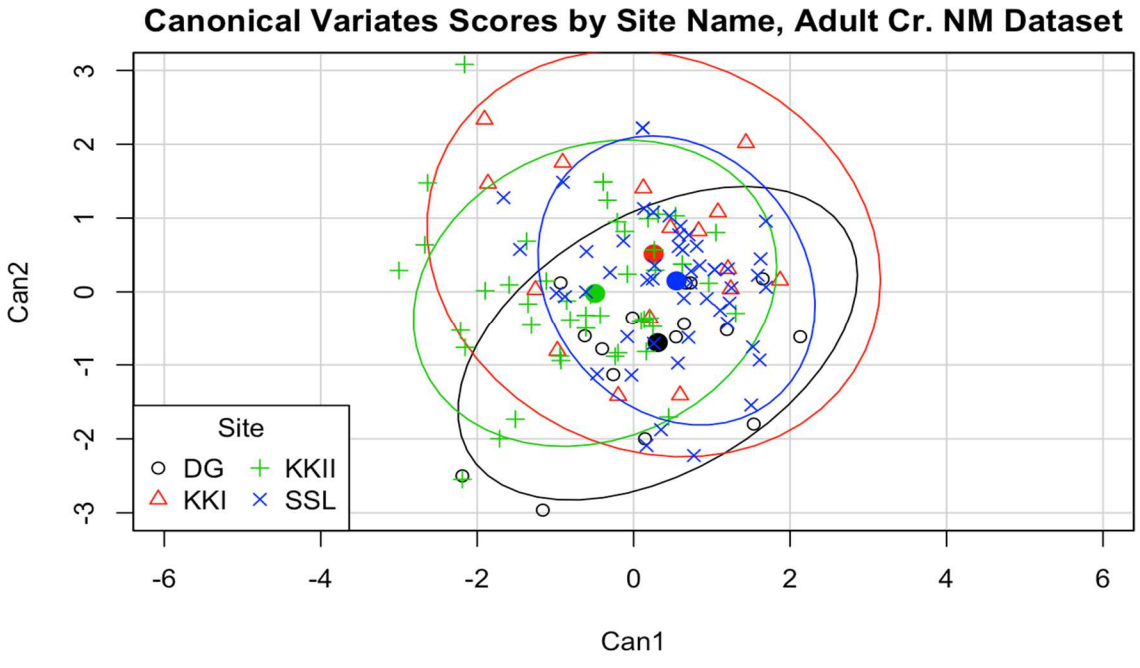

Figure D - 20: Canonical variates 1 and 2 by site name for the cranial non-metric – adult only sample (n=140).

The MCA of the cranial non-metric – adult only sample was explored using the *dimdesc()* function of the *FactoMineR* package, which performs a one-way analysis of variance to identify variables and categories that are the most characteristic of each MCA dimension (Husson, et al. 2011). Using one-way analysis of variance, the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table 7-10. Examination of the dimensions showed Dimension 1, Dimension 3, Dimension 6, Dimension 7, and Dimension 8 did not separate individuals by site name (Figure D-21 through D-24). Only Dimension 2, Dimension 4 and Dimension 5 separated individuals by site name (Figure D-21 through Figure D-23). Sex correlations were not identified on any of the MCA dimensions.

Dimension 2 accounted for 8.23% of the sample variance and separated individuals by site name (R^2=0.0638, *p*-value=0.0395) (Figure D-21): individuals from the Drinovci-Greblje site were negatively correlated with Dimension 2. Dimension 2 was characterized most by the positive correlation of the following traits: supranasal suture-absent, metopic suture-present, occipital-mastoid ossicle-present, basilar-sphenoid bridging-present, condylar canal-absent and biasterionic suture-present; and the negative correlation of the opposite of these traits: supranasal suture-present, metopic suture-absent, occipital-mastoid ossicle-absent, basilar-sphenoid bridging-absent, condylar canal-present and biasterionic suture-absent (Table 7-10). Individuals from the Drinovci-Greblje site had higher frequencies of supranasal suture-present, metopic suture-absent, occipital-mastoid ossicle-absent, basilar-sphenoid bridging-absent, condylar canal-present and biasterionic suture-absent: making the Drinovci-Greblje individuals negatively correlated with Dimension 2.

Dimension 4 accounted for 7.24% of the sample variance and separated individuals by time period (R^2=0.0969, *p*-value=0.0049) (Figure D-22): Koprivno-Križ II individuals were

positively correlated, while Šibenik-Sv. Lovre individuals were negatively correlated on Dimension 4. Dimension 4 was characterized most by the positive correlation of the following traits: frontal grooves-present, ossicle at asterion-present, mylohyoid bridging-absent and metopic suture-present; and the negative correlation of the opposite of these traits: frontal grooves-absent, ossicle at asterion-absent, mylohyoid bridging-present, and metopic suture-absent (Table 7-10). Therefore, individuals from the Šibenik Sv. Lovre site had higher frequencies of frontal grooves-absent, ossicle at asterion-absent, mylohyoid bridging-present, and metopic suture-absent: making the Šibenik Sv. Lovre individuals negatively correlated with Dimension 4. While individuals from the Koprivno-Križ II site had higher frequencies of frontal grooves-present, ossicle at asterion-present, mylohyoid bridging-absent and metopic suture-present: making the Koprivno-Križ II individuals positively correlated with Dimension 4.

Dimension 5 accounted for 6.63% of the sample variance and separated individuals by time period (R^2=0.0708, *p*-value=0.0022) (Figure D-23): Koprivno-Križ II individuals were positively correlated, while Šibenik-Sv. Lovre individuals were negatively correlated on Dimension 5. Dimension 5 was characterized by the positive correlation of the following traits: pharyngeal tubercle-absent, lateral supraorbital foramen-present, flexure of the superior sagittal sulcus-right, ossicle at asterion-absent and occipital foramen-present; and the negative correlation of the opposite of those traits: pharyngeal tubercle-present, lateral supraorbital foramen-absent, flexure of the superior sagittal sulcus-other, ossicle at asterion-present and occipital foramen-absent (Table 7-10). Individuals from the Koprivno-Križ II site had higher frequencies of pharyngeal tubercle-absent, lateral supraorbital foramen-present, flexure of the superior sagittal sulcus-right, ossicle at asterion-absent and occipital foramen-present: making the Koprivno-Križ II individuals positively correlated on Dimension 5. Individuals from the

Šibenik-Sv. Lovre site had higher frequencies of pharyngeal tubercle-present, lateral supraorbital foramen-absent, flexure of the superior sagittal sulcus-other, ossicle at asterion-present and occipital foramen-absent: making the Šibenik-Sv. Lovre individuals negatively correlated on Dimension 5.

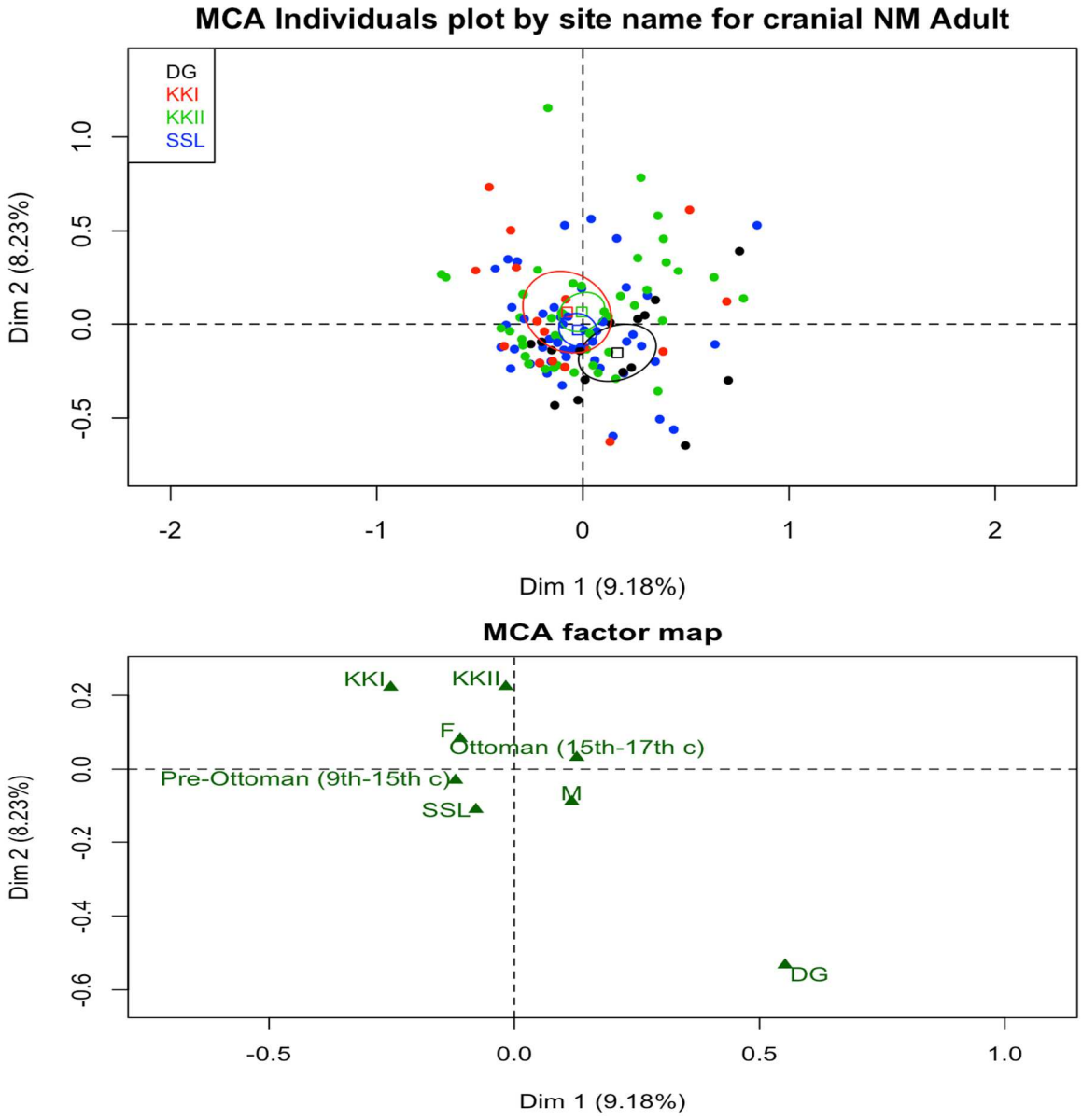

Figure D - 21: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for cranial non-metric – adult only sample (n=140), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

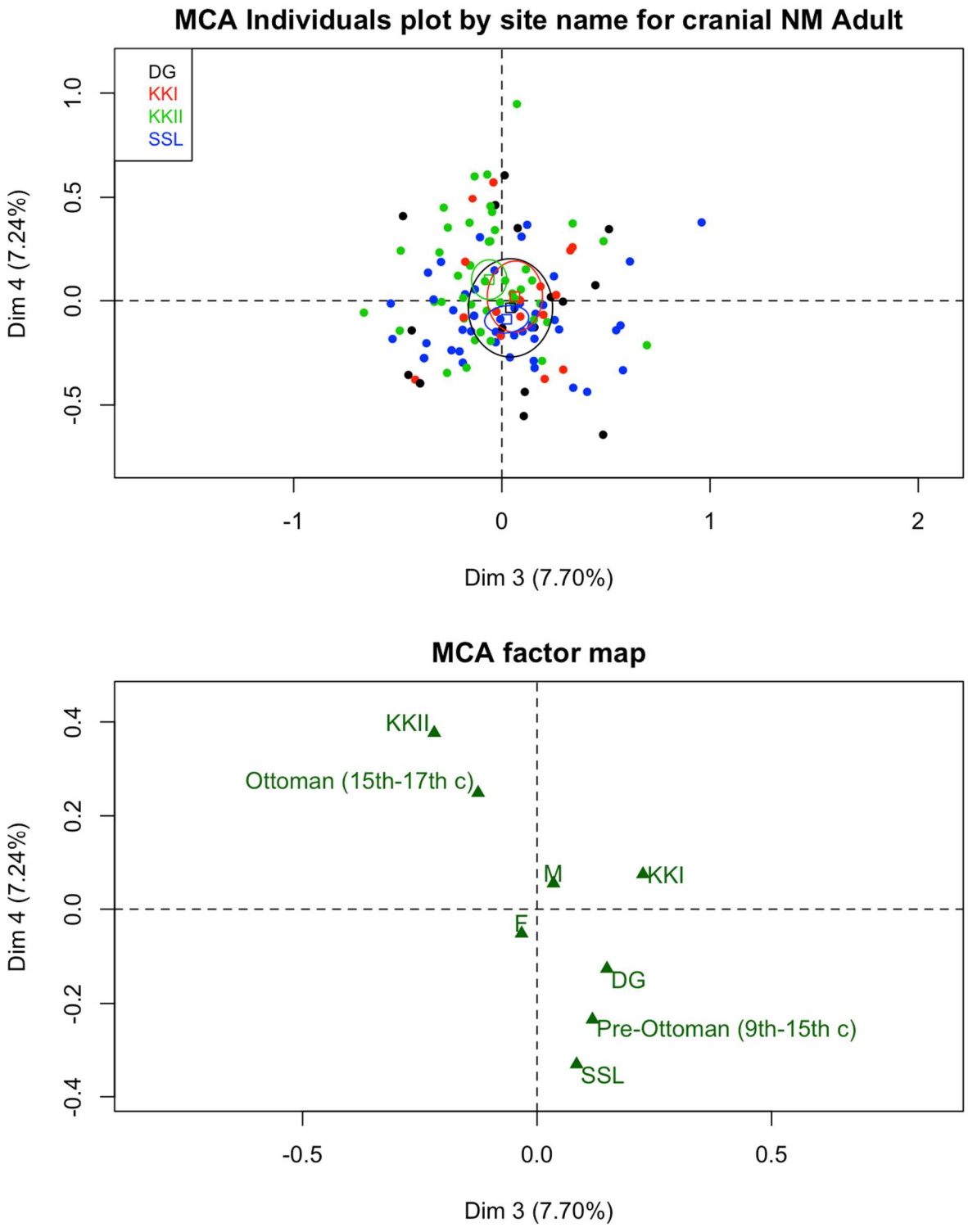

Figure D - 22: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for cranial non-metric – adult only sample (n=140), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

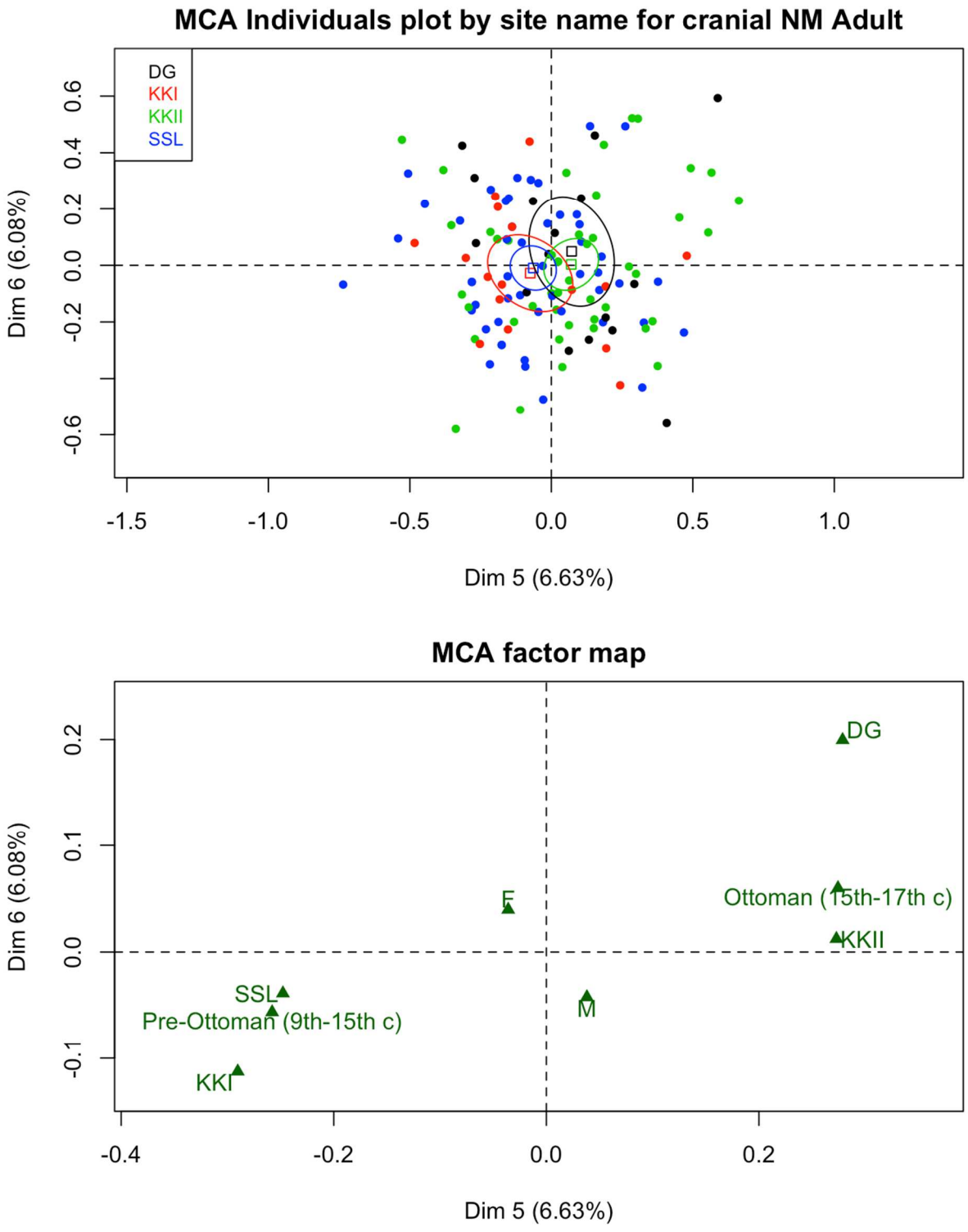

Figure D - 23: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for cranial non-metric – adult only sample (n=140), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

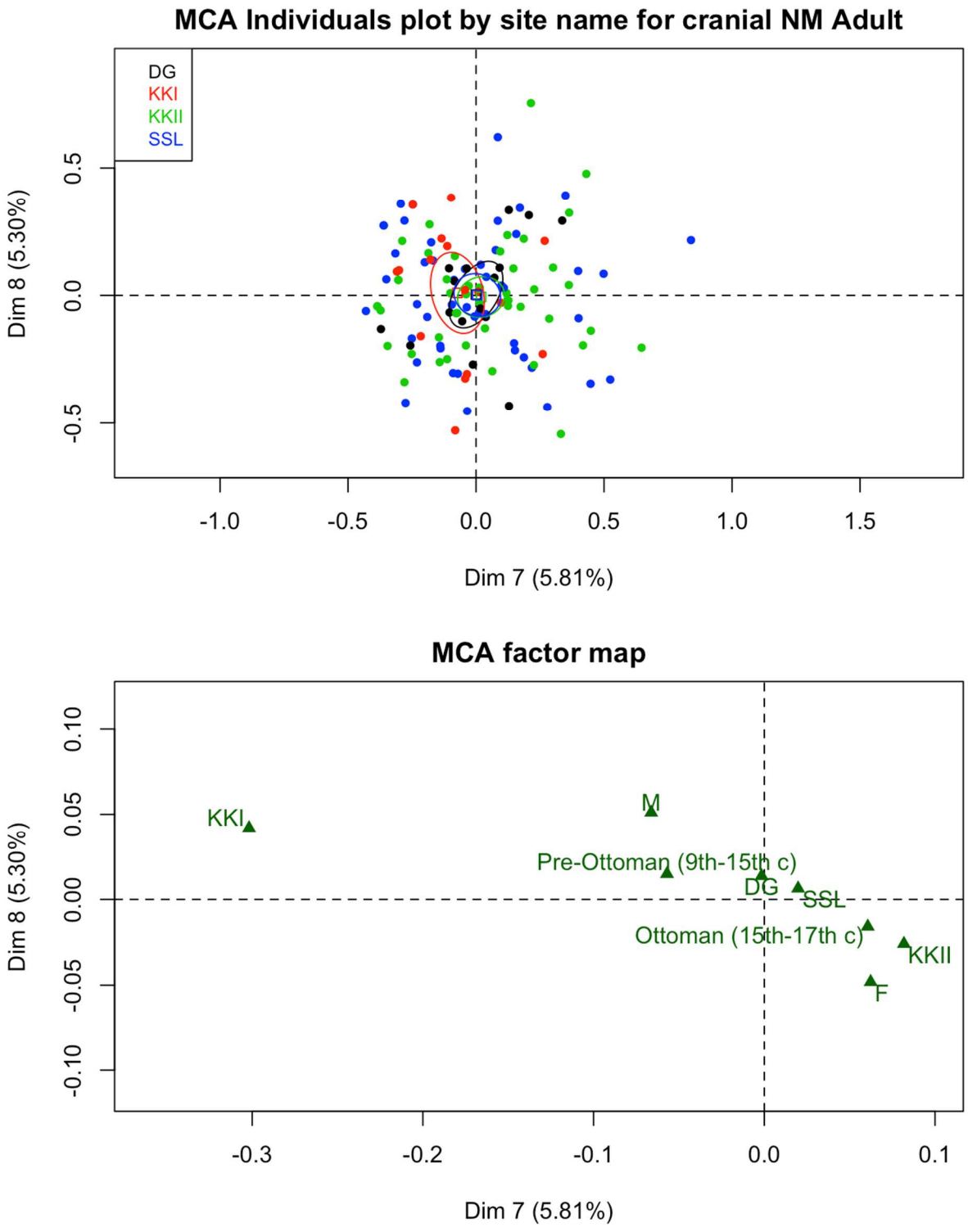

Figure D - 24: Upper: Dim 7 and Dim 8 individuals factor plots (MCA) for cranial non-metric – adult only sample (n=140), colored by site name. Lower: individual data points are removed and barycenters of the supplementary variables are retained.

Male sample comparisons

The significant dimensions of the PCA and MCA analyses for the male sample can be found in Table 7-1 of Chapter 7: Results. The significant dimensions for each dataset were submitted to a MANOVA test to identify group separation by site name (Table D-1). The dental metric, cranial metric, dental non-metric, and cranial non-metric results for the male sample are presented in this section.

Dental metric – male sample (n=53)

The first four PCA dimensions of the dental metric – male sample (n=53) had significant eigenvalues and represented 72% of the cumulative variance in the sample (Table 7-1). For the dental metric – male sample none of the MANOVA by site name results were signficant (Table D-1). Therefore, the dental metric – male sample does not differ by time period and the null hypothesis cannot be disproven.

Results of the DDA analysis using the first four principal components by site name identified no significant differences between individuals (Canon 1: F=1.15, p-value=0.32) (Figure D-25). These results are not a surprise since the MANOVA tests were also not significant.

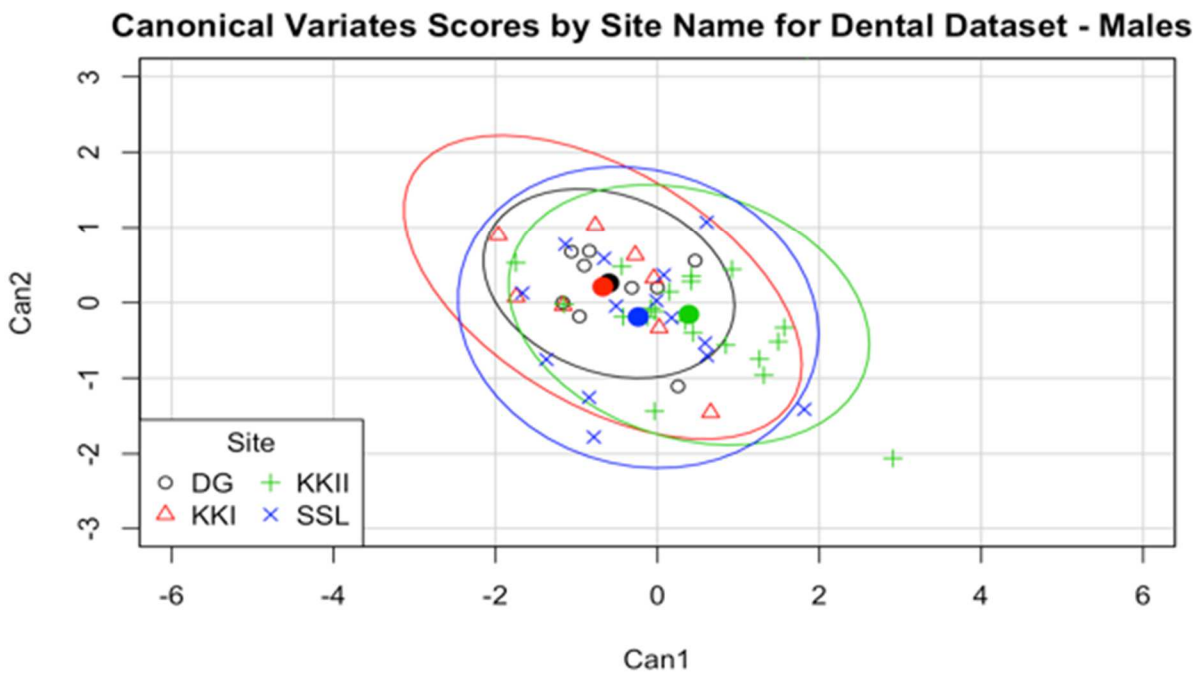

Figure D - 25: Canonical variates 1 and 2 by site name for the dental metric - male sample (n=53).

One-way analysis of variance of the PCA dimensions showed no significant separation of individuals by site name on Dimensions 1 through Dimension 4 (Figure D-26). However, age did correlate with Dimension 2 (R^2=0.13, p=0.01): subadults were positively correlated, while adults were negatively correlated on Dimension 2. However, this age association is likely a result of small sample sizes, there are only five older adolescents included in the sample. The component loadings for each dimension can be found in Table C-2.

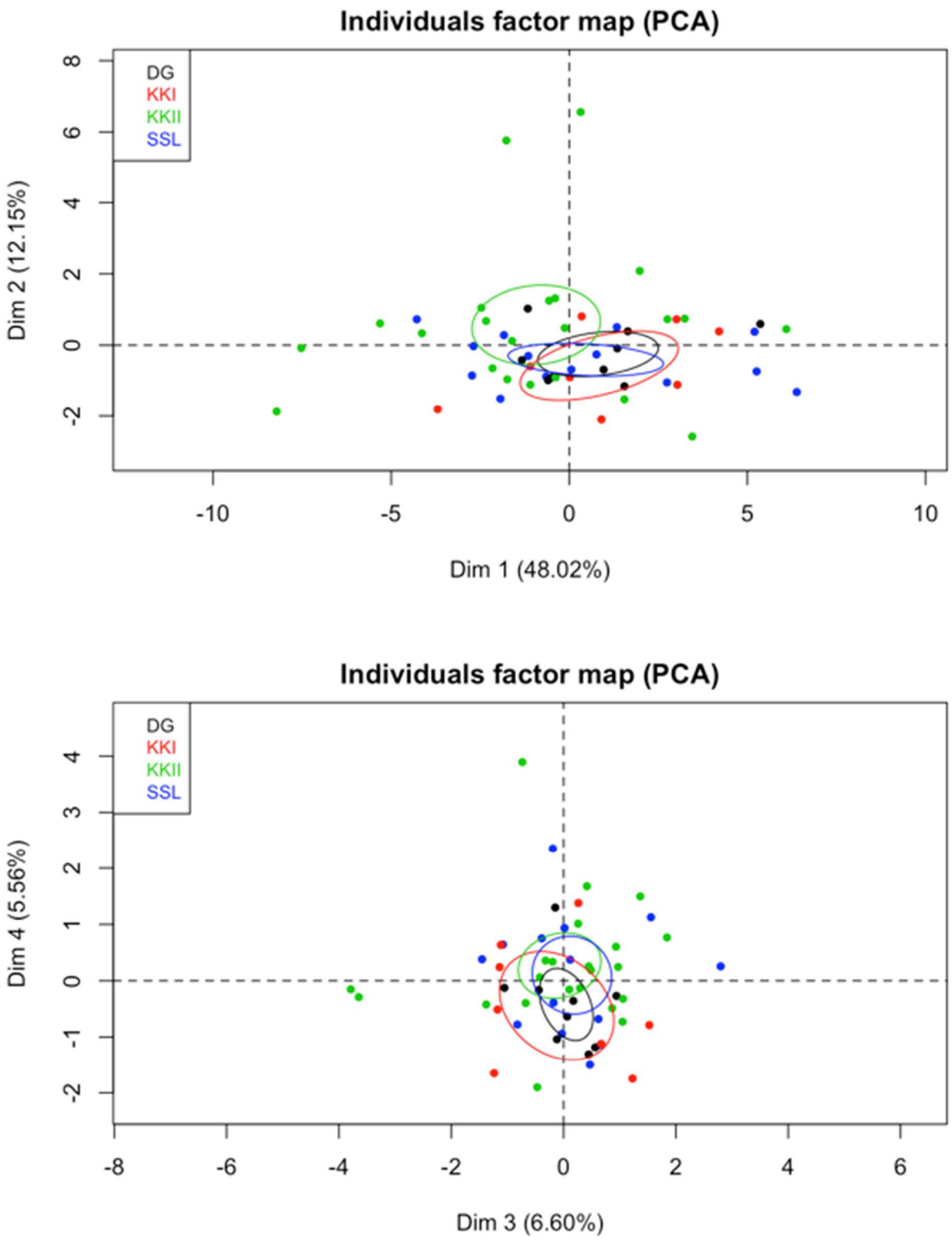

Figure D - 26: Upper: Dim 1 and Dim 2 of individuals factor plot (PCA) for the dental metric - male sample (n=53), colored by site name. Lower: Dim 3 and Dim 4 of individuals factor plot (PCA) for the dental metric - male sample (n=53), colored by site name.

Cranial metric – male sample (n=62)

The first six dimensions of the cranial metric – male sample (n=62) had significant eigenvalues and represented 73% of the cumulative variance in the sample (Table 7-1). For the cranial metric – male sample all of the MANOVA by site name results were significant (Table D-1). Therefore, the cranial metric – male sample differs by site name.

Results of the DDA analysis of the first six principal components and site name identified a significant correlation with Canon 1 (Canon 1: F=3. 78, *p*-value=3e-06), and with Canon 2 (Canon 2: F=2.63, *p*-value=0.0066) (Figure D-27). Canon 3 is not significant.

For Canon 1, all six dimensions are positively correlated (see Table 7-11 for component loadings of PCA dimensions). The Šibenik-Sv. Lovre site is the only site to be positively correlated on Canon 1; the other three sites are negatively correlated (Figure D-27). Dimension 2, Dimension 3, and Dimension 6 had the largest standard coefficients and therefore contributed most the to formation of Canon 1.

For Canon 2, Dimension 1, Dimension 2, and Dimension 3 are negatively correlated, while Dimension 4, Dimension 5 and Dimension 6 are positively correlated (see Table 7-11 for component loadings of PCA dimensions). For Canon 2, Drinovci-Greblje is negatively correlated, Šibenik Sv. Lovre is negatively correlated but near zero, and both Koprivno phases are positively correlated (Figure D-27). Dimension 1, Dimension 2, and Dimension 5 had the largest standard coefficients and therefore contribute most to the formation of Canon 2.

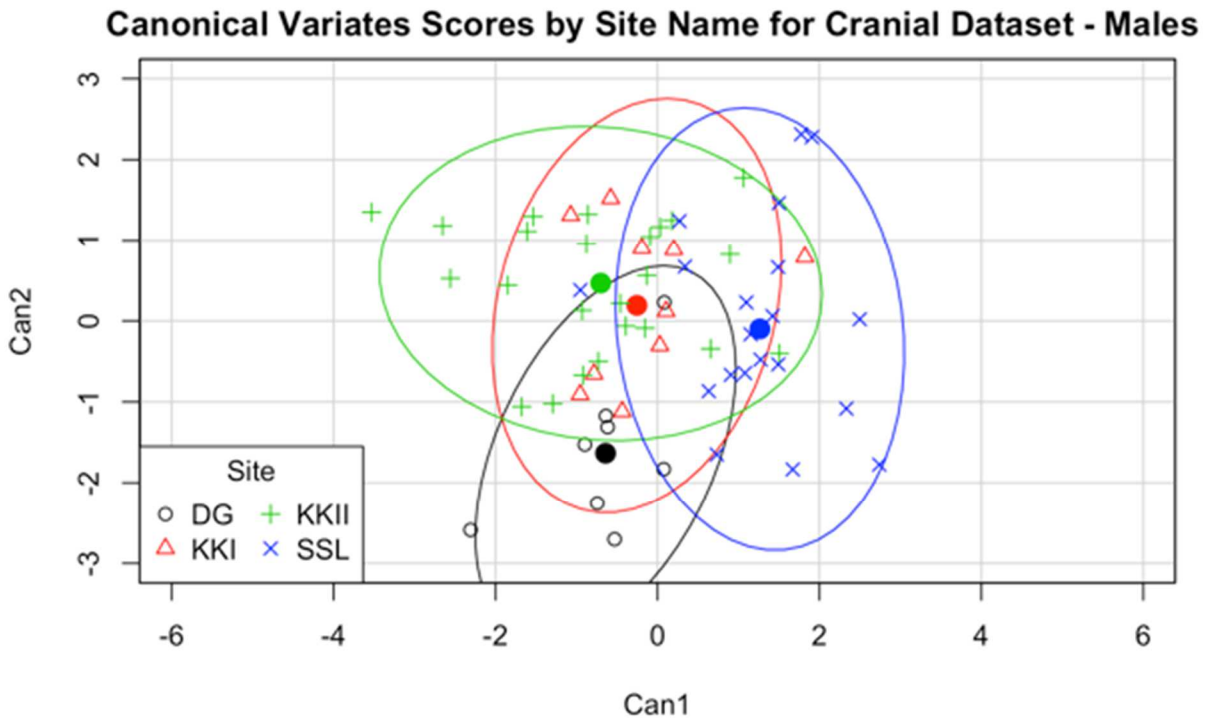

Figure D - 27: Canonical variates 1 and 2 by site name for the cranial metric - male sample (n=62).

Figure D-28 and Figure D-29 present the individuals factor plots for the first six PCA dimensions. Using a one-way analysis of variance, Dimension 1, Dimension 4, Dimension 5 did not separate individuals by site name. Dimension 2, Dimension 3, and Dimension 6 did separate individuals by site name. These same dimensions contributed the most to the formation of the DDA Canon 1.

Dimension 2 accounted for 11.7% of the sample variance and separated individuals by site name (R^2=0.16, *p*-value=0.02) (Figure D-28): Šibenik-Sv. Lovre was positively correlated while Koprivno-Križ II was negatively correlated with Dimension 2. For the most part, Dimension 2 separated measurements of the upper face and orbit (negative) from measurements of the mandible (positive) (Table 7-11). Šibenik-Sv. Lovre males had larger mandibular

measurements: making them positively correlated on Dimension 2. The Koprivno-Križ II males had higher upper face and orbit measures: making them negatively correlated on Dimension 2.

Dimension 3 accounted for 10.2% of the sample variance and separated individuals by site name (R^2=0.21, *p*-value=0.00) (Figure D-29): Šibenik-Sv. Lovre was positively correlated, while Koprivno-Križ II was negatively correlated on Dimension 3. Variable component loadings identified the mastoid length, occipital chord, foramen magnum breadth and orbital breadth measures to be positively correlated, while the maximum ramus breadth, nasal height and interorbital breadth measures were negatively correlated with Dimension 3 (Table 7-11). Šibenik-Sv. Lovre males had high values for mastoid length, occipital chord, foramen magnum breadth and orbital breadth measures: making them positively correlated with Dimension 3. Koprivno-Križ II males had high maximum ramus breadth, nasal height and interorbital breadth measures: making them negatively correlated with Dimension 3.

Dimension 6 accounted for 6% of the total sample variance and separated individuals by site name (R^2=0.13, *p*-value=0.00) (Figure D-29): Šibenik-Sv. Lovre was positively correlated, while Drinovci-Greblje was negatively correlated. Variable component loadings identified the foramen magnum breadth as negatively correlated, while the nasal height, occipital chord and parietal chord were positively correlated on Dimension 6 (Table 7-11). Šibenik-Sv. Lovre males had larger nasal heights, occipital chord, and parietal chord measurements: making them positively correlated with Dimension 6. The Drinovci-Greblje males had larger foramen magnum breadth measures: making them negatively correlated with Dimension 6.

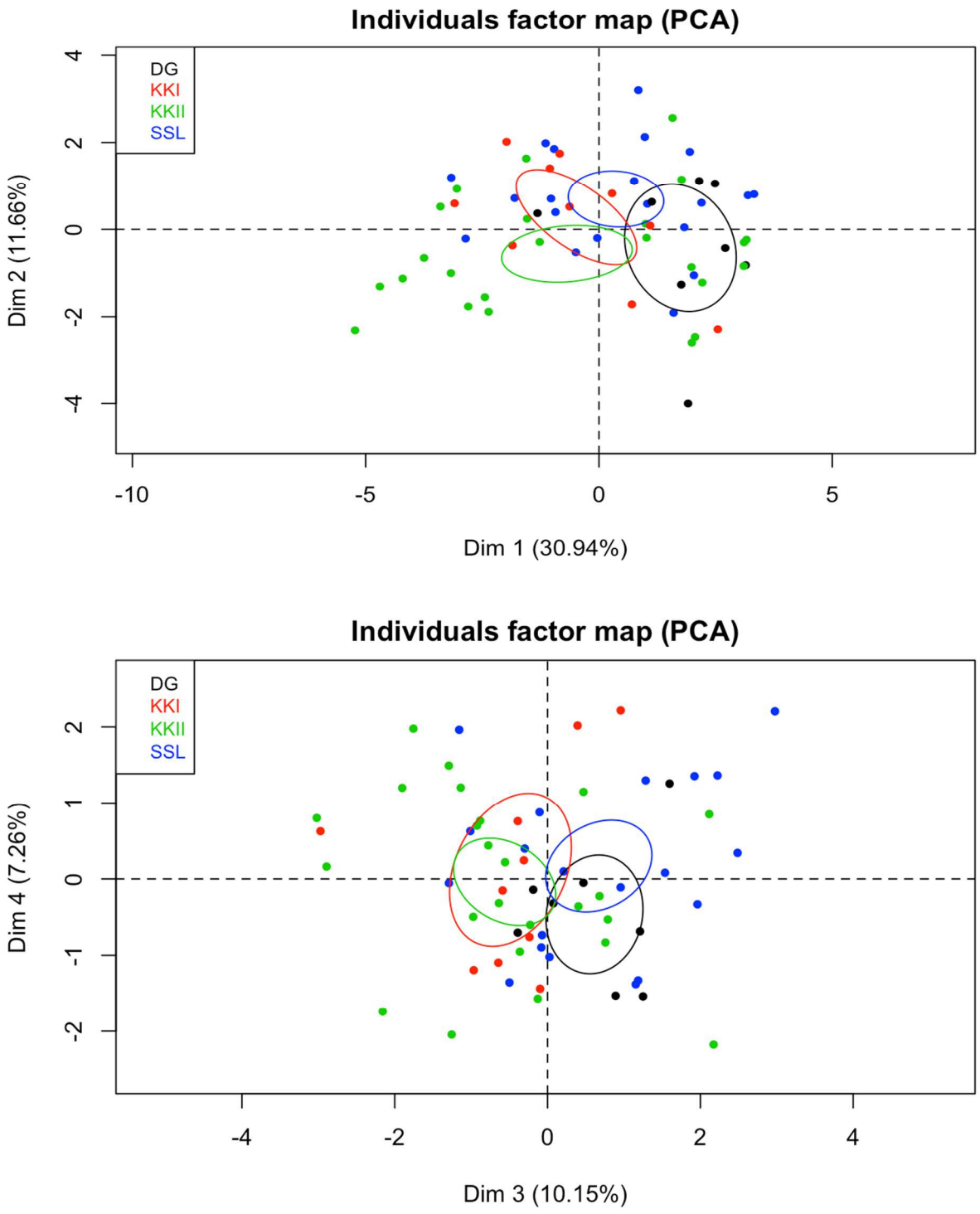

Figure D - 28: Upper: Dim 1 and Dim 2 individuals factor plot (PCA) for the cranial metric - male sample (n=62), colored by site name. Lower: Dim 3 and Dim 4 individuals factor plot (PCA) for the cranial metric - male sample (n=62), colored by site name.

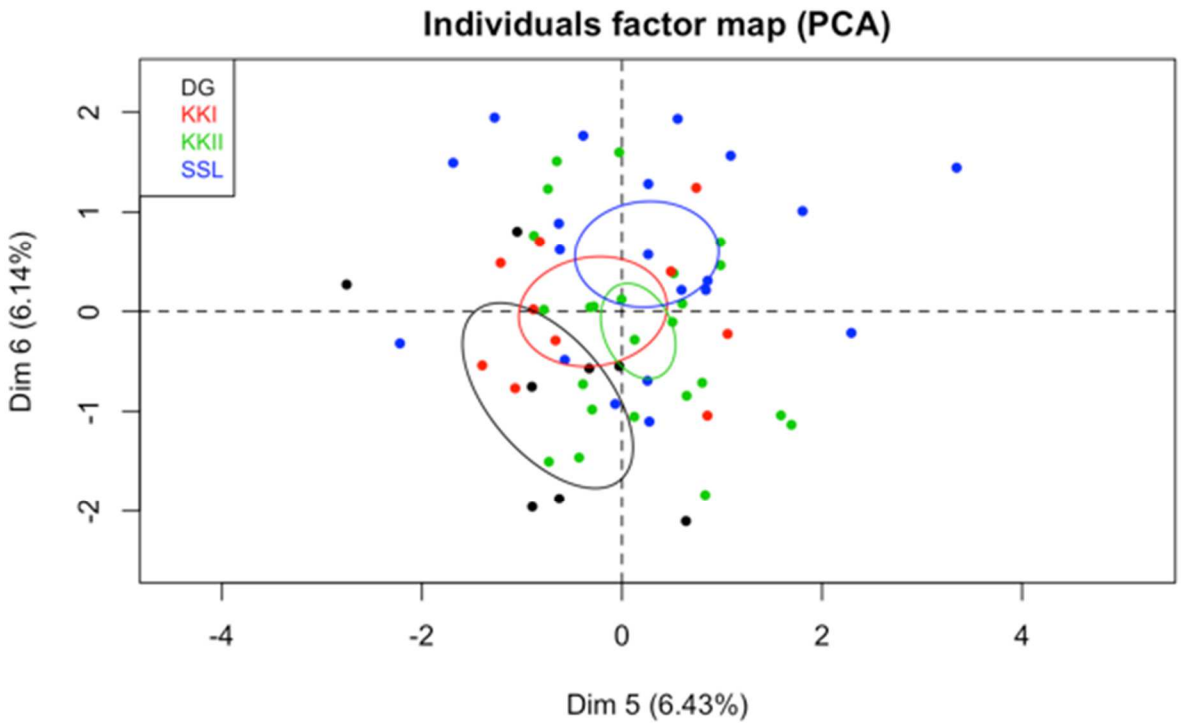

Figure D - 29: Upper: Dim 5 and Dim 6 individuals factor plot (PCA) for the cranial metric - male sample (n=62), colored by site name.

Dental non-metric – male sample (n=53)

The first seven MCA dimensions of the dental non-metric – male sample (n=53) had significant eigenvalues and represented 73.9% of the cumulative variance in the sample (Table 7-1). For the dental non-metric – male sample all of the MANOVA by site name results were signficant (Table D-1). Therefore, the dental non-metric – male sample differs by site name.

Results of the DDA analysis using the first seven MCA dimensions identified significant differences between individuals when grouped by site name on Canon 1 (Canon 1: F=1.99, p-value=0.01), but not for the other canons (Figure D-30): Šibenik Sv. Lovre was positively correlated, while Koprivno-Križ I, Koprivno-Križ II and Drinovci-Greblje were negatively correlated on Canon 1. Dimension 2 and Dimension 6 were negatively correlated, while

Dimension 1, Dimension 3, Dimension 4, Dimension 5 and Dimension 7 were positively correlated with Cannon 1 (see Table C-3 for component loadings). Dimension 2, Dimension 5, and Dimension 7 have the largest standard coefficients and therefore contributed most to the formation of Canon 1.

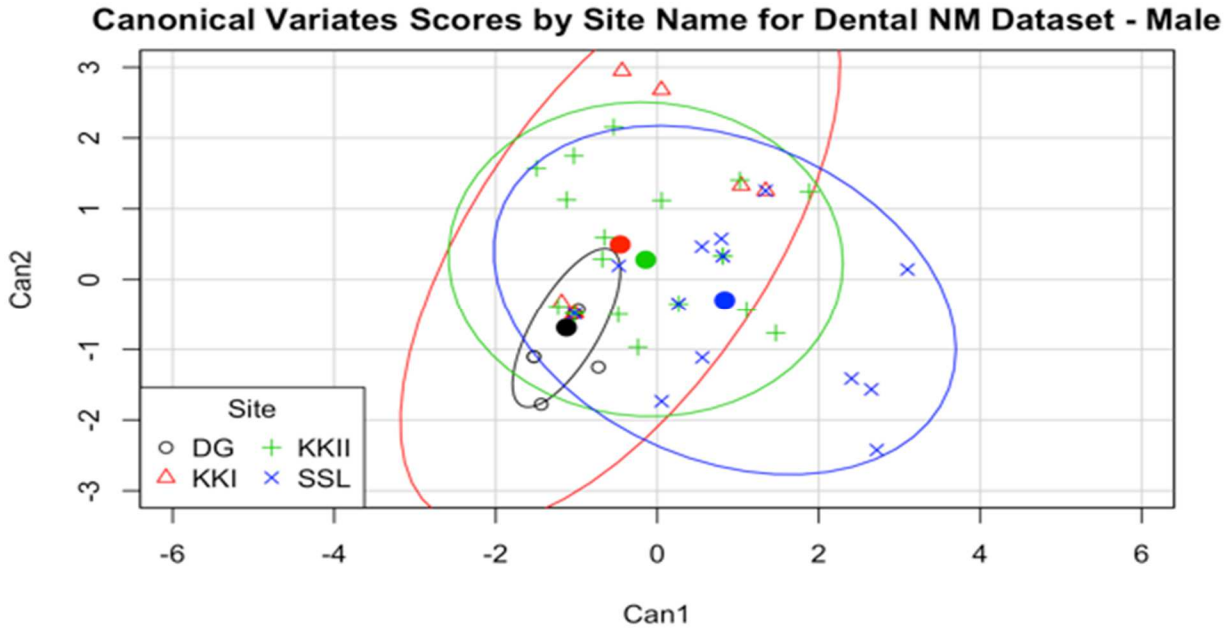

Figure D - 30: Canonical variates 1 and 2 by site name for the dental non-metric - male sample (n=53).

The component loadings and eigenvalues for the first seven MCA dimensions are presented in Table C-3. Individual factor plots for the first six MCA dimensions are presented in Figure D-31 and Figure D-32. Dimension 1, Dimension 3, Dimension 4, Dimension 6 and Dimension 7 did not separate individuals by site name (Figure D-31 and Figure D-32), therefore the component loadings of the significantly contributing variables for each of these dimensions are not examined here but are still highlighted in Table C-3. Dimension 2 and Dimension 5 did separate individuals by site name.

Dimension 2 accounts for 12.78% of the sample variance and separated individuals by site name (R^2=0.1958, p-value=0.0130) (Figure D-31): Šibenik-Sv. Lovre males were negatively correlated on Dimension 2. Dimension 2 was characterized by a positively correlated LM2 groove pattern-non-Y, and the UM3 mesial paracone tubercle-absence, while the LM2 groove pattern-Y and UM3 mesial paracone tubercle-presence were negatively correlated (Table C-3). Therefore, Šibenik-Sv. Lovre males had higher frequencies of the LM2 groove pattern-Y and UM3 mesial paracone tubercle-presence: making them negatively correlated on Dimension 2.

Dimension 5 separated individuals by site name (R^2=0.1701, *p*-value=0.0264) (Figure D-32): Drinovci-Greblje males were negatively correlated on Dimension 5. The LM3 congenital absence was positively correlated, while the LM3-tooth presence was negatively correlated (Table C-3). Drinovci-Greblje males had a lower frequency of the LM3-congenital absence than the other sites: making Drinovci-Greblje males negatively correlated on Dimension 5.

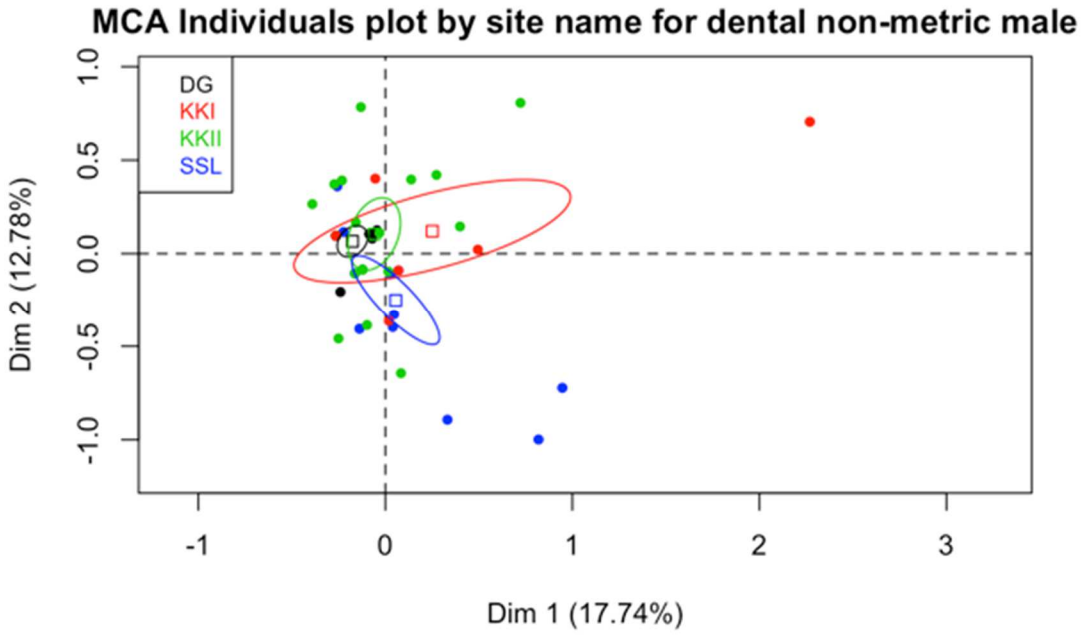

Figure D - 31: Dim 1 and Dim 2 individuals factor plots (MCA) for the dental non-metric - male sample (n=53), colored by site name.

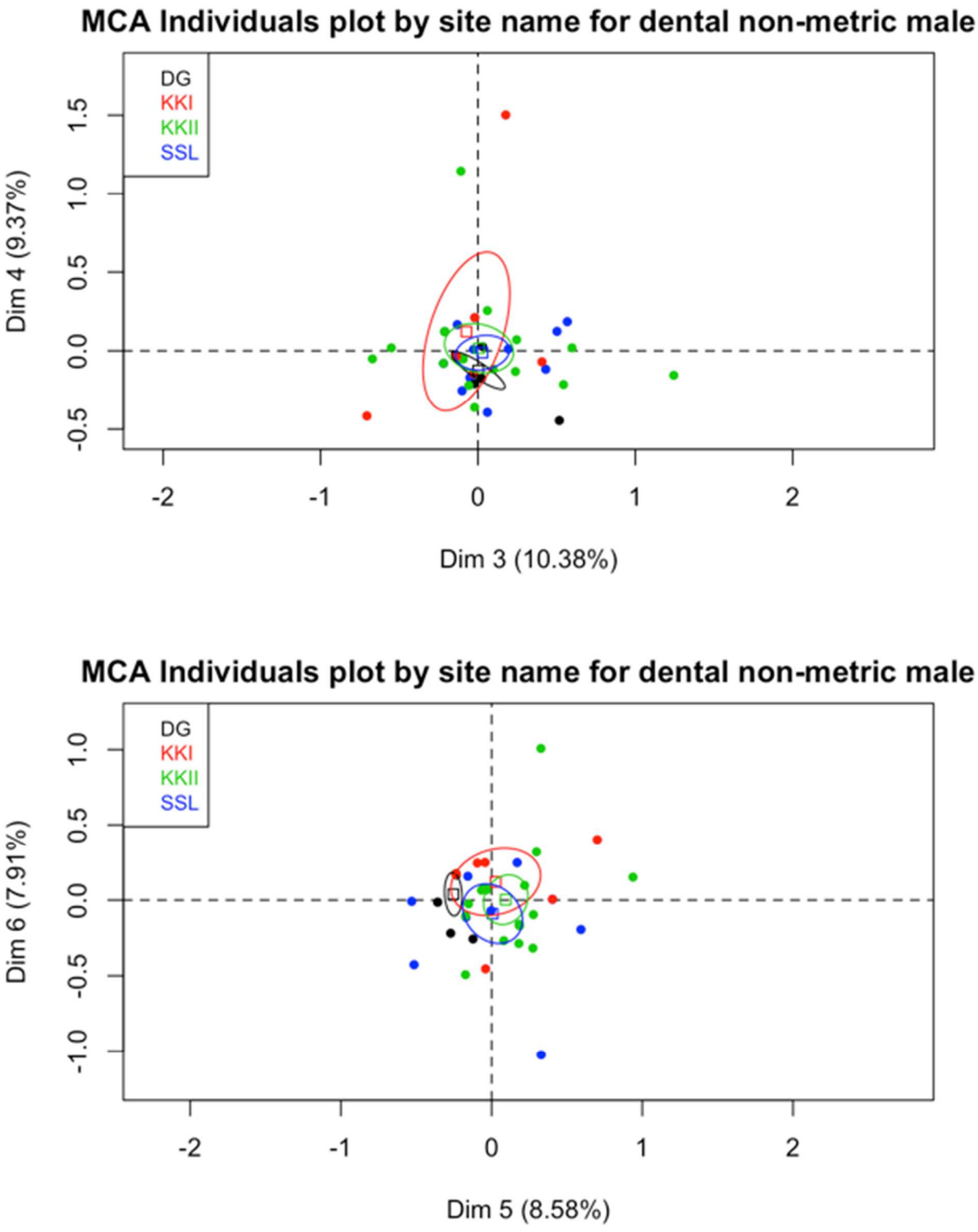

Figure D - 32: Upper: Dim 3 and Dim 4 individuals factor plots (MCA) for the dental non-metric - male sample (n=53), colored by site name. Lower: Dim 5 and Dim 6 individuals factor plots (MCA) for the dental non-metric - male sample (n=53), colored by site name.

Cranial non-metric – male sample (n=68)

The first eight MCA dimensions of the cranial non-metric – male sample (n=68) had significant eigenvalues and represented 64.42% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – male sample, only the Roy and Hotelling-Lawyley tests of the MANOVA by site name results were signficant (Table D-1).

Results of the DDA analysis of the first eight MCA dimensions and site name identified no significant correlations with Cannon 1, Cannon 2 or Cannon 3 (Figure D-33). There are no identified differences between male individuals based on site name using cranial non-metrics.

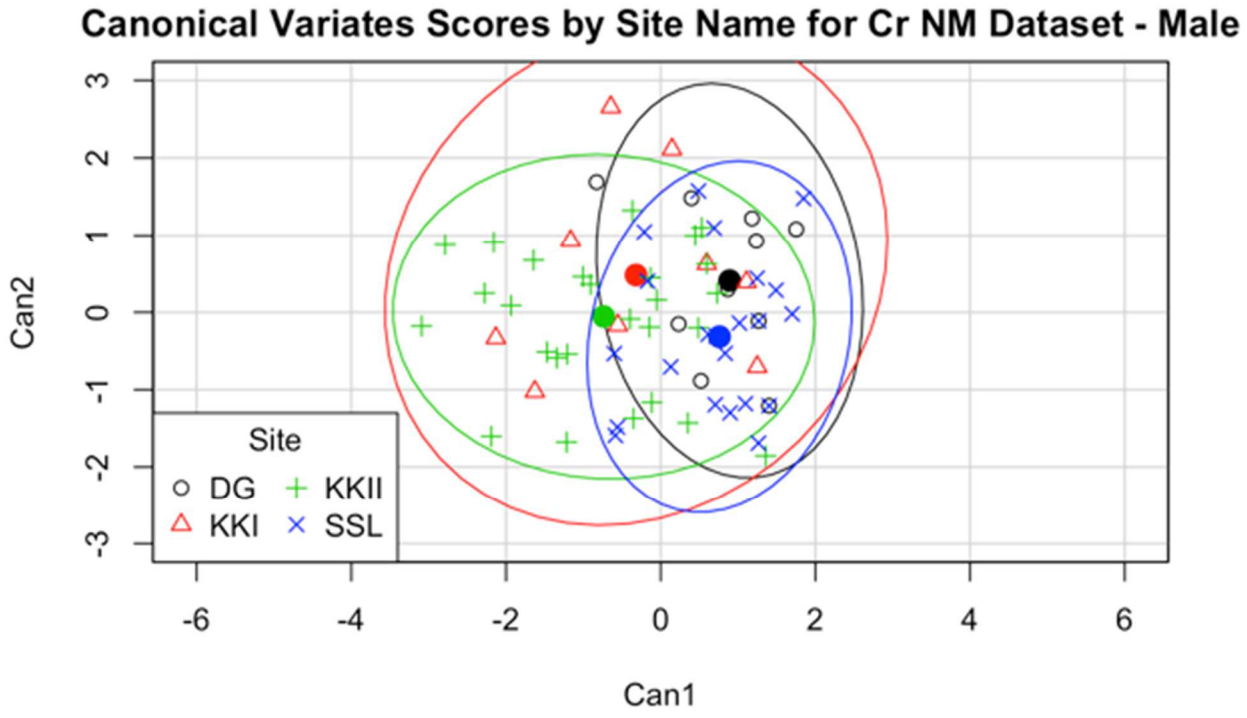

Figure D - 33: Canonical variates 1 and 2 by site name for the cranial non-metric - male sample (n=68).

The component loadings and eigenvalues for the first eight MCA dimensions are presented in Table C-4. Using one-way analysis of variance, the variables that contribute

significantly to the formation of each dimension are highlighted in gray in Table C-4. Figure D-34 and Figure D-35 present the individual factor plots for the first eight MCA dimensions. Only Dimension 2 separated individuals by site name. Therefore, only the component loadings of Dimension 2 are discussed here. Age does not separate individuals on any of the dimensions.

Dimension 2 separated individuals well by site name (R^2=0.1211, *p*-value=0.0398) (Figure D-34): Koprivno-Križ II males were positively correlated, while Drinovci-Greblje males were negatively correlated on Dimension 2. Dimension 2 was characterized by the positive correlation of biasterionic suture-present, mastoid foramen-extrasutural, supranasal suture-absent, and pharyngeal tubercle-absent; and the negative correlation of biasterionic suture-absent, mastoid foramen-in suture, supranasal suture-present, and pharyngeal tubercle-present (Table C-4). Therefore, Koprivno-Križ II males had higher frequencies of biasterionic suture-presence, mastoid foramen-extrasutural, supranasal suture-absence, and pharyngeal tubercle-absence: making Koprivno-Križ II males positively correlated on Dimension 2. While, Drinovci-Greblje males had higher frequencies of biasterionic suture-absence, mastoid foramen-in suture, supranasal suture-presence, and pharyngeal tubercle-presence: making Drinovci-Greblje males negatively correlated on Dimension 2.

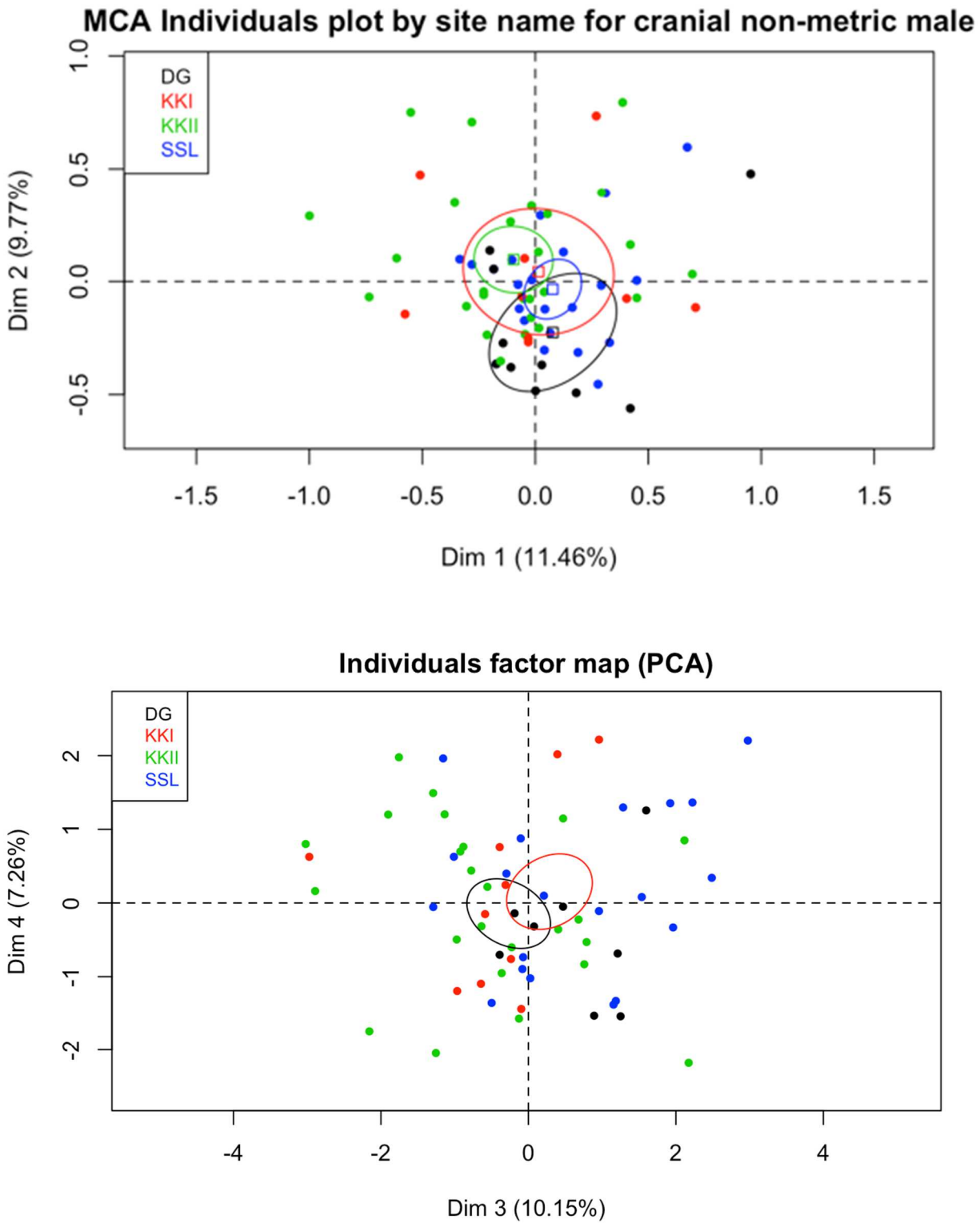

Figure D - 34: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the cranial non-metric - male sample (n=68), colored by site name. Lower: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - male sample (n=68), colored by site name.

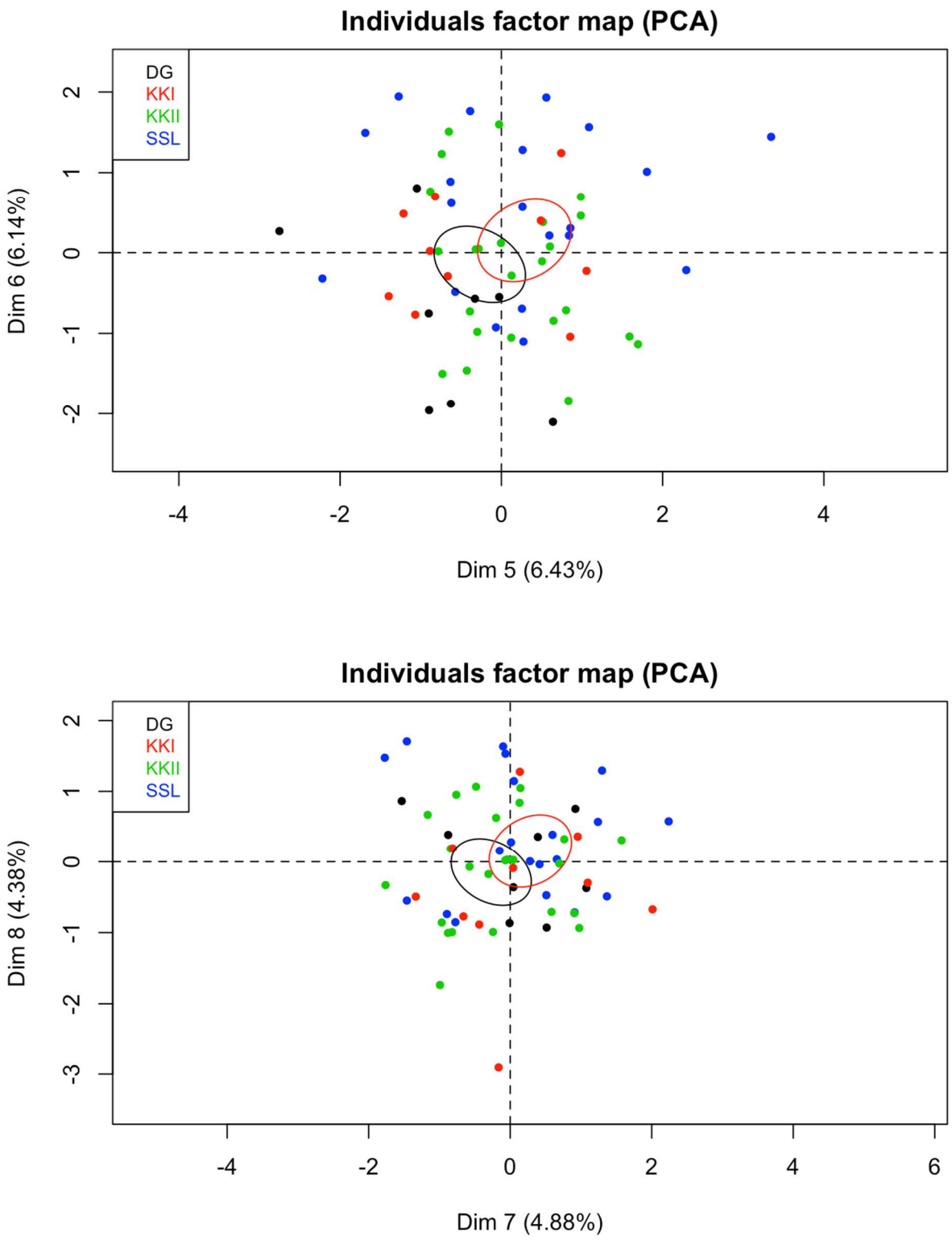

Figure D - 35: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the cranial non-metric - male sample (n=68), colored by site name. Lower: Dim 7 and Dim 8 individuals factor plots (MCA) for the cranial non-metric - male sample (n=68), colored by site name.

Female sample comparisons

The significant dimensions of the PCA and MCA analyses for the female sample can be found in Table 7-1 of Chapter 7: Results. The significant dimensions for each dataset were submitted to a MANOVA test to identify group separation by site name (Table D-1). The dental metric, cranial metric, dental non-metric, and cranial non-metric results for the total sample are presented in this section.

Dental metric – female sample (n=58)

The first five PCA dimensions of the dental metric – female sample had significant eigenvalues and represented 71% of the cumulative variance in the sample (Table 7-1). For the dental metric – female sample all of the MANOVA by site name results were significant (Table D-2). The dental metric – female sample differs by site name.

Results of the DDA analysis using the first five PCA dimensions by site name identified significant differences between individuals on Canon 1 (Canon 1: F=2.14, p-value=0.011) (Figure D-36): Šibenik-Sv. Lovre and Koprivno-Križ I are positively correlated, while Koprivno-Križ II and Drinovci-Greblje are negatively correlated on Canon 1. Canon 2 and Canon 3 showed no significant differences. Dimension 1 and Dimension 2 are negatively correlated with Canon 1 while Dimension 3, Dimension 4, and Dimension 5 are positively correlated with Canon 1. Dimension 3 and Dimension 4 had the largest standard coefficients and therefore contributed most to the formation of Canon 1 (see Table 7-12 for component loadings of PCA dimensions).

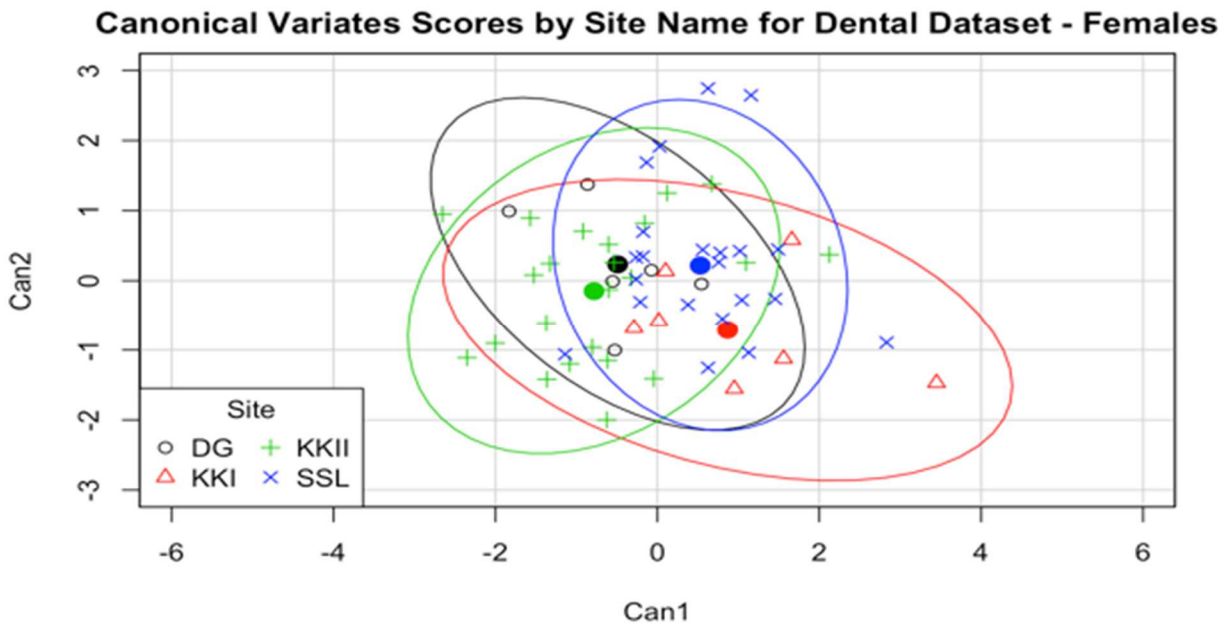

Figure D - 36: Canonical variates 1 and 2 by site name for the dental metric - female sample (n=58).

The PCA of the dental metric – female sample was explored by site name using a one-way analysis of variance. Dimension 1, Dimension 2, and Dimension 5 did not separate individuals by site name and therefore discussion of the component loadings for these dimensions has been omitted (Figure D-37 and Figure D-38). Dimension 3 and Dimension 4 were the only PCA dimensions that separated individuals by site name (Figure D-38).

PC3 accounts for 9.08% of the sample variance and separated individuals by site name (R^2=0.22, p-value=0.00) (Figure D-38): Šibenik-Sv. Lovre females were positively correlated, while Koprivno-Križ II females were negatively correlated on Dimension 3. Examination of the component loadings showed Dimension 3 to separate crown measures (negative) from CEJ measures (positive). Therefore, Šibenik-Sv. Lovre females had larger CEJ measures making them positively correlated with Dimension 3. While, Koprivno-Križ II females had larger crown measures making them negatively correlated with Dimension 3.

PC4 accounts for 6.64% of the sample variance and also separated individuals by site name (R^2=0.15, p-value=0.03) (Figure D-38): Koprivno-Križ I females were positively correlated with Dimension 4. Examination of the component loadings for the dental metric variables showed Dimension 4 to separate maxillary (positive) from mandibular measurements (negative) (Table 7-12). Therefore, Koprivno-Križ I females had larger maxillary measures making them positively correlated with Dimension 4.

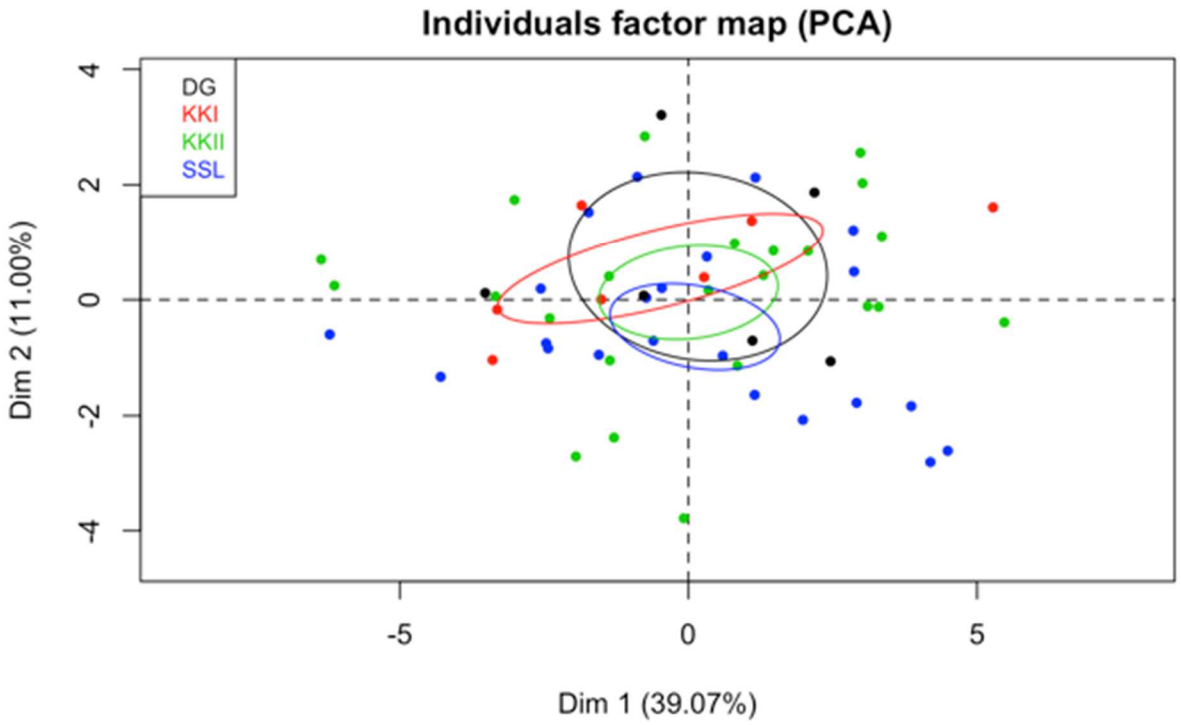

Figure D - 37: Upper: Dim1 and Dim 2 individuals factor plot (PCA) for the dental metric - female sample (n=58), colored by site name.

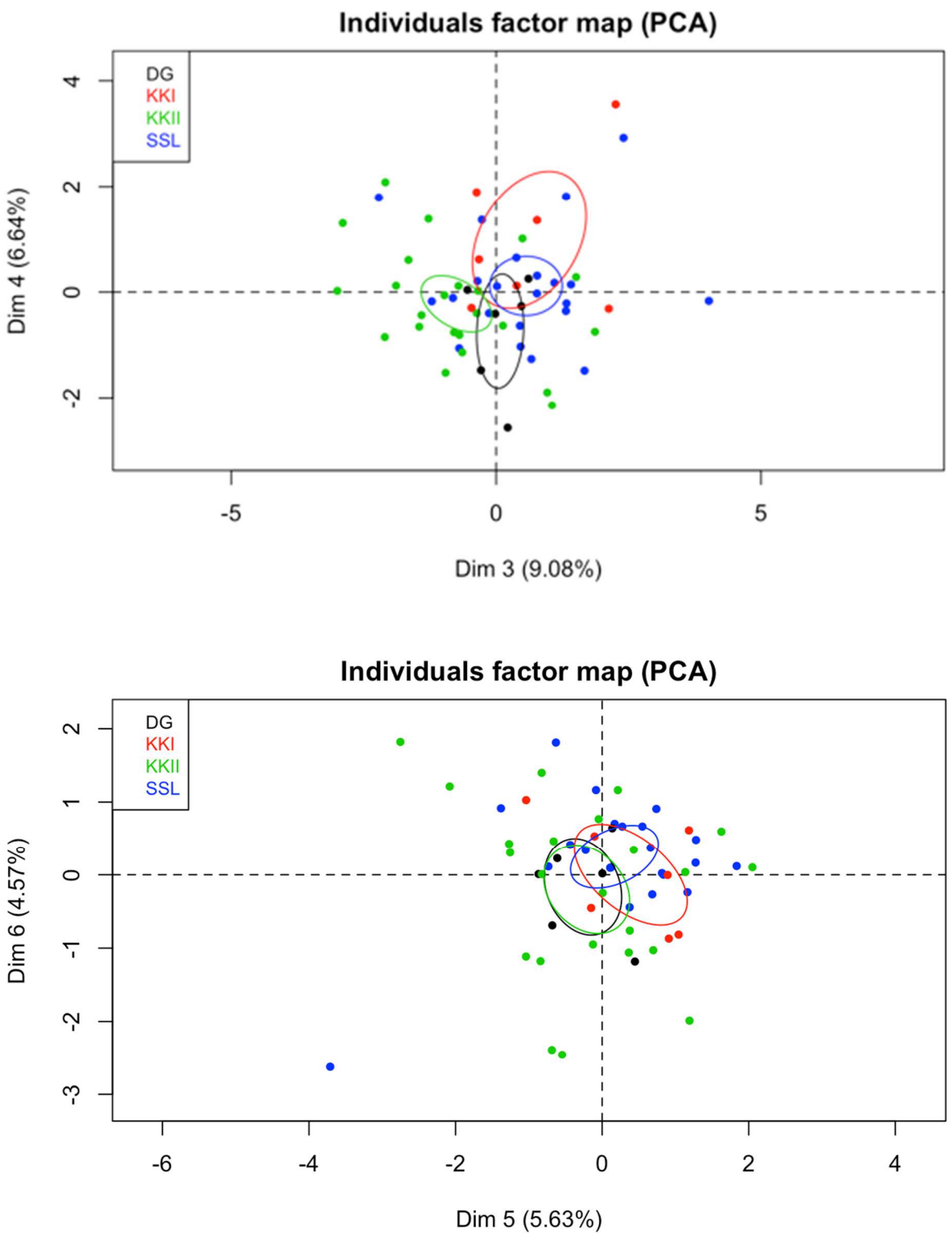

Figure D - 38: Upper: Dim 3 and Dim 4 individuals factor plot (PCA) for the dental metric - female sample (n=58), colored by site name. Lower: Dim 5 and Dim 6 individuals factor plot (PCA) for the dental metric - female sample (n=58), colored by site name.

Cranial metric – female sample (n=70)

The first six PCA dimensions of the cranial metric – female sample had significant eigenvalues and represented 71% of the cumulative variance in the sample (Table 7-1). For the cranial metric – female sample three of the MANOVA by site name results were significant (Table D-1). The cranial metric – female sample differs by site name.

Results of the DDA analysis of the first six PCA dimensions and site name identified a significant correlation with Canon 1 (Canon 1: F=1.660,p-value=0.05), but Canon 2 and Canon 3 were not significant (Figure D-39). The Šibenik-Sv. Lovre site is negatively correlated, while the other three sites are positively correlated on Canon 1. Dimension 1, Dimension 4 and Dimension 6 are positively correlated, while Dimension 2, Dimension 3 and Dimension 5 are negatively correlated on Canon 1 (see Table 7-13 for component loadings of PCA dimensions). Dimension 2 and Dimension 3 had the largest standard coefficients and therefore contributed most to the formation of Canon 1.

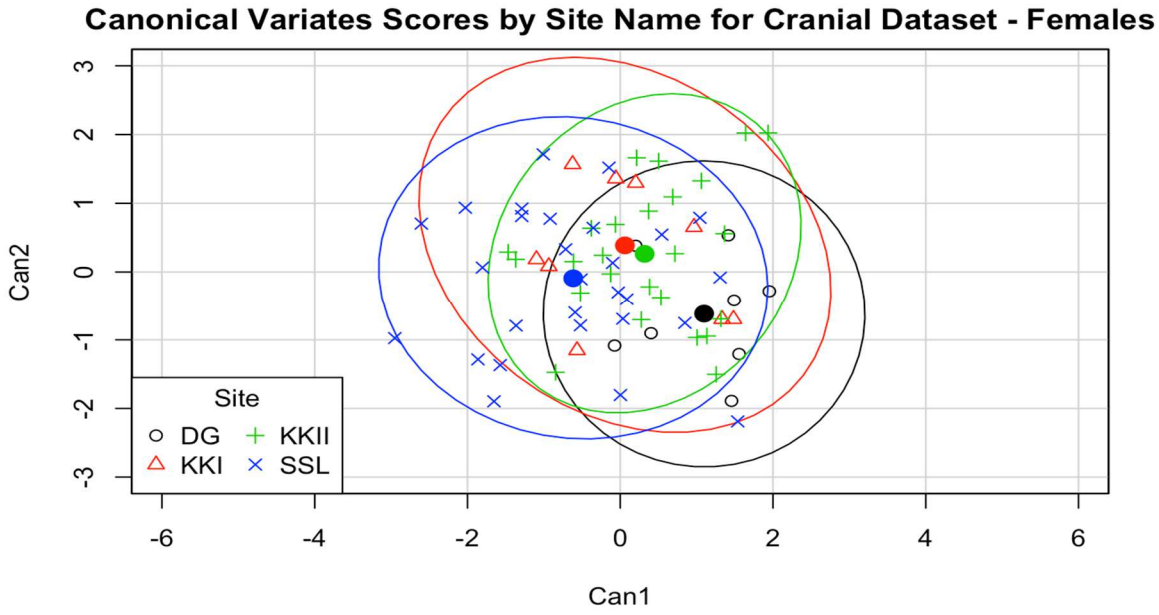

Figure D - 39: Canonical variates 1 and 2 by site name for the cranial metric - female sample (n=70).

The PCA of the cranial metric – female sample was explored by site name using one-way analysis of variance. Figure D-40 and Figure D-41 present the individuals factor plots for the first six PCA dimensions. Dimension 1, Dimension 3, Dimension 4, Dimension 5, and Dimension 6 did not separate individuals by site name. Only Dimension 2 separated individuals by site name (Figure D-40).

Dimension 2 accounted for 15.9% of the sample variance and separated individuals by site name (R^2=0.12, p-value=0.02) (Figure D-40): the Šibenik-Sv. Lovre females were positively correlated, while the Drinovci-Greblje females were negatively correlated with Dimension 2. For the most part, Dimension 2 separated the biauricular breadth, orbital breadth and orbital height (negative) from measurements of the mandible (positive) (Table 7-13). Šibenik-Sv. Lovre females had larger mandibular measurements: making them more positively correlated on Dimension 2. Drinovci-Greblje females had larger orbital measurements: making them more negatively correlated with Dimension 2.

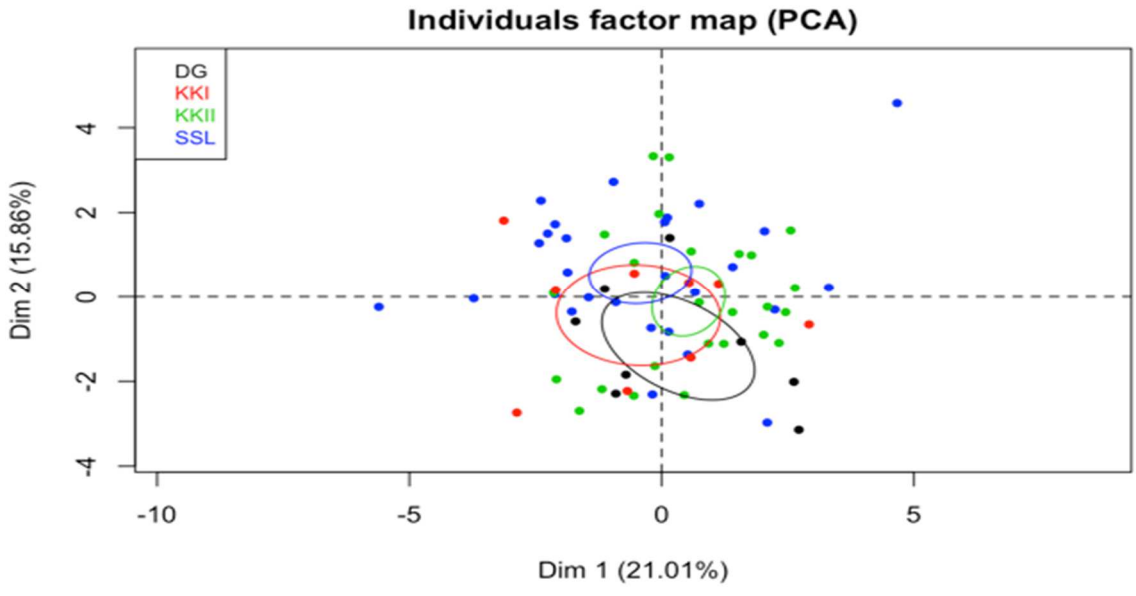

Figure D - 40: Dim 1 and Dim 2 individuals factor plot (PCA) for the cranial metric - female sample (n=70), colored by site name.

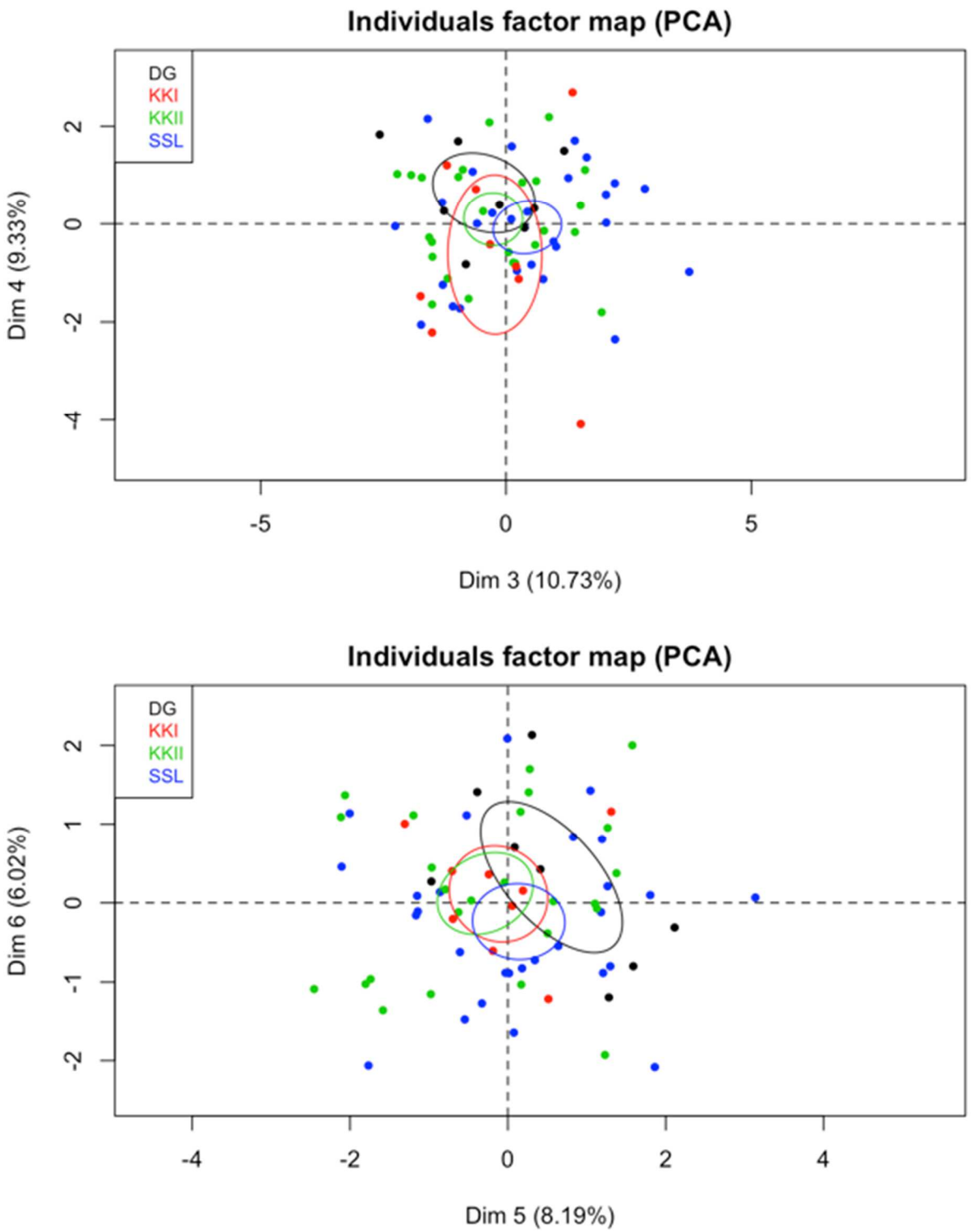

Figure D - 41: Upper: Dim 3 and Dim 4 individuals factor plot (PCA) for the cranial metric - female sample (n=70), colored by site name. Lower: Dim 5 and Dim 6 individuals factor plot (PCA) for the cranial metric - female sample (n=70), colored by site name.

Dental non-metric – female sample (n=58)

The first seven MCA dimensions of the dental non-metric – female sample (n=58) had significant eigenvalues and represented 71.28% of the cumulative variance in the sample (Table 7-1). For the dental non-metric – female sample all of the MANOVA by site name results were significant (Table D-1). Therefore, the dental non-metric – female sample differs by site name.

Results of the DDA analysis using the first seven MCA dimensions identified significant differences between individuals when grouped by site name on Canon 1 (Canon 1: F=1.87, *p*-value=0.02), but not for the other canons (Figure D-42). Šibenik Sv. Lovre and Koprivno-Križ I were positively correlated, while Koprivno-Križ II and Drinovci-Greblje were negatively correlated on Canon 1. Dimension 1, Dimension 5 and Dimension 7 are negatively correlated, while Dimension 2, Dimension 3, Dimension 4 and Dimension 6 are positively correlated with Canon 1 (see Table 7-14 for component loadings). Dimension 1 and Dimension 7 had the largest standard coefficients and therefore contributed most to the formation of Canon 1.

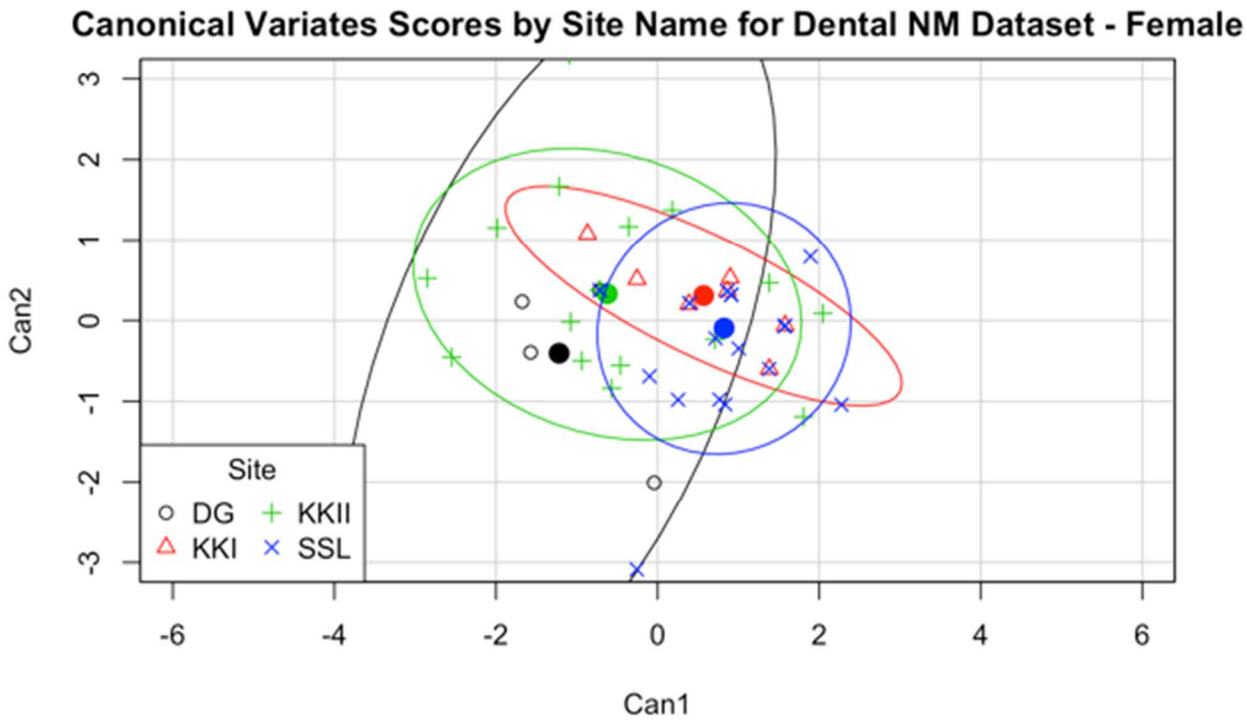

Figure D - 42: Canonical variates 1 and 2 by site name for the dental non-metric - female sample (n=58).

The component loadings and eigenvalues for the first seven MCA dimensions are presented in Table 7-14. One-way analysis of variance identified no separation of individuals by site name on Dimension 2 through Dimension 6 (Figure D-43 and Figure D-44).

Dimension 1 accounted for 15.36% of the sample variance and separated individuals by site name (R^2=0.1428, p-value=0.0385) (Figure D-43): Šibenik-Sv. Lovre females were negatively correlated on Dimension 1. Age was not identified as a significant separating factor for Dimension 1. The component loadings illustrate that Dimension 1 is characterized by the positive correlation of the UM3 hypocone-absence, UM3 mesial paracone tubercle-absence, and LM3 congenital absence, and the negative correlation of the presence of these traits (Table 7-14). Therefore, Šibenik-Sv. Lovre females show higher frequencies of the presence of UM3

hypocone, UM3 mesial paracone tubercle, and LM3 congenital absence: making Šibenik-Sv. Lovre females negatively correlated on Dimension 1.

Dimension 7 accounted for 7.07% of the sample variance and separated individuals by site name (R^2=0.2294, *p*-value=0.0026) (Figure D-44): Koprivno Križ II and Drinovci-Greblje females were positively correlated, while Šibenik-Sv. Lovre females were negatively correlated on Dimension 7. However, Dimension 7 also separated individuals by age (R^2=0.0984, *p*-value=0.0165): adults were negatively correlated, while subadults were positively correlated on Dimension 7. The Koprivno-Križ II site had five female adolescents comprising 9% of the female sample (Table B-2), while the Šibenik-Sv. Lovre site had 14 middle and older adults comprising 24% of the female sample. Therefore, Dimension 7 may reflect dental wear and demographic differences between the sites rather than phenotypic/genetic differences. Dimension 7 was characterized by the positive correlation of the UM2 metacone-absence, LC double root-presence and UM2 parastyle-absence; and the negative correlation of the UM2 metacone-presence, LC double root-absence and UM2 parastyle-presence (Table 7-14). Koprivno-Križ II and Drinovci-Greblje females had higher frequencies of UM2 metacone-absence, LC double root-presence, and UM2 parastyle-presence: making them positively correlated on Dimension 7. While, Šibenik-Sv. Lovre females had higher frequencies of UM2 metacone-presence, LC double root-absence, and UM2 parastyle-absence: making them negatively correlated on Dimension 7.

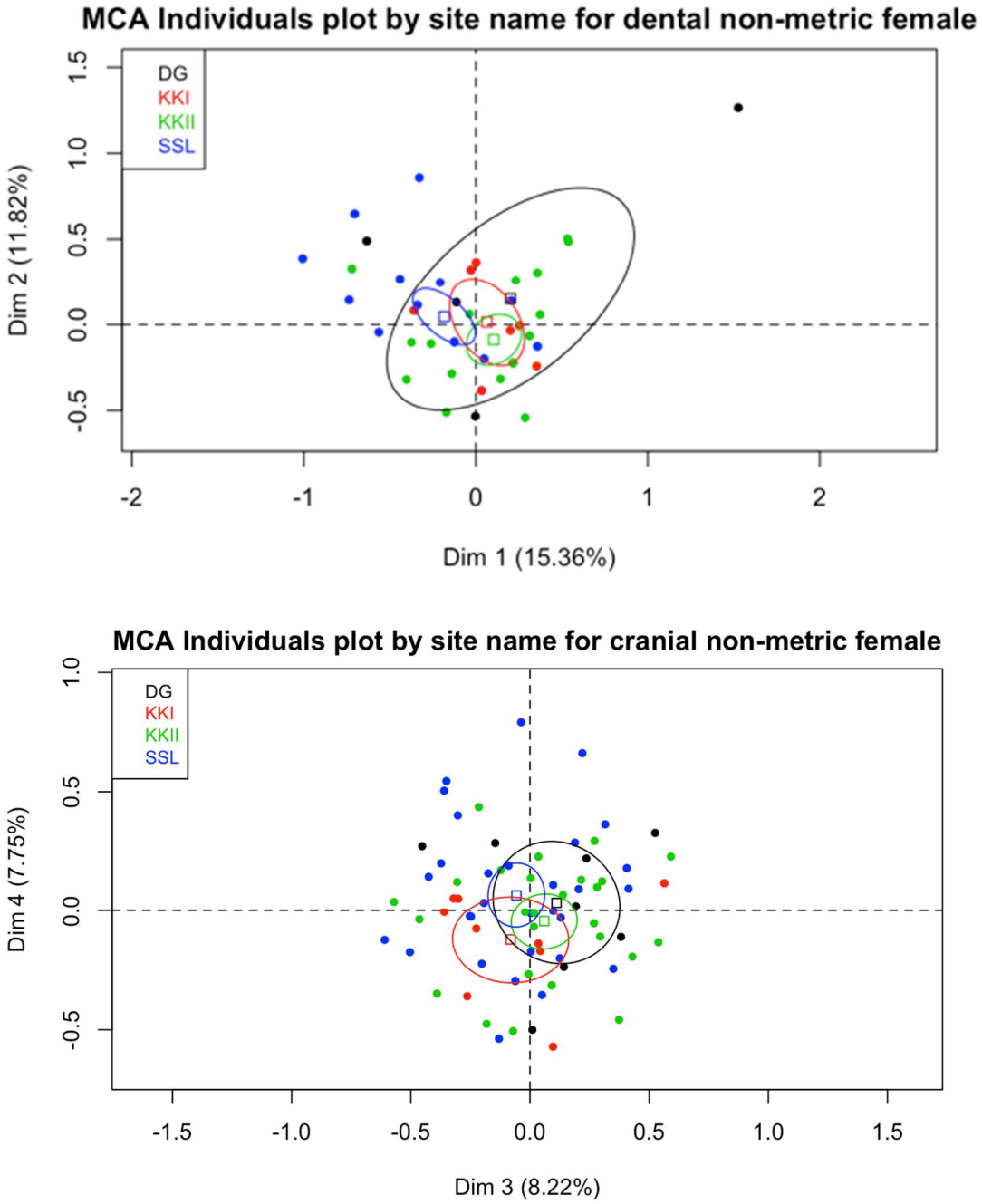

Figure D - 43: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the dental non-metric - female sample (n=58), colored by site name. Lower: Dim 3 and Dim 4 individuals factor plots (MCA) for the dental non-metric - female sample (n=58), colored by site name.

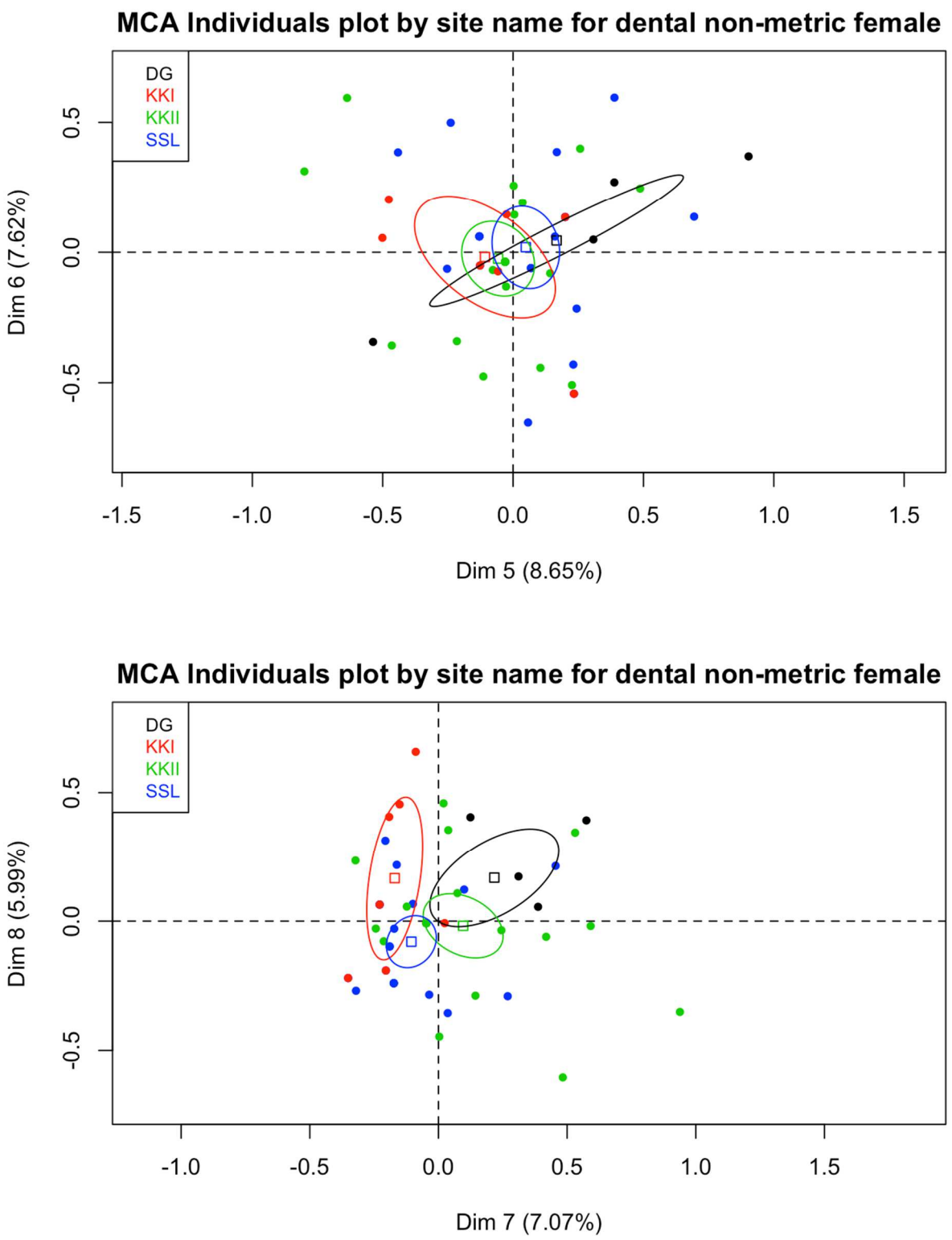

Figure D - 44: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the dental non-metric - female sample (n=58), colored by site name. Lower: Dim 7 and Dim 8 individuals factor plots (MCA) for the dental non-metric - female sample (n=58), colored by site name.

Cranial non-metric – female sample (n=75)

The first eight MCA dimensions of the cranial non-metric – female sample (n=75) had significant eigenvalues and represented 62.43% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – female sample only the Roy test of the MANOVA by site name results was significant (Table D-1). Therefore, the cranial non-metric – female sample does not differ by site name.

Results of the DDA analysis of the first eight MCA dimensions and site name did not identify any significant correlations on Cannon 1, Canon 2 or Canon 3 (Figure D-45). There are no identified differences between females based on site name using cranial non-metrics.

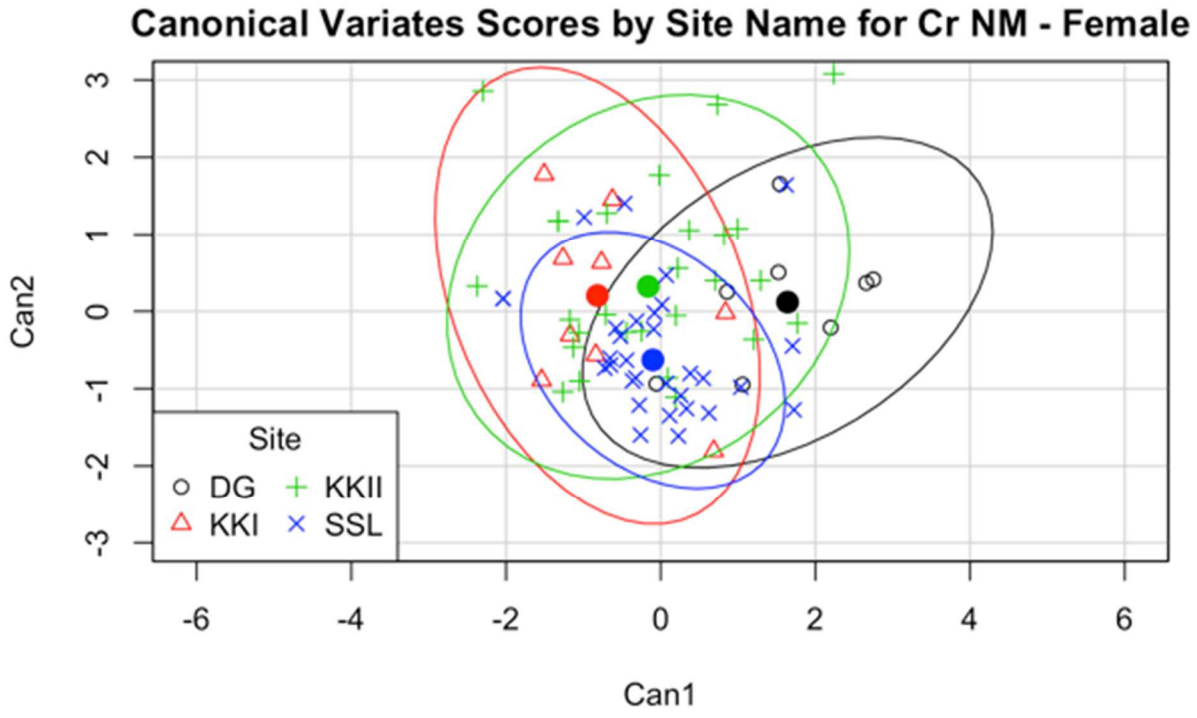

Figure D - 45: Canonical variates 1 and 2 by site name for the cranial non-metric - female sample (n=75).

The component loadings and eigenvalues for the first eight components are presented in Table C-5. Individual factor plots for the first eight dimensions are presented in Figure D-46 and Figure D-47. Dimension 2 through Dimension 8 did not separate individuals by site name (Figure D-46 and Figure D-47). Dimension 1 did separate individuals by site name (Figure D-46). Age does not separate individuals on any of the significant dimensions.

One-way analysis of variance identified Dimension 1 as separating individuals by site name (R^2=0.1926, p-value=0.0016) (Figure D-46): Drinovci-Greblje females were positively correlated with Dimension 1. Dimension 1 was characterized most by positively correlated supranasal suture-present, condylar canal-present, frontal grooves-present, and metopic suture-absent; and negatively correlated supranasal suture-absent, condylar canal-absent, frontal grooves-absent and metopic suture-present (Table C-5). Therefore, Drinovci-Greblje females had higher frequencies of supranasal suture-presence, condylar canal-presence, frontal grooves-presence and metopic suture-absence: making Drinovci-Greblje females positively correlated on Dimension 1.

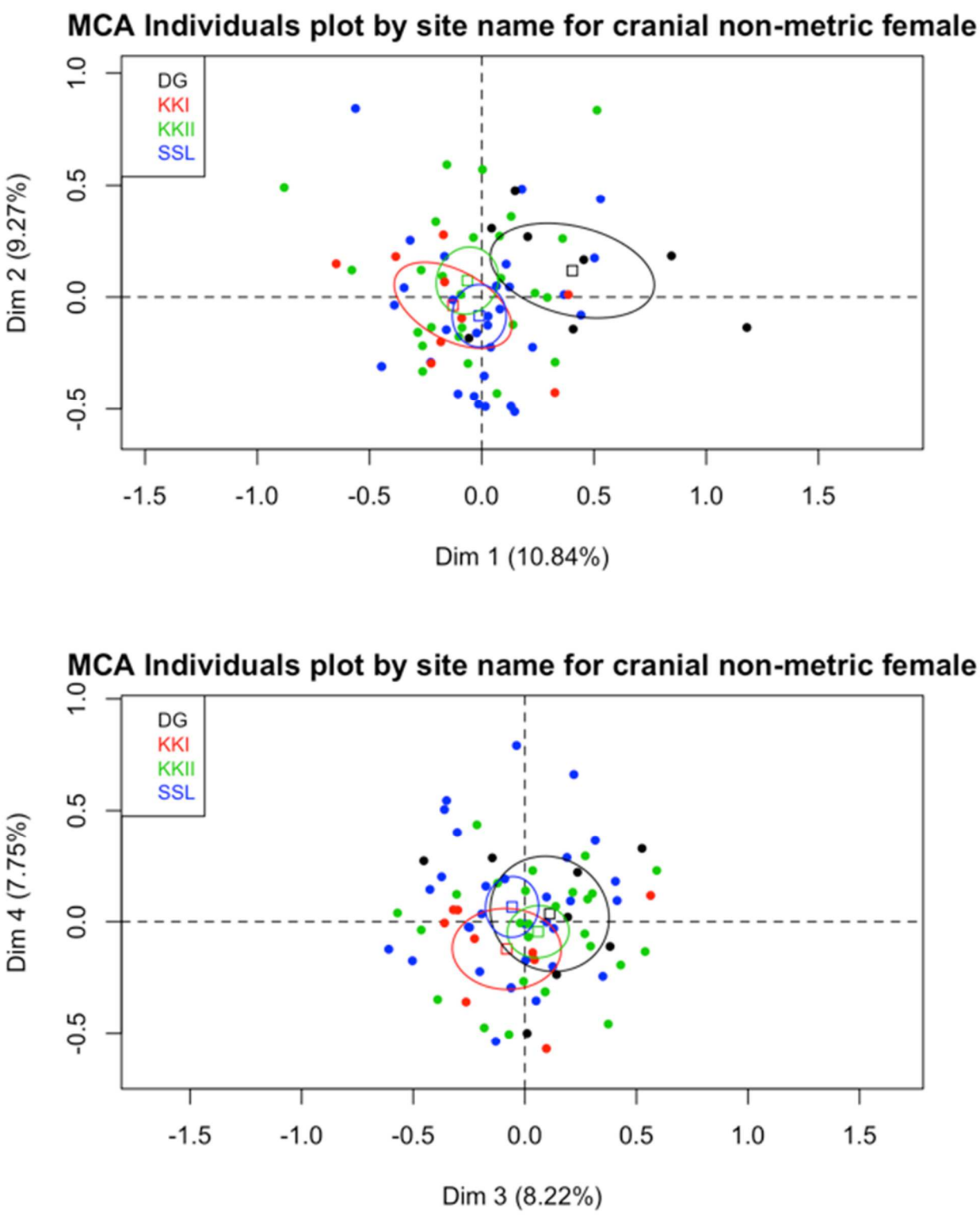

Figure D - 46: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the cranial non-metric - female sample (n=75), colored by site name. Lower: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - female sample (n=75), colored by site name.

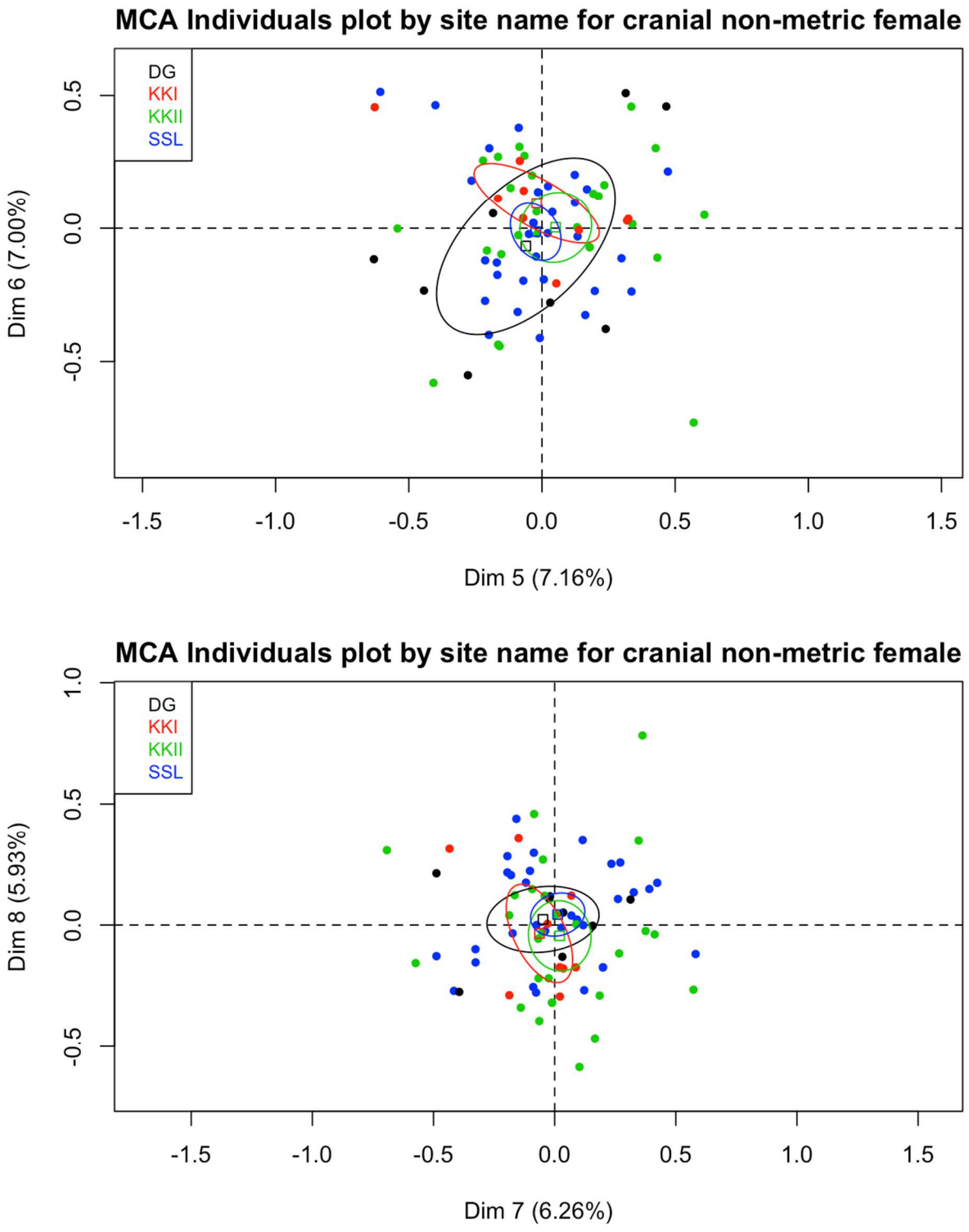

Figure D - 47: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the cranial non-metric - female sample (n=75), colored by site name. Lower: Dim 7 and Dim 8 individuals factor plots (MCA) for the cranial non-metric - female sample (n=75), colored by site name.

Indeterminate sample comparisons

The significant dimensions of the PCA and MCA analyses for the indeterminate sample can be found in Table 7-1 of Chapter 7: Results. The significant dimensions for each dataset were submitted to a MANOVA test to identify group separation by site name (Table D-1). The dental metric, dental non-metric, and cranial non-metric results for the indeterminate sample are presented in this section. Indeterminate individuals were excluded for the cranial metric comparisons due to differential growth and therefore there are no cranial metric – indeterminate sample comparisons to present.

Dental metric – indeterminate sample (n=28)

The first six PCA dimensions of the dental metric – indeterminate sample (n=28) had significant eigenvalues and represented 78.5% of the cumulative variance in the sample (Table 7-1). For the dental metric – indeterminate sample none of the MANOVA by site name results were significant (Table D-1). Therefore, the dental metric – indeterminate sample does not differ by site name and the null hypothesis cannot be disproven. Since the MANOVA results were insignificant and the dental metric – indeterminate sample size is small, no follow-up DDA was completed.

The PCA of the dental metric – indeterminate sample was explored by site name. Figure D-48 and Figure D-49 present the individuals factor plots for the first six PCA dimensions. A one-way analysis of variance found none of the dimensions separated individuals by site name. Since none of the dimensions separated individuals by site name, a discussion of the component loadings for each dimension has been omitted here, however Table C-6 contains the component

loadings and eigenvalues for the PCA dimensions. Variables that significantly contribute to the formation of each dimension are highlighted in gray in Table C-6.

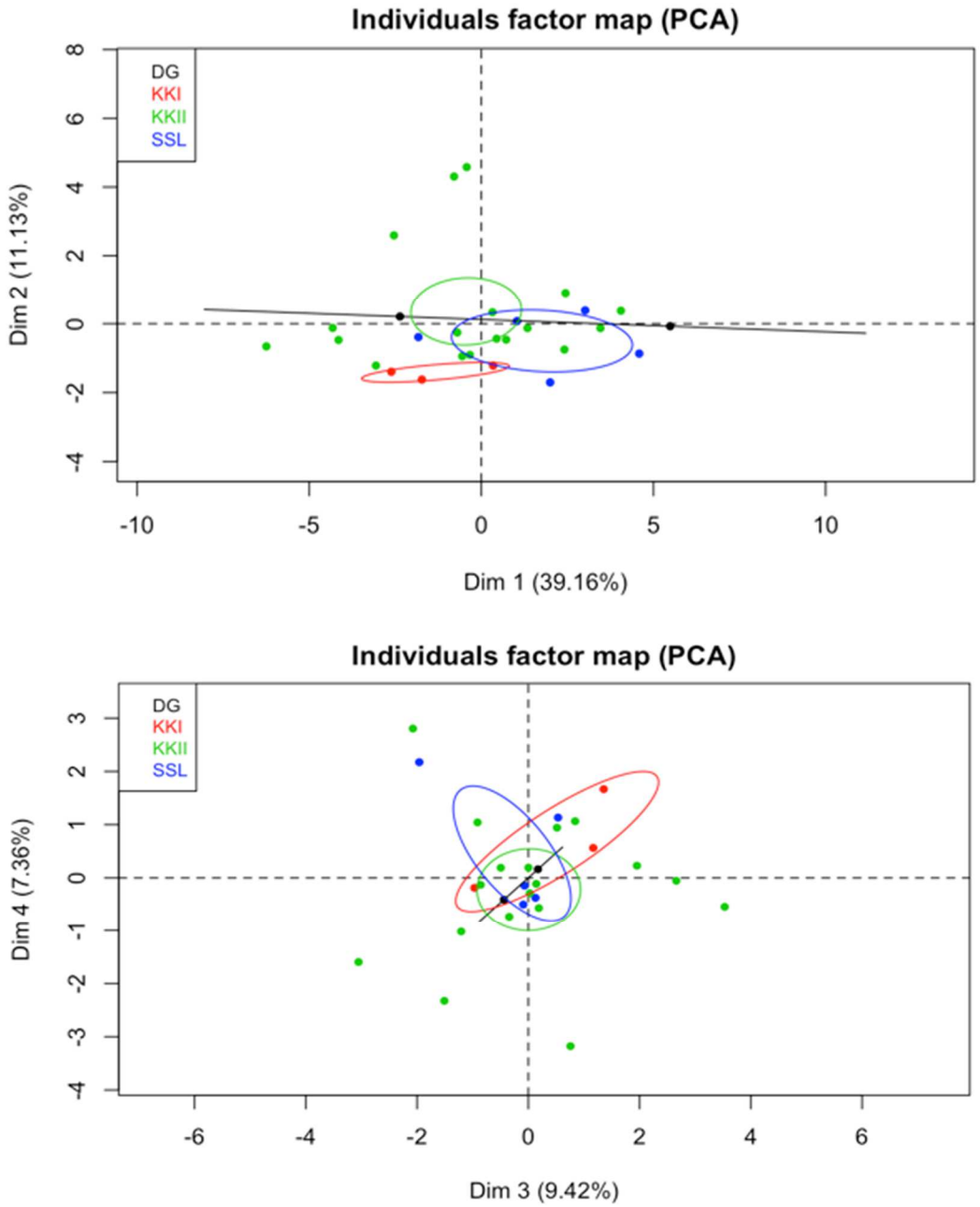

Figure D - 48: Upper: Dim 1 and Dim 2 individuals factor plot (PCA) for the dental metric - indeterminate sample (n=28), colored by site name. Lower: Dim 3 and Dim 4 individuals factor plot (PCA) for the dental metric - indeterminate sample (n=28), colored by site name.

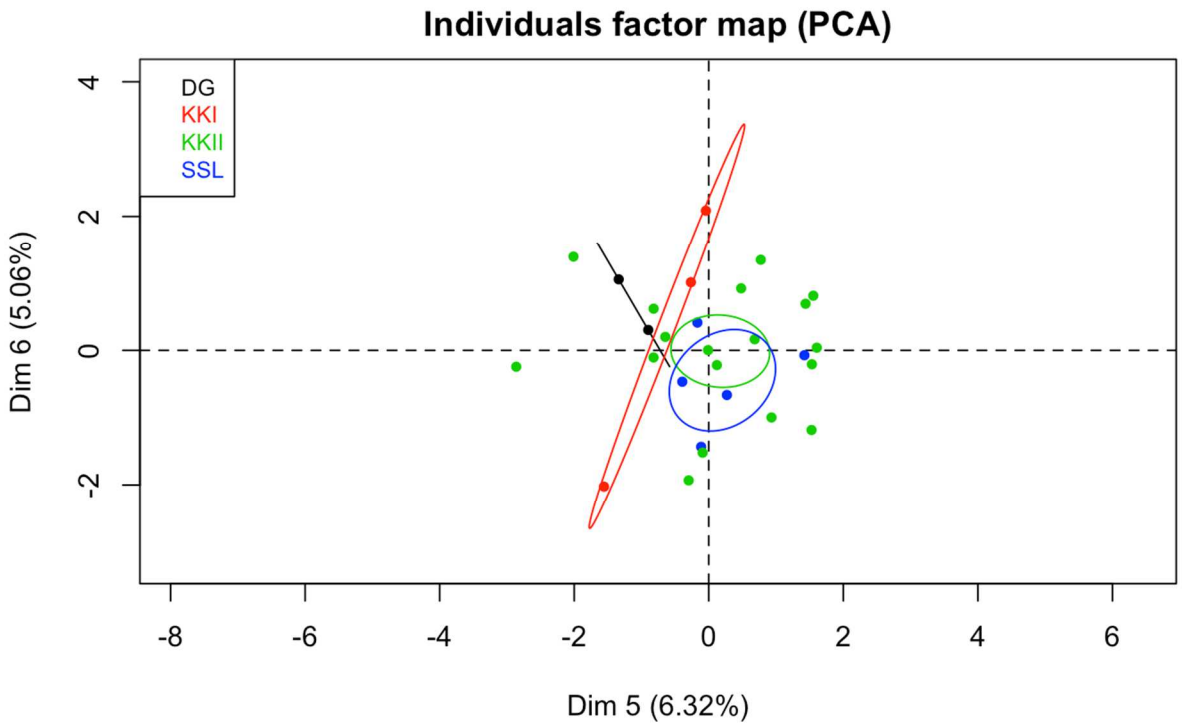

Figure D - 49: Dim 5 and Dim 6 individuals factor plot (PCA) for the dental metric - indeterminate sample (n=28), colored by site name.

Dental non-metric – indeterminate sample (n=29)

The dental non-metric – indeterminate sample has a small sample size, and therefore interpretations of the results are tentative. The first six MCA dimensions of the dental non-metric dataset – indeterminate sample (n=29) had significant eigenvalues and represented 77.1% of the cumulative variance in the sample (Table 7-1). For the dental non-metric – indeterminate sample all of the MANOVA by site name results were significant (Table D-1). Therefore, the dental non-metric – indeterminate sample differs by site name.

Results of the DDA analysis using the first six MCA dimensions identified significant differences between individuals when grouped by site name on Canon 1 (Canon 1: F=4.54, p-value=0.00), but not for the other canons (Figure D-50): Šibenik Sv. Lovre and Koprivno-Križ I

are negatively correlated, while Koprivno-Križ II and Drinovci-Greblje are positively correlated with Canon 1. Dimension 1, Dimension 2, Dimension 3 and Dimension 6 are negatively correlated, while Dimension 4 and Dimension 5 are positively correlated with Cannon 1 (see Table 7-15 for component loadings). Dimension 1 and Dimension 5 had the largest standard coefficients for Canon 1 and therefore contributed most to the formation of Canon 1.

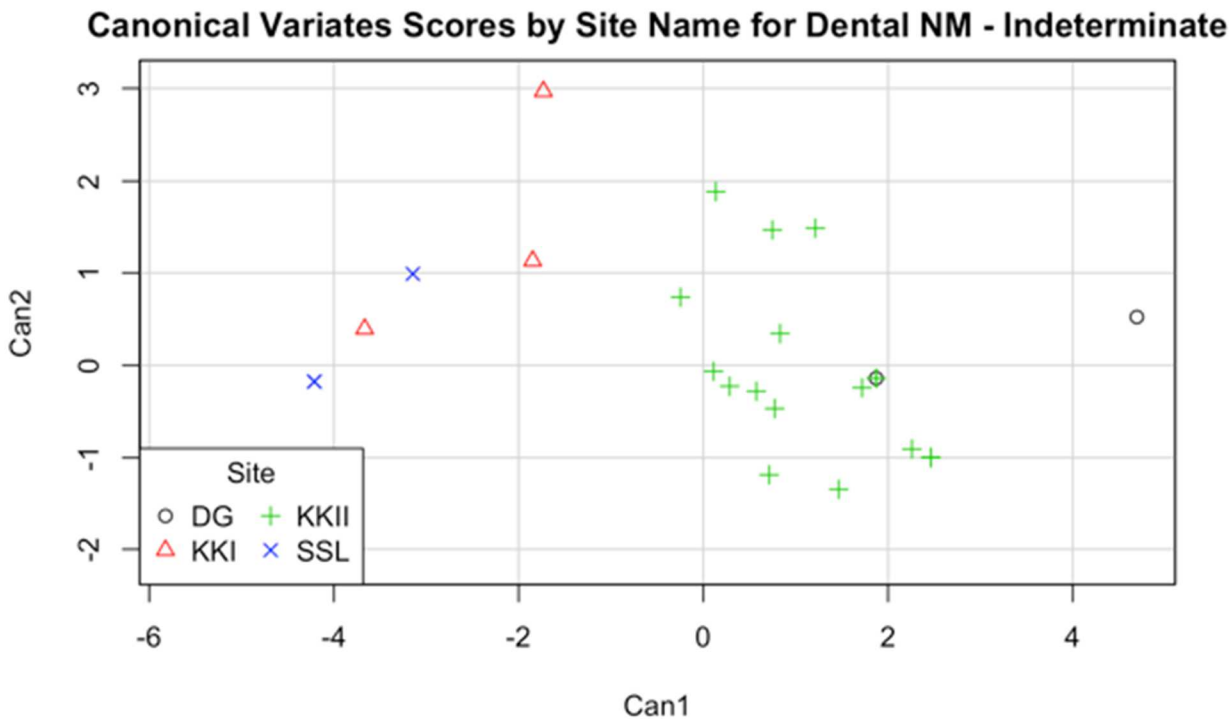

Figure D - 50: Canonical variates 1 and 2 by site name for the dental non-metric - indeterminate sample (n=29). No ellipses are drawn due to DG having only two individuals.

The component loadings and eigenvalues for the first six components are presented in Table 7-15. Using factor analysis, the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table 7-15. Dimensions 2 through 6 did not separate individuals by site name (Figure D-51 and Figure D-52).

Examination of the MCA dimensions using factor analysis showed Dimension 1 accounted for 28.63% of the sample variance and separated individuals by site name (R^2=0.777, *p*-value=0.00) (Figure 7-51): Šibenik-Sv. Lovre was positively correlated, while Koprivno-Križ II was negatively correlated with Dimension 1. The component loadings illustrate that Dimension 1 was characterized by the positive correlation of the presence of the UM3 metaconule (cusp 5), UM2 Carabelli's cusp, UM3 hypocone (cusp 4), LP4 multiple lingual cusps, and the UI1 radical number (one radical); while the absence of these traits and UI1 radical number (2+ radicals) are negatively correlated on Dimension 1. Indeterminate individuals from the Šibenik-Sv. Lovre site had higher frequencies of the UM3 metaconule-presence, UM2 Carabelli's cusp-presence, UM3 hypocone-presence, LP4 multiple lingual cusp-presence, and UI1 radical number-one radical: making them positively correlated on Dimension 1. Indeterminate individuals from the Koprivno-Križ II site had higher frequencies of UM3 metaconule-absence, UM2 Carabelli's cusp-absence, UM3 hypocone-absence, LP4 multiple lingual cusp-absence, and UI1 radical number-2+ radicals: making them negatively correlated on Dimension 1.

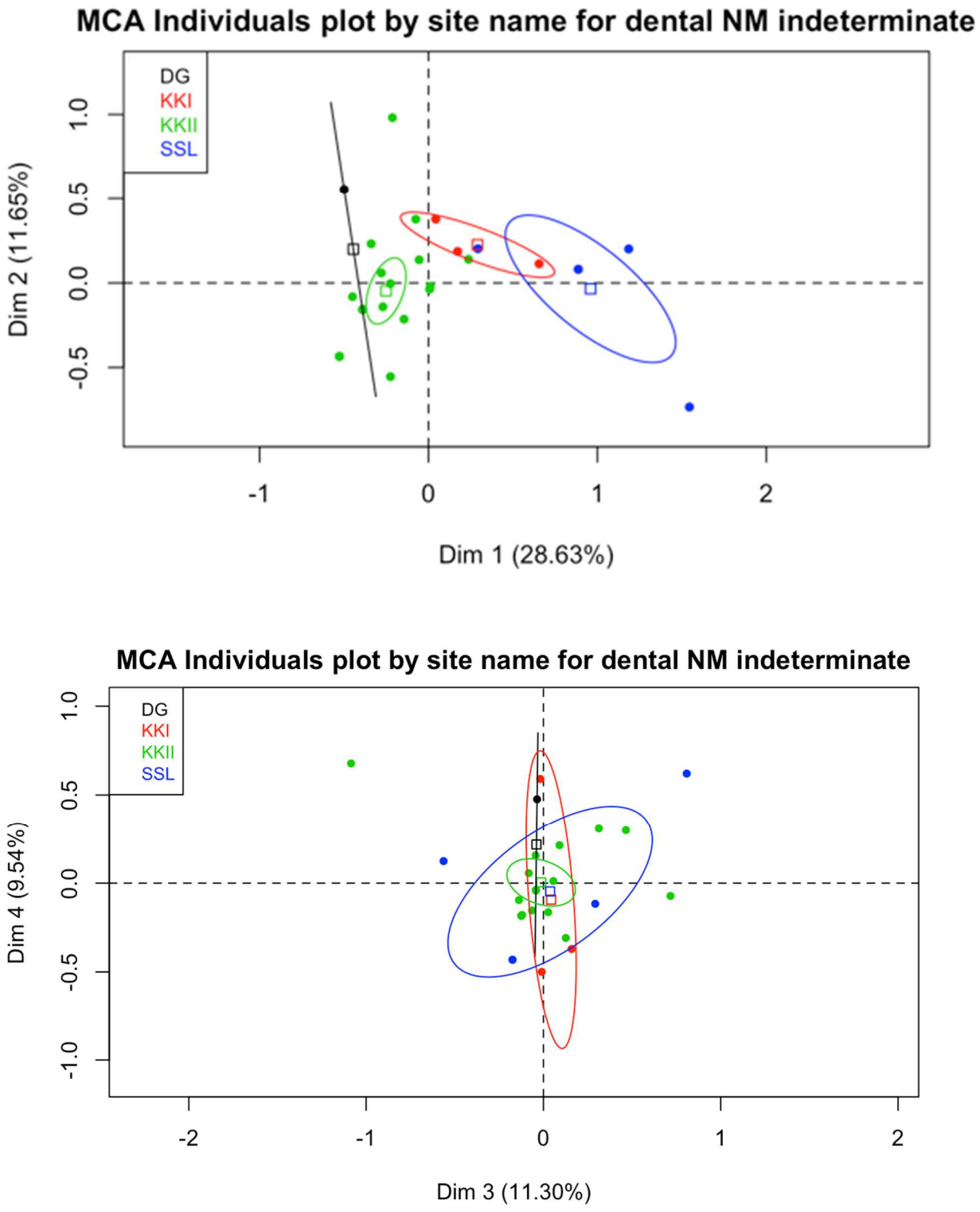

Figure D - 51: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the dental non-metric – indeterminate sample (n=29), colored by site name. Lower: Dim 3 and Dim 4 individuals factor plots (MCA) for the dental non-metric – indeterminate sample (n=29), colored by site name.

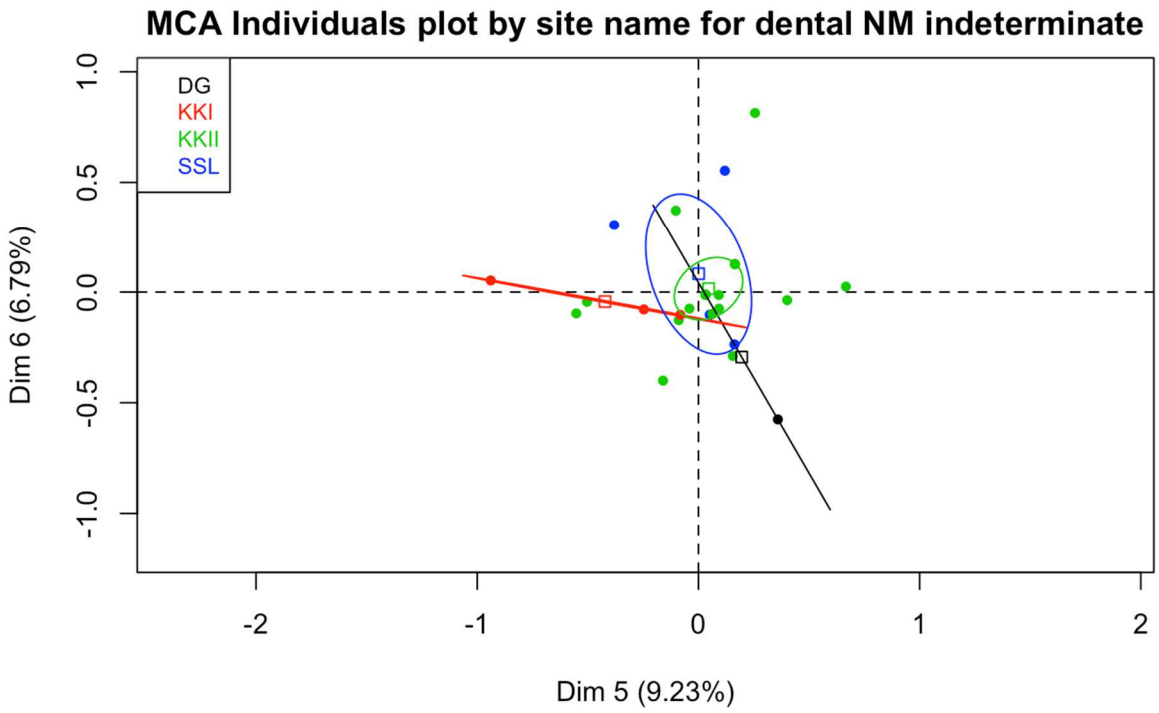

Figure D - 52: Dim 5 and Dim 6 individuals factor plots (MCA) for the dental non-metric – indeterminate sample (n=29), colored by site name.

Cranial non-metric – indeterminate sample (n=102)

The first seven MCA dimensions of the cranial non-metric – indeterminate sample (n=102) had significant eigenvalues and represented 60.06% of the cumulative variance in the sample (Table 7-1). For the cranial non-metric – indeterminate sample only the Roy test of the MANOVA by site name results was significant (Table D-1). Results of the DDA analysis of the first seven MCA dimensions and site name identified no significant correlations with Cannon 1, Canon 2, or Canon 3 (Figure D-53). There were no identified differences between indeterminate individuals based on site name using cranial non-metrics.

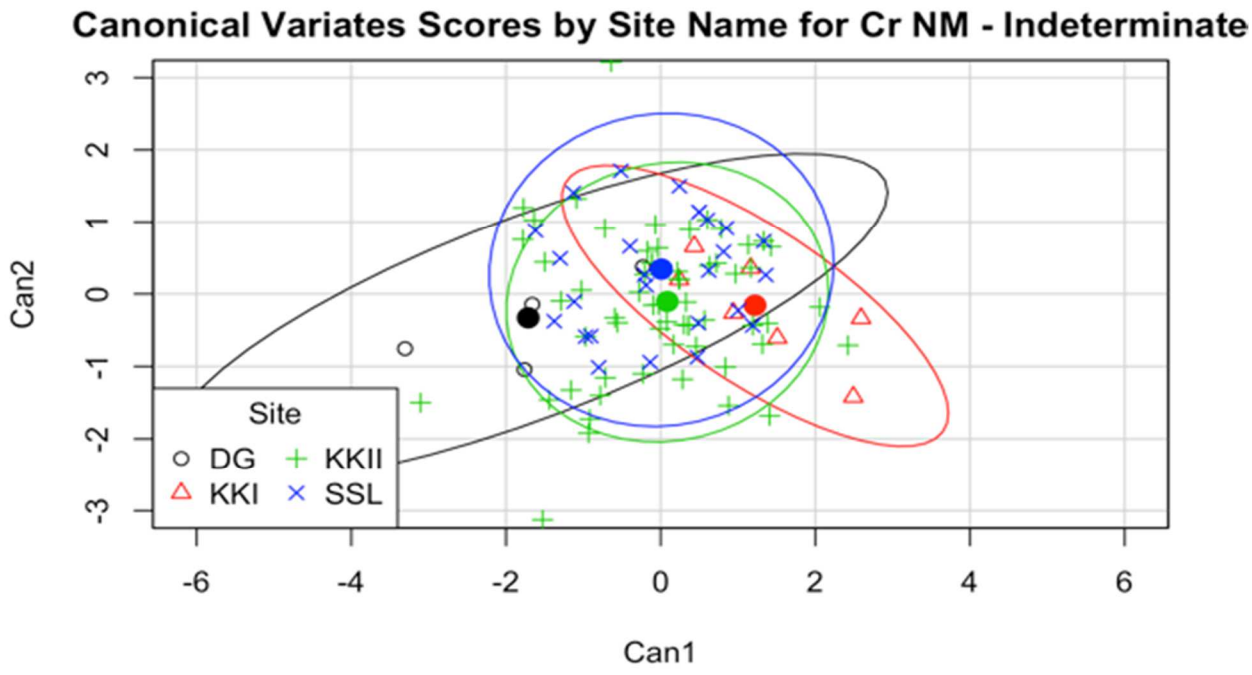

Figure D - 53: Canonical variates 1 and 2 by site name for the cranial non-metric - indeterminate sample (n=102).

The component loadings and eigenvalues for the first seven components are presented in Table C-7. Using one-way analysis of variance the variables that contribute significantly to the formation of each dimension are highlighted in gray in Table C-7. Individual factor plots for the first eight dimensions are presented in Figure D-54 and Figure D-55. One-way analysis of variance failed to identify any separation of individuals by site name on Dimension 1, Dimension 2, Dimension 4, Dimension 6 or Dimension 7 (Figure D-54 and Figure D-55). Dimension 3 and Dimension 5 separated individuals by site name (Figure D-54 and Figure D-55).

Dimension 3 separated individuals by site name (R^2=0.0891, *p*-value=0.0269) (Figure D-54): individuals from Drinovci-Greblje are negatively correlated with Dimension 3. Dimension 3 was characterized by the positive correlation of the medial supraorbital foramen-absence, parietal foramen-presence, accessory mental foramen-absence and mylohyoid bridging-presence: while the opposite of these traits was negatively correlated (medial supraorbital foramen-presence,

parietal foramen-absence, accessory mental foramen-presence and mylohyoid bridging-absence). Therefore, indeterminate individuals from the Drinovci-Greblje site had higher frequencies of medial supraorbital foramen-presence, parietal foramen-absence, accessory mental foramen-presence and mylohyoid bridging-absence: making them negatively correlated on Dimension 3.

Dimension 5 separated individuals by site name (R^2=0.0931, *p*-value=0.0220) (Figure D-55): individuals from Koprivno-Križ I are negatively correlated on Dimension 5. Dimension 5 is characterized by the positive correlation of frontal grooves-presence, biasterionic suture-presence, lateral supraorbital foramen-absence, and metopic suture-absence, while the opposite of these traits was negatively correlated (frontal grooves-absence, biasterionic suture-absence, lateral supraorbital foramen-presence, and metopic suture-presence). Therefore, indeterminate individuals from the Koprivno-Križ I site had higher frequencies of frontal grooves-absence, biasterionic suture-absence, lateral supraorbital foramen-presence, and metopic suture-presence, making them negatively correlated on Dimension 5.

The indeterminate cranial non-metric data only identified differences between the two smaller sites, Drinovci-Greblje and Koprivno-Križ I. These differences may simply be a result of the small number of indeterminate individuals contributing to the dataset rather than a true sample difference (see demographics of dataset Table B-2). Furthermore, once the pre-Ottoman and Ottoman period sites are pooled, there are no longer any identifiable differences (see Appendix C).

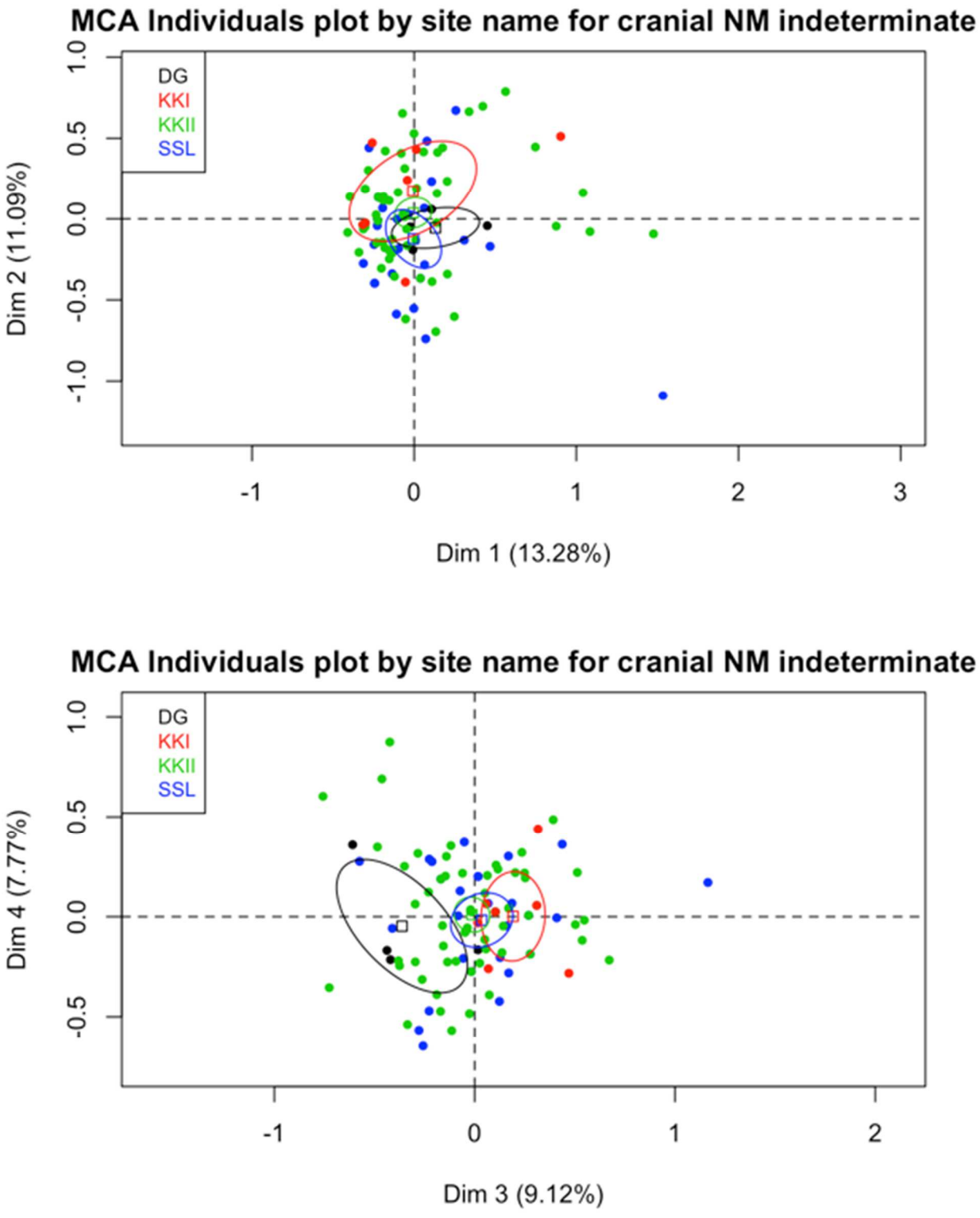

Figure D - 54: Upper: Dim 1 and Dim 2 individuals factor plots (MCA) for the cranial non-metric - indeterminate sample (n=102), colored by site name. Lower: Dim 3 and Dim 4 individuals factor plots (MCA) for the cranial non-metric - indeterminate sample (n=102), colored by site name.

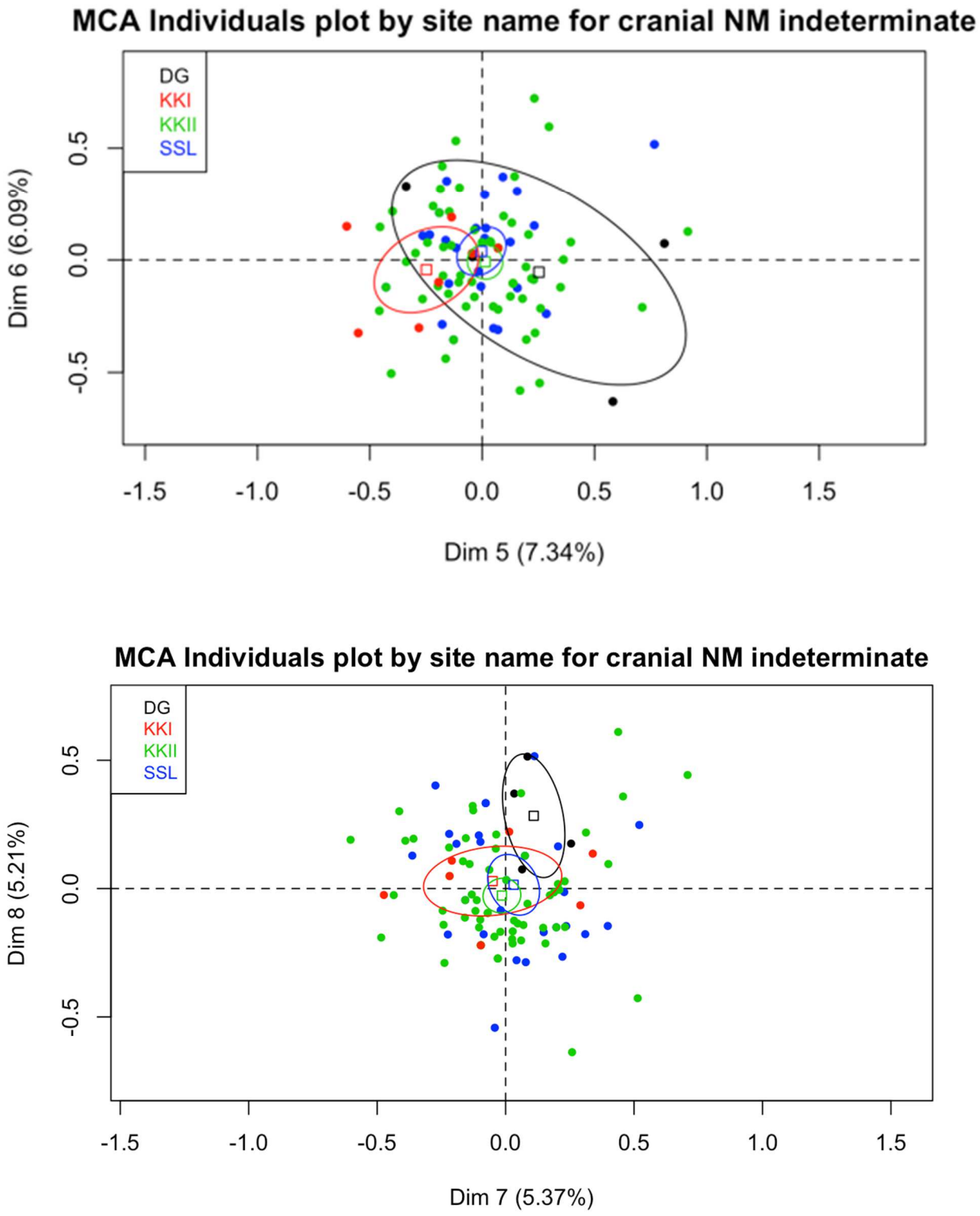

Figure D - 55: Upper: Dim 5 and Dim 6 individuals factor plots (MCA) for the cranial non-metric - indeterminate sample (n=102), colored by site name. Lower: Dim 7 and Dim 8 individuals factor plots (MCA) for the cranial non-metric - indeterminate sample (n=102), colored by site name.

Summary of results

The results presented above are summarized and presented in Table D-7. Results have identified significant group separation of individuals by site name for the total cranial metric, total cranial non-metric, total dental non-metric, male cranial metric, male dental non-metric, female dental metric, female cranial metric, and female dental non-metric samples. Therefore, for these datasets the null hypothesis can be rejected, and the research hypothesis of a differences between sites is supported. The total dental metric, male dental metric, female cranial non-metric, indeterminate dental metric and indeterminate cranial non-metric datasets were inconclusive. Therefore, for these datasets the null hypothesis cannot be disproven and no differences between sites were identified.

Table D - 6: Summary of results by site name.

	n	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6	Dim 7	Dim 8	MANOVA	DDA	MMD
Total Sample												
Dental metric	139	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	NA	NA	NA	NA	$p>0.05$	$p>0.05$	NA
Cranial metric	132	$p>0.05$	$p=0.01$	$p=0.00$	$p>0.05$	$p=0.03$	$p>0.05$	NA	NA	$p=0.00$	$p=0.00$	NA
Dental non-metric	140	$p=0.00$	$p=0.00$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p=0.00$	$p=0.00$	$p<0.05$
Cranial non-metric	245	$p>0.05$	$p=0.00$	$p=0.04$	$p>0.05$	$p=0.02$	$p>0.05$	$p>0.05$	$p>0.05$	$p=0.00$	$p=0.00$	$p<0.05$
Cranial non-metric adult only	140	$p>0.05$	$p=0.04$	$p>0.05$	$p=0.01$	$p=0.03$	$p>0.05$	$p>0.05$	$p>0.05$	$p=0.00$	$p=0.01$	NA
Male Sample												
Dental metric	53	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	NA	NA	NA	NA	$p>0.05$	$p>0.05$	NA
Cranial metric	62	$p>0.05$	$p=0.02$	$p=0.00$	$p>0.05$	$p>0.05$	$p=0.00$	NA	NA	$p=0.00$	$p=0.00$	NA
Dental non-metric	53	$p>0.05$	$p=0.01$	$p>0.05$	$p>0.05$	$p=0.03$	$p>0.05$	$p>0.05$	*NA*	$p=0.01$	$p=0.01$	NA
Cranial non-metric	68	$p>0.05$	$p=0.04$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p=0.05$	$p>0.05$	NA
Female Sample												
Dental metric	58	$p>0.05$	$p>0.05$	$p=0.00$	$p=0.03$	$p>0.05$	NA	NA	NA	$p=0.02$	$p=0.01$	NA
Cranial metric	70	$p>0.05$	$p=0.02$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	NA	NA	$p=0.06$	$p=0.05$	NA
Dental non-metric	58	$p=0.04$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p=0.00$	*NA*	$p=0.02$	$p=0.02$	NA
Cranial non-metric	75	$p=0.00$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	NA
Indeterminate Sample												
Dental metric	28	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	NA	NA	$p>0.05$	NA	NA
Dental non-metric	29	$p=0.00$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	*NA*	*NA*	$p=0.00$	$p=0.00$	NA
Cranial non-metric	102	$p>0.05$	$p>0.05$	$p=0.03$	$p>0.05$	$p=0.02$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	NA

*MANOVA *p*-values are those of the Pillai test, except for the cranial non-metric – male sample MANOVA *p*-value, which is from the Hotelling-Lawley test. DDA *p*-values are for Canon 1 only. NA cells did not have the test performed. Significant values are highlighted in gray.

Curriculum Vitae
Lindsey Jo Helms Thorson, PhD

EDUCATION

August 2012-May 2018 University of Wisconsin – Milwaukee, Milwaukee, WI
Doctor of Philosophy in Anthropology

- Concentration in Biological Anthropology
- Dissertation: *Population Change in Times of War: Biodistance analysis of Medieval and Early Modern skeletal populations from Adriatic Croatia.*
- Field Research: Croatian Academy of Arts and Sciences – Anthropology Center (2013-Present)
- Cumulative GPA: 3.9

August 2010-August 2012 Illinois State University, Normal, IL
Master of Arts in Archaeology

- Concentration in bioarchaeology
- Lambda Alpha Honor Society Sigma Xi Honor Society
- MA Thesis: *Health and Disease at Ledford Island: A Study of Late-Mississippian Human Remains from East Tennessee.* 2012.
- Cumulative GPA: 4.0
- Field Schools:
  2011 Bioarchaeological Field School, McClung Museum, Knoxville TN.
  2012 Archaeological Field School, Grad Island, MI.

September 2004-May 2008 Hamline University, St. Paul, MN
Bachelor of Arts

- Major: Anthropology Certificate: Forensic Science
- Cumulative GPA: 3.752 Magna Cum Laude Graduate
- Phi-Beta Kappa Pi Gamma Mu
- Departmental Honors Thesis: *Perforation of Human Remains: Temporal, Regional, and Cultural Comparisons of Mortuary Tapping in Minnesota.* 2008.

RESEARCH INTERESTS

Regional: medieval archaeology, Balkan history and prehistory, Croatian bioarchaeology and archaeology, North American bioarchaeology, Late Mississippian archaeology, Woodland archaeology, Great Lakes mortuary archaeology.

Topics: Migration, human variation, bioarchaeology, life history, identity, assimilation, forensic anthropology, mortuary archaeology, conflict and warfare, climate change, trophy-taking and ancestor veneration, development and growth, nutrition and disease.

Methods: trauma, paleopathology, morphological analysis, demography, metric and nonmetric skeletal analysis, biomechanics, anthropological statistics.

PRESENTATIONS

Thorson, LJH. 2017. Biodistance Analysis of population change among eastern Adriatic Croatian populations in the context of Ottoman Expansion (15th-16th centuries). Podium Presentation at the Midwest Bioarchaeology and Forensic Anthropology Association (BARFAA) Meetings, Milwuakee, WI.

Thorson LJH, Vyroubal V, Šlaus M. 2017. A characterization of nutritional stress among ealry Medieval subadult females of the central Dalmatian region of Croatia. Poster Presentation at the American Association of Physical Anthropologists Meetings, New Orleans, LA.

Smith M, Thorson LJH, Lloyd D. 2017. Pre-Columbian health status and climate change: AD 1300-1600 in southern Appalachia. Poster presentation at the Paleopathology Association Meetings, New Orleans, LA.

Bedić Z, Thorson LJH, Demo Ž. 2015. Jesu Li U Drinovcima Žene I Muškarci Živjeli Drugacije? [Did Drinovci Women and Men Live Differently?]. Podium Presentation at the Resultati Archeoloških istraživanja na prostoru Šibensko-Kninske Županije, Znanstveni skup [Results of Archaeological Research in the Area of the Šibensko-Kninske County Conference]. Krke, Croatia.

Helms LJ, Richards PB. 2013. Granting Little Earth for Charity: Health and Trauma Reflected in the Milwaukee County Institution Grounds Cemetery. Poster presentation at the American Anthropological Association Meetings, Chicago, IL.

Helms, LJ. 2013. Health and Disease at Ledford Island: A Study of Late Mississippian Human Remains. Poster presentation at the American Association of Physical Anthropologists Meetings, Knoxville, TN.

Helms, LJ. 2012. Porotic pitting and hyperostosis as separate indicators of nutritional stress from Ledford Island, TN. Presented at the Southeastern Archaeological Conference, Baton Rogue, LA.

Myster SMT, Helms LJ, Smith MO. 2011. A Meta-analysis of a Unique Late Woodland Mortuary Practice in the Upper Midwest. Presented at Midwest Bioarchaeological & Forensic Anthropology Meeting, Normal, IL.

Myster SMT, Helms LJ, Smith MO. 2011. Post-Mortem Human Bone Modification: Demographic Analysis of Mortuary Tapping in Northern Minnesota. Presented at the Midwest Archaeological Conference Annual Meetings, Lacrosse, WI.

INVITED LECTURE

Thorson, Lindsey JH. 2017. Using Skeletal morphological data to track population change: The case of Ottoman expansion into eastern Adriatic Croatian territories during the 15th and 16th centuries. October Speaker for the Robert Ritzenthaler Chapter of Wisconsin Archaeological Society, Oshkosh, WI.

PUBLICATIONS

Betsinger T, Smith M, Thorson LJH, Williams LL. 2017. Endemic Treponemal disease in late pre-Colombian prehistory: new parameters, new insights. Journal of Archaeological Sciences:Reports 15:252-261.

Thorson LJH. 2017. A book review essay on recent publications concerning human skeletal trauma analysis, violence and conflict. Field Notes: A Journal of Collegiate Anthropology Vol. 9: 92-104.

Helms LJ. 2014. Review: Bioarchaeology of Violence. Edited by DL Martin, RP Harrod, and VR Pérez. Gainesville: University of Florida Press, 2012. Field Notes: A Journal of Collegiate Anthropology 6:68-72.

WORK & TEACHING EXPERIENCE

July 2017- Sept 2017 Hamline University Anthropology Department, St. Paul, MN
Burial Recovery Technician

- Assist in recovery of human skeletal material from disturbed Native American burial site.

Aug 2015-May 2017 UWO Religious Studies & Anthropology, Oshkosh, WI
Academic Staff

- Lab instructor for ANTHRO 202: Intro to Biological Anthropology
  - Primary lab instructor, where students are introduced to the field of biological anthropology and theory of evolution. Students gain introductory experience working with basic human biology and genetics, the theory of evolution by natural selection, primatology, human and primate skeletal anatomy, the human fossil record, modern human variation, bioarchaeology and forensic anthropology.

Aug 2012-May 2014 UWM Anthropology, Milwaukee, WI
Anthropology Department Teaching Assistant

- Fall 2012 & Spring 2013 – TA for ANTH 101: Intro to Human Origins
  - Lead hands on labs where students gain experience working with human and primate skeletal anatomy and the human fossil record. Proctor and grade exams, quizzes, and labs.
- Fall 2013 – TA for ANTH 501: Archaeology of Death.

- Organize and lead osteology labs and exams, grade undergraduate assignments, provide guidance for student's final projects.
- Spring 2014 – TA for ANTH 213: American Indian Peoples of Wisconsin (Online).
  - Monitor student discussion forums, grade assignments and manage the online classroom materials.

July-August 2013 Historic Resource Management Services, Milwaukee, WI
Field and Laboratory Technician

- Excavation of human remains from the Milwaukee County Institution Grounds Cemetery Project (Summer 2013 field excavations).
- Stabilization and analysis of recovered skeletal material.

Aug 2010-Aug 2012 ISU Sociology & Anthropology, Normal, IL
Graduate Research Assistant

- Assistant to Dr. Maria Smith with research needs in paleopathology and Southeastern bioarchaeology.
- Assist Dr. Fred Smith in Teaching Human Osteology to Undergraduate students

Oct. 2008-Aug 2010 & Summer 2014 Messerli and Kramer, P.A. Plymouth, MN
Legal Assistant

- Review accounts for legal suit, and prepare accounts for court
- Recognized for speed, accuracy & quick learning
- Document processing, filing, copy, fax and mail machines
- Review closed files and convert physical files to electronic documents
- MN Notary of the public (expires January 2014)

Sep 2007-Dec 2007 MN Regional ME's Office, Hastings, MN
Medical Examiner and Medico-legal Investigator Intern

- Experience in human anatomy, autopsy procedures and prosecting Medico-legal death investigation and confidential medical environment
- Forensic Research Report: *Rate of Deterioration of Cotton Fabric: Its Role in Estimating Postmortem Interval.* 2007.

PROFESSIONAL ORGANIZATIONS

American Association of Physical Anthropologists (2011-Present)
Paleopathology Association (2016-Present)
Midwest Bioarchaeological & Forensic Anthropology Association (2011-Present)
American Anthropological Association (2013-2014)
Midwest Archaeological Conference (2011-2013)
Southeastern Archaeological Conference (2012-2013)
UWM Anthropology Student Union (2012-Present): Vice President (2013-2014)
Field Notes: A Journal of Collegiate Anthropology (Reviewer and Editor)

AWARDS RECEIVED

Co-author and recipient of Student Appropriations Committee Event Grant (2013)
Winner UWM Anthropology Student Union Student Paper Competition (2013)
Winner of Fisher's Thesis Award Competition (2012)
Recipient of Scott Elliott Award for research support (Fall 2012)
Member of Lambda Alpha (Spring 2012) and Sigma Xi (Spring 2012)
Graduated Magna Cum Laude (Spring 2008)
Member of Phi Beta Kappa (Spring 2008) & Pi Gamma Mu (Spring 2007)

SKILLS

Bioarchaeological Fieldwork
McClung Museum Bioarchaeological Field School, Dr. Maria Smith 2011
Croatian Academy of Arts and Sciences –Anthropology Center, Dr. Mario Šlaus 2013 – Present
Archaeological Fieldwork
Dr. James Skibo's Grand Island MI, field school 2012;
Historical Resource Management Services Milwaukee County Institution Grounds Cemetery Project 2013
Burial Recovery Technician, Hamline University, St. Paul, MN 2017
Leadership
Honor Societies: Phi Beta Kappa '08, Pi Gamma Mu '07, Lambda Alpha '12, Sigma Xi '12,
UW-Milwaukee Anthropology Student Union (ASU) Vice-President 2013-2014
UW-Milwaukee ASU Student Colloquium Chair 2013-2014
Field Notes: A Journal of Collegiate Anthropology-Editor (2-14-2017)
Reviewer for *Field Notes: A Journal of Collegiate Anthropology* (2013-2018)