A MORPHOLOGICAL AND BIOMETRIC STUDY OF THE FACIAL CHARACTERISTICS OF TWO SOUTH AFRICAN CHILDHOOD POPULATIONS AT DIFFERENT AGE LEVELS

By

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Declaration of Original Work

I, Nanette Briers, hereby declare that this thesis entitled:

"A morphological and biometric study of the facial characteristics of two South African childhood populations at different age levels"

that I submit for the degree of Doctor Philosophy in Anatomy at the University of Pretoria is my own original work and has not been submitted for any degree at other tertiary institutions.

_____ _____

Nanette Briers Date

Dedicated to

†J. Hugo, M. Viljoen,

Helena & Thys Lourens (Snr),

James and Matthew Lizamore

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Summary

Positive identification can be problematic if fingerprinting, DNA, dental history, etc. are no longer available. This may be possible through techniques such as facial approximation, but any form of craniofacial identification requires intimate knowledge of human craniofacial anatomy. Where children are involved, craniofacial changes due to facial growth further complicate matters and require knowledge of tissue thickness and variation in facial shapes. These have hardly been studied in children of African descent.

The aims of this study were to provide data on tissue thickness and craniofacial proportions of South African Black and Coloured children and to document the lateral profile shape changes between the ages of 6 and 13 years.

Tissue thickness was measured using cephalograms of South African children (n = 388). After digitizing the images, tissue thickness measurements were taken at 11 mid-facial landmarks from each image using the iTEM measuring program. Craniofacial proportions were assessed through assessing standardized anterior and lateral facial photographs of 1749 children. Measurements of facial features were taken using iTEM, from which 28 standard facial indices were calculated. For both tissue thickness and craniofacial indices comparisons between groups per age, sex and ancestry were statistically analyzed. In addition, geometric morphometrics were used to describe lateral facial shape changes and differences age, sex and ancestry (n = 800).

The results showed that tissue thickness differences at lower face landmarks are more pronounced in age groups per ancestry as opposed to differences per age and sex. Facial profile per facial shape, class and ancestry showed differences at all landmarks. Craniofacial indices indicated that Coloured children have wider heads, foreheads and faces compared to Black children. The height of the nose and lower lip is longer in Coloured children compared to Black children. In Coloured children, mandibular height and lower face height is shorter in relation to total face height. Males have wider heads, foreheads, mandibles and faces compared to females. The degree of prognathism is dictated by ancestry and to a lesser extent by age and sex as findings showed that maxillary prognathism was more prominent in Black children, while mandibular prognathism were more pronounced in male children**.** South Africans have a relative concave lateral facial profile due to the maxilla and mandible being more prognathic than in North American children. Differences in lateral face shape between children of various ages, sexes and ancestral groups were visualized through the relative displacement of landmarks related to the forehead and lower face. The resultant differences in lateral facial profile can assist in more accurate estimation of age and ancestry of unknown children.

This research created reference datasets for tissue thickness and craniofacial indices of South African children of Black and Coloured ancestry per age and sex that will be useful in the diagnosis of facial dysmorphology and for facial reconstruction / approximation of juvenile remains. It also shed more light on facial growth patterns in the various groups.

Keywords: Craniofacial reconstruction, craniofacial approximation, facial growth, tissue thickness, facial indices, geometric morphometrics, children, facial profile, face shape, South African population

Chapter 1: Introduction

1.1. Background

Crime is a serious problem in all parts of South Africa and it affects every citizen, including children. The South African Police Service (SAPS) annual report of 2010/2011 stated that 28% of cases regarding neglect and ill treatment of children occurred in Gauteng and 19% in the Western Cape. Although figures in the SAPS annual report of 2011/2012 indicated a decrease of 1.3% and 0.8% for Gauteng and the Western Cape respectively, an increase was seen in Limpopo, Mpumalanga and the North West Province. The annual SAPS statistics for 2012/2013 again confirms higher incidence for the category "neglect and ill treatment of children", which includes underage victims for both murder and sexual crimes, in Gauteng and the Western Cape. SAPS statistics presented in the SAPS annual report of 2008/2009 indicated that children below the age of 14 are more affected by social contact crime in which the perpetrator such as a family member or friend is known to the child. Unfortunately the way in which statistics are presented in subsequent reports did not distinguish between the different age groups, therefore the trend after 2009 could not be determined. Two other shortcomings in the SAPS statistical reports further hinder accurate estimate of crime that involves children: 1) SAPS statistics on violent crime such as murder and kidnapping do not distinguish between cases involving adults and children; and 2) SAPS statistics on missing South African children are not presented in the reports. The information on the SAPS missing children website is sparse. As a result, no reliable statistics on missing children are available. Several other websites have been created, notably *missing.kids.co.za*, *missingkids.org*, and a Facebook page which appears more active than the SAPS site. Despite these efforts, information on the actual number of missing children in South Africa still does not exist. These lay websites estimate numbers between 10 and 40 missing children at any given time.

In South Africa, as in other countries, positive identification of a missing person or skeletal remains is required by the legal system. Positive identification is based on a characteristic that is unique to a specific individual. Unique characteristics include fingerprinting, DNA and dental history. Sometimes identifying characteristics are no longer available due to burn damage, skeletonization or mutilation. In cases where children are involved, craniofacial changes due to facial growth in the prepubescent and pubescent stages complicate matters even further. The police investigation will then attempt to make a presumptive identification with only the physical anthropologist' s report to guide them in terms of sex, age and ancestry to generate information on the case.

Typical applications of juvenile craniofacial identification are approximation of a face from skeletal remains and aging a face where no photographs of the child are available.

Craniofacial identification, whether it is used in the context of adults or children, require intimate knowledge of human craniofacial anatomy. This knowledge includes tissue thickness and variation in human facial shapes. In children, it also requires knowledge of changes in size and shape that occur with age. Craniofacial variation has not been studied on children of African descent.

Facial approximation/reconstruction of South African children from European ancestry can be based on European standards as a study on White British children by Wilkinson (2002) showed good correlation to results from Manhein et al. (2000) on White North American children. The same may not be true for Black South African children. In a study by Cavanagh and Steyn (2011), adult Black female faces were three dimensionally reconstructed based on North American and South African Black female tissue thickness data. Results suggested that North American data cannot be transferred to South Africans. Coloured children also pose a problem as Philips and Smuts (1996) found significant differences when they compared tissue thickness of adult Black South Africans to an adult Coloured sample. Data on tissue thickness for South African children are still absent in the scientific literature and adult data cannot be used as studies have shown that tissue thickness changes with age, especially between the ages of 6 and 13 (Wilkinson, 2002; Peckman *et al*., 2013).

Knowledge of facial proportions and growth at various ages is also essential for clinicians, maxillo-facial and plastic surgeons. Clinicians use craniofacial indices to diagnose syndromes based on facial dysmorphology. Facial dysmorphology often presents evidence of more serious clinical problems such as mental retardation and lack of postnatal growth associated with other conditions such as Fetal Alcohol Syndrome (FAS) (Grobbelaar and Douglas, 2007; Moore *et al*., 2007; Foroud *et al*., 2012), while severe defects such as cardiac and palatal deformities are associated with Velocardiofacial Syndrome (VCFS) (Brown *et al*., 2010). In some Coloured South African communities in the Western Cape, an incidence of 51.3 to 67.2 per 1000 children with FAS has been reported (May *et al*., 2010). Knowledge of the normal range of facial proportions is essential in order to determine facial dysmorphology that is associated with FAS so that children with FAS can be diagnosed and receive proper treatment.

Research and datasets by Farkas and Munro (1987) and Farkas (1994) are considered the gold standard in the clinical and forensic fields as experts and clinicians utilize data

from Farkas and Munro (1987) and Farkas (1994) to produce a facial approximation or treatment management plan. After the original Farkas studies, many subsequent studies on groups of different ancestry in the northern hemisphere followed with some studies obtaining data by means of cephalometric measurements (Smith *et al*., 1986; Peng *et al*., 2005; Thordarson *et al*., 2005) used in orthodontics, anthropomentric measurements on living subjects (Little *et al*., 2006; Evereklioglu *et al*., 2001; Buretic-Tomljanovic *et al*., 2006), photoanthropometry (Cattaneo *et al*., 2012; Cummaudo *et al*., 2013) or three dimensional laser scanning (Sforza *et al*., 2013). Only studies by Winning *et al*. (1999) and Morris (1992) mentioned adults from Australia and skulls from South Africa respectively. Several excellent studies concerning general growth have been conducted in South Africa (e.g., Cameron and Leschner, 1990; Henneberg and Louw, 1990; Goduka, 1992; Henneberg and Louw, 1993; Henneberg and Louw, 1995; Henneberg *et al*., 1998; Monyeki et al., 1999; Cameron and Demearth, 2002; Cameron, 2003; Armstrong *et al*., 2006; Cameron, 2007; Richter *et al*., 2007; Jones *et al*., 2008; Monyeki *et al*., 2008, Lanigan and Singhal, 2009; Norris *et al*., 2009; Sheppard *et al*., 2009; Wiley *et al*., 2009; Kimani-Murage *et al*., 2010; Kimani-Murage, 2013; Hutchinson *et al*., 2014). Growth studies covered a wide range of topics which will be elaborated upon in later sections, however facial growth and facial changes during growth were not addressed. As a result, no data on craniofacial dimensions and facial growth changes in living South African children are available.

In broad terms, the aim of this study was to provide data on craniofacial proportions, facial growth and tissue thickness of South African children as a means to improve the reliability and validity of craniofacial approximations/reconstruction, superimpositions and identikits for children between the ages of 6 and 13 years. The data will also have clinical application in reconstructive maxillofacial surgery and orthodontic treatment as it will be specific to South African children and document the changes in face shape at various ages.

1.2. Aims

The primary aims of this study were to develop standards for soft tissue thickness and craniofacial indices for South African children aged 6 to 13 years. In addition, changes in craniofacial morphology at different age levels were assessed using geometric morphometrics. The specific objectives were as follow:

- Primary objective 1: Develop standards for soft tissue thickness for South African children aged 6 to 13 years from cephalograms

- Secondary objective 1.1: Assess differences in soft tissue thickness with respect to age, sex and ancestry; and
- Secondary objective 1.2: Assess whether facial profile had a significant effect on soft tissue thickness.

- Primary objective 2: Develop standards for craniofacial indices for South African children from 6 to 13 years using photoanthropometry
  - Secondary objective 2.1: Assess differences in craniofacial indices with regard to age, sex and ancestry;
- Primary objective 3: Study facial growth at different age levels using geometric morphometrics.
  - Secondary objective 2.2: Document changes in craniofacial morphology at different age levels using geometric morphometrics.
  - Secondary objective 2.3: Determine changes in craniofacial morphology and whether these changes are sex and ancestry specific.

This knowledge will assist us to understand how the face shape changes from early childhood until adolescence. It will also show in which part of the face the changes will be most prominent.

Chapter 2: Literature review

2.1. Introduction

The purpose of this chapter is to examine both broad and specific issues that affect craniofacial morphology in children of pre-pubescent and pubescent age. This discussion is separated into three main sections.

First, the historical background and current views on human variation, the use of the word “race” or “ancestry” and its relationship to craniofacial morphology are discussed. A large part of the literature review is dedicated to issues of social race and scientific human variation and the impact thereof on the modern history of South Africa. In addition, historical migration, dispersion and amalgamation theories will be touched upon as these theories contributed to the shaping of the current economic and political landscape, and social structures within which the current study was conducted. In addition, the current status of social contact crime (murder, attempted murder, sexual offences, assault with grievous bodily harm) relating to missing persons/children in South Africa is explained. Methods used for personal identification in the case of missing persons/children in South Africa, with special reference to craniofacial approximation/reconstruction, are described.

Second, craniofacial approximation/reconstruction and the factors (tissue thickness, body mass index, age, sex and ancestry) that influence its accuracy are highlighted.

Lastly, the development and application of craniofacial anthropometry and geometric morphometric methods are explained as these methods were used to document the craniofacial indices and shape changes of South African children in this study and also for comparison to other international databases.

2.2. Human diversity and variation

Researchers in the fields of biology, anthropology, epidemiology and human genetics have been interested in human diversity and variation for many years. *Homo sapiens sapiens* is a relatively new species and the demographic history of our ancestors has resulted in the variation we observe in modern populations today (Tishkoff and Gonder, 2007). Physical traits as indicators of human variation are viewed by some researchers as unreliable, but others, such as forensic scientists, consider human variation and patterns of variation an essential tool to use in establishing a presumptive identification.

The debate regarding human diversity and variation is on-going with each discipline standing its ground. In the United States, the concept of an “emerging view” of human

variation is gaining support. This theory is the first to consider multi-factorial co-variation which allows for separation both between groups based on inter-group variation (geographical, linguistic, cultural etc) and intra-group variation (Ousley et al., 2009).

2.2.1. The semantics of "race"

The definition of "race" has always been controversial with many scientists arguing that it is a social construct and cannot be scientifically justified. Smedley (2007, p18) provides a general explanation of race as follows: "a culturally structured, systematic way of looking at, perceiving, and interpreting reality". Relethford (2009) argues that "race" is a culturally constructed concept, that it is only generally and loosely based on scientific principles of biological variation. Relethford (2009, p18) describes race as "a first-order approximation of human biological variation" that is not well-defined and is not able to describe human variation on a scientific basis. Most classic definitions of race rely on phenotypic traits such as skin and hair colour and craniofacial shape as these features have a visual effect in everyday life.

Although "race" has been widely used in biological and cultural variation studies (Relethford, 2009), the context in which the word "race" is used often differs according to the discipline, for example, law, social anthropology, biological anthropology, biology and genetics. The legal definition of race in the United States differs widely. Some legal systems even adapted the "One Drop Rule" such that one drop of blood from African ancestry would designate an individual as Black (Wright, 1995). Genetic evidence is often sought as a more definitive way to assess population variation. Biological race is considered a fallacy as humans are one group and no real differences exist in order to sub categorize humans into different species or "races". Humans are essentially one species which share the same distribution of genes, but due to our social behaviour (geography, mating patterns etc.) we can be separated into groups based on differential distribution of genetic variation.

Our social perception of race further determines the nature of the interpretation of differences between groups (Ousley et al., 2009). The biological concept of race has been defined by Hooton (1926), Boyd (1950) and Brues (1977) as a divide among species which differs from other divisions by the rate at which some inherited characteristics are found among its members.

From this definition it follows that biological race is evident when heritable traits are shared between animals (including humans) that highlight their similarities, but also

distinguish them from others. Hooten (1926) was the originator of the idea of biological separation, whereas others (e.g., Caspari, 2003, 2009; Edgar and Hunley, 2009; Ousley *et al.*, 2009) emphasize that our differences in biology are based on external factors such as environment and social behaviour. The question arises on how to quantify the differences or similarities.

The social concept of race and the biological concept of race differ and often cause ambiguity and disagreement between forensic anthropologists and biological anthropologists (Ousley *et al*., 2009). Biological anthropologists use genetic markers to classify individuals into groups (Relethford, 2009), while forensic anthropologists rely on morphology and statistics. It is essential for a forensic anthropologist to be practical and to be as specific as possible to limit variables and narrow down possible identifications. The concordance between social race and biological features will prompt forensic anthropologists to consider the geographical area from which the forensic case originates and as a result also consider individuals as Black, White, etc. Biological anthropologists explore the matter further in order to determine relationships between randomly defined populations, which may include social racial groups or genetic populations, language groups, different nationalities or groups of the same population that lived in different time periods (Ousley et al., 2009). In this regard, biological anthropologists often claim that there is not enough human variation on genetic level to substantiate dividing humans into different ancestral groups.

2.2.2. Scientific views on race and ancestry

The word “race” has for a long time been unwelcome in scientific writings due to its negative connotations (Caspari, 2009; Ousley et al., 2009; Relethford, 2009; Templeton, 2013). The political ideologies of both South Africa and the United States are examples where the use of social “race” as a means of discrimination has created long-lasting effects.

In science, the works of Livingston (1962) and Lewontin (1972) are often used to substantiate the widely advocated fact that variation between human populations is geographical rather than genetic or morphological (Lieberman and Kirk, 2004). According to Livingston (1962), human variation shows a clinal pattern without distinct boundaries such that some of the traits used to define biological race do not form distinct clusters, but are inherited independently. Lewontin (1972) examined genetic variation using classical genetic markers. He found that within human populations, 85% genetic

variation occurs, while only 8% variation occurs within populations of the same race and 6% variation is found between race and or regions. Lieberman and Kirk (2004) suggested that these results provide evidence that ”race does not exist” as the difference between (6%) and within (8%) human populations are too small to allow accurate classification of groups. For more than 30 years, Lewontin’s approach dominated physical anthropology. However, errors in the methodology have been found.

Lewontin’s (1972) work has been criticized because he independently analyzed genetic markers at a single locus level and, as expected, these results demonstrated great overlap between and among population groups (Edwards, 2003). Therefore, he did not consider that significant correlation of variables occurred and as a result, he ignored the fact that some genetic markers are not independently distributed among populations (Edwards, 2003). Molecular analysis studies that investigated several allele insertions (Pritchard *et al*., 2000; Rosenberg *et al*., 2002; Bamshad *et al*., 2003; Allocco *et al*., 2007) indicate large intra-regional variation but with conformation to a geographical pattern (Jorde and Wooding, 2004). The classical view of “race” is based on typology. It has evolved from the separatist view to Lewontin’s all encompassing view and finally to the “emerging view” of human variation that accounts for co-variation of variables (Ousley *et al*., 2009).

Currently expressions such as ancestry and population affinity are used instead of “race”. These terms describe geographical settings of humans into continental groupings (e.g., Africans, Asians, Europeans) and/or subcontinental groupings (e.g., East Asians, Southeast Asians).

Relethford (2009) suggests that researchers use clusters rather than racial groups to describe a population. Clusters are able to express the correlation between genetics and geography. He advises that the geographical distances between clusters should exceed the geographical distance within a cluster. With a sufficient use of genetic markers, this will produce a high degree of accuracy in cluster classification. In practical terms, for use in physical anthropology, Relethford (2009) asks whether one should rather refer to “geographical regions” when investigating the specific relationship of phenotypic distance and geography. In these cases, local populations make better units of analysis (Relethford, 2004a; Relethford, 2004b). Relethford (2009) also suggests that geographic groupings are more useful for forensic anthropologists when skeletal remains are assigned to an ancestral group in order to aid in personal identification. Ousley et al. (2009) also supports this view, but in view of populations, not races.

2.2.3. Ancestry in forensic anthropology

Sauer (1992) stated that skeletal biology and the social concept of race correlate well as it enables forensic anthropologists to effectively distinguish between the crania of Black and White Americans. This difference is ascribed to the different morphology in the crania of individuals from European ancestry and the individuals of African ancestry. However, distinguishable characteristics of the crania do not validate the use of biological race, namely that individuals from small groupings are inherently different.

Goodman (1997) disagrees with Sauer (1992) as he remarks that if forensic anthropologists follow Sauer's definition, they should not make mistakes in the estimation of ancestry from crania. Mistakes in this regard are often made and some are even described in the literature (Goodman, 1997), but the true situation cannot be determined as many failures and successes are not reported. In this regard, Stephan Ousley and Richard Jantz from the University of Tennessee developed FORDISC to estimate sex, age and ancestry from cranial measurements.

Craniometric variation is not due to random variation alone and displays a geographic pattern enabling the forensic anthropologist to often classify a person into a group from the same region despite overlap between groups (Ousley et al., 2009). However, accurate classification based on dissimilarities per region is still greater than chance rates (Howells, 1970; Howells, 1989; Howells, 1995; Relethford, 1994, Relethford, 2002; Roseman, 2004; Roseman and Weaver, 2004; Ousley et al., 2009).

From this short summary, it is clear that there is no consensus on the existence or non-existence of "race".

In forensic anthropology, estimation of a biological profile of a person from skeletal or semi-skeletal remains after a crime or mass disaster, such as Malaysia Airline flight MH17 that was shot down in July 2014 and the tsunamis that hit Thailand (2004) and Japan (2011), is crucial to identification of the victim. The biological profile includes aspects such as age, sex, stature and ancestry. Also, as far as facial appearances are considered, it is clear that differences exist between children of from various geographical regions even though it is difficult to exactly define their origin and meaning. This study will focus specifically on indigenous South African children, in this case children from African and Coloured groupings.

2.3. The diversity of South Africans

There are many theories, based on genetic, archaeological and linguistic evidence, regarding the origin of the diversity of the peoples of South Africa. In general, the Khoesan are seen as the first nation in Southern Africa as evidence suggests that they were in the region since the Stone Age. Modern African populations undertook long range migrations from Central and East Africa into the northwestern parts of southern Africa during the Iron Age, around 2000 years ago (Hall, 1987; Deacon and Deacon, 1999; Giliomee and Mbenga, 2007**;** Huffman, 2007; Tishkoff and Gonder, 2007). Around the same time, hunter-gatherers from Botswana became efficient herders after adopting domestic sheep and cattle from the Iron Age people in Central and West Africa. These herders became known as the Khoikhoi who migrated south and south-west into the Cape Province (Giliomee and Mbenga, 2007). In addition to the Khoikhoi, other hunter-gatherers were present in the southwestern Cape. These people, known as the "San" or "Bushmen", did not keep cattle or sheep. Some Khoikhoi people joined the San after losing cattle and sheep to disease or theft. They reverted back to the hunter-gatherer lifestyle and collectively this group of people became known as the Khoisan or Khoesan (Hall, 1987; Deacon and Deacon, 1999).

The original geographical separation between the groups forms the basis on which the sample of this study was selected.

2.3.1. Brief history of Black South Africans

Based on the current language diversity, older texts by Stow (1905) and Theal (1907) suggested that migration occurred in three distinct streams. The stream of emigrants from Central and East Africa first diverged into the Sotho-Tswana group in the central southern African region. The second divergence was the Nguni group in the southeastern areas of southern Africa. One of the prominent Nguni groups, the Zulu, later invaded and replaced the other Nguni groups during the Mfecane (also known as the Difaqane or interior wars) which was seen as the third divergence.

However, Giliomee and Mbenga (2007) suggest that segmentation and differentiation into social categories (chiefs, commoners and clients) caused the dispersion of the African people in Southern Africa. Segmentation occurs when domestic sons move away from their parental home in order to establish their own homes. External factors also impacted on the dispersion of people in South Africa (Giliomee and Mbenga, 2007):

1. Colonization of the Cape by the British in 1814 and the emancipation of the slaves in 1838 initiated migration of Dutch colonists from the Cape into the north; and
2. The discovery of diamonds and gold resulted in the population dramatically increasing in the north as men from all over the southern part of Africa left to find work on the mines;
3. Clustering of Africans into locations on the edges of areas of dense populations. The practice of clustering people into certain areas was initiated by Sir Theophilus Shepstone, British secretary of Native affairs in Natal in 1853. According Giliomee and Mbenga (2007), the Shepstone model served as a template for future segregation laws, namely the National Administration Act of 1927 and the homeland policies.
4. The passing of the new Constitution of the Republic of South Africa, Act 108 of 1996 which allowed free social integration and urbanization as people are no longer restricted to certain areas.

2.3.2 Brief history of the Coloured people of South Africa

"Coloured" or "mixed race" in the South African context refers to a social group with a wide variety of phenotypes that signals a diverse social, cultural and geographical origin (Adhikari, 2005). The Coloured identity is dependent on a range of historical, social, cultural and political factors. The Coloured people of South Africa are descendants of Cape slaves dating back to Dutch colonial rule, indigenous Khoisan people, and people of African, Asian and European origins. They also include several sub-groups such as Namas, Griquas, Basters and Malays (Adhikari, 2005; Morris, 2011).

Rapid integration of the Coloured people with Black labourers at the Cape occurred after the emancipation of the Khoisan and slaves in 1828 and 1838, respectively. More Black people started to migrate into the Cape region from 1870 to work or to be transported as miners to Kimberley within the northern region of the Cape Province. A Coloured identity, based on a shared socio-economic status, emerged as the freed slaves, colonial Black and Khoisan people came together to assert a separate identity from the Black migrants.

Despite a tumultuous history in the apartheid era, with forced relocations and social segregation, approximately 60% of the 3.5 million Coloured people of South Africa still live in the Western Cape (Giliomee and Mbenga, 2007).

2.4 Crime in South Africa

The SAPS annual report provides an analysis of the crime situation on a national level. It reports crime statistics during one financial year, for example the report of 2012/2013 was determined from statistics for 1 April 2012 to 31 March 2013. The report considers the following broad categories: Contact crimes (crimes against a person such as murder, attempted murder, rape, grievous bodily harm, assault, common assault and indecent assault); contact-related crimes; property-related crimes; other serious crimes; and crimes detected as result of active action by the SAPS. Crime has decreased with 2.8% from 2011/2012 to 2012/2013, with a decrease of 10.6% over the last four years (on average 2.7% per year).

2.4.1 Children as victims of crime

Children are a vulnerable group and the media regularly reports on social contact crimes against children. From the statistics of the last 10 years, the Crime Research and Statistics component of Crime Intelligence has determined that the majority of perpetrators of social contact crimes know their victims and are their family members, friends, acquaintances or colleagues. Social contact crimes are also frequently committed in conjunction with alcohol abuse and to a lesser extent drug abuse. In a recent study by the Medical Research Council (MRC) it was found that girls are more likely to be murdered at home by their mothers, while boys are more often killed in public places by another person known to them. Girls are often strangled and boys are stabbed or shot to death. The number of social contact or violent crimes committed against adult women and children of both sexes under the age of 18 are presented in Table 2.1.

The SAPS annual reports of 2009/2010 and 2010/2011 reported crime statistics for the categories of attempted murder, all sexual offences and murder compared to all crime against children below the age of 18 years. Between 2008 and 2010 42.3% of the crimes were for attempted murder, 36.1% for sexual offences and 14.5% for murder (See Tables 2.1 and 2.2). In 2010/2011 the situation improved as a decrease in all categories was noted, except for sexual offences which increased by 2.5%. The SAPS annual report for 2012/2013 shows a slight decrease of 0.4% since last year.

Crime statistics are often difficult to interpret as the format of the report may change from year to year. For example, the SAPS annual reports of 2011/2012 and 2012/2013 did not include similar detail on crime per age category for children. Furthermore, the recent SAPS report for 2012/2013 states that the numbers for murder and kidnapping of children

are classified together with adult numbers. Therefore the current situation regarding children is unknown. Administrative changes within the SAPS also complicate the interpretation of crime statistics. An example of how administrative changes affected the system can be seen since 2009, when an administrative change was implemented in the Crime Administration System (CAS) (December 2007 to April 2009). The SAPS use the CAS as the system to document crime and to generate crime statistics. During this time, sex and age characteristics of the victims of sexual offences were not recorded as it was not required fields within the system. This situation was corrected in April 2009. Since then, a significant increase (36.1%) in crimes of sexual nature between 2008/2009 to 2009/2010 has been recorded. However, an overall reduction of 12.3% in sexual offenses was reported for the last four years (2009/2010 – 2012/2013) in the 2012/2013 SAPS annual report.

The question has arisen as to which age groups were most affected. Figures 2.1 to 2.3 were generated from data in the SAPS annual report of 2008/2009. No similar statistics have been compiled after 2009. Figures 2.1 to 2.3 show that the majority of crimes were committed against children aged 15 to 17 years. An increase in all types of crime against children after the age of 11 preceded this trend (Tables 2.2 and 2.3). In the United States, most child abduction murders take place between the ages of 6 and 15 years (See Table 2.4). The MRC study determined that fatal child abuse, abandonment of babies and violence among teenage boys were the main causes for murder among children between the ages of 0 and 17 years. In terms of age specific murders, the MRC found that in the category of 0 – 4 years, girls were more often murdered than boys. After age 4, the murder rate among boys increased. At age 15, almost double the number of boys is murdered compared to girls of the same age.

2.4.2 Missing children

Although many dated off-hand references are found in the local press, official statistics on missing children in South Africa are difficult to find. The missing persons section of the SAPS was not able to assist with information and referred the researcher to the section of the SAPS annual report entitled “Kidnapping”. Unfortunately no distinction is made in the statistical data between kidnapping or murder of adults and children (SAPS annual reports: 2009/2010; 2010/2011; 2011/2012; 2012/2013).

Numbers of missing children quoted in popular and local press vary between 60 and 70 children per month (Pretoria News, 2006).

According to a local newspaper in Northern Gauteng, the Pretoria News (2006), two children per day go missing in the Tshwane Metropole of which Pretoria forms part. This adds up to 60 children per month. The newspaper quoted SAPS statistics, of which the source document could not be found, as more than double this number, or 130 children per month. Reddy (2007) quoted another report from the SAPS Missing Persons Bureau which stated that every 6 hours, a child goes missing in South Africa. The reasons vary from children who run away from home to crime related disappearances such as child sex-trafficking gangs, fathers committing infanticide to avoid paying maintenance and muti murders.

Muti murder or medicine murder refers to murder of someone in order to remove certain body parts to be used as part of medicine. Using body parts of the elderly and especially children is said to be very strong and is rumored to help the user to become rich and powerful. William Mpembe, Deputy Provincial Commissioner of the SAPS, was quoted in the Sowetan Newspaper of 22 February 2010, stating that muti murders, particularly those involving young children, seem to be on the rise in the Tshwane areas including Soshanguve, Garankua and Rietgat.

The Media Club of South Africa (Kearney and Erasmus, 2010) reported that one in 10 children below the age of 18 were victims of assault. Joan van Niekerk, director of Childline, was quoted in the same article saying that 17% of offenders in the Childline offender programme (a rehabilitation project) are paedophiles and that 40% to 50% of rape cases involve children. These numbers may be higher as only one in 10 cases are usually reported to the SAPS.

Social contact crimes such as attempted murder (59%) and assault with grievous bodily harm (GBH) (89%) are high for all age groups (Keraney, 2010). These categories of crime are more likely to occur between people who know one another and are linked to social behaviour patterns, such as alcohol and other substance abuse as well as problems inherent to informal settlements in megatownships where a lack of jobs creates poverty and leads to crime (Kearney and Erasmus, 2010).

Child fatalities are often the tragic consequence of abuse and / or kidnapping. As many as 89% children are killed within 24 hours after abduction (McKenna, 2006). In the US a specific category was created in FBI reports termed as “murder abduction”. Children below 12 years of age are considered to be particularly vulnerable, as they often know the perpetrator as an uncle, cousin of family friend and hesitate to report the crime (McKenna, 2006). However, McKenna (2006) reported that the killers’ reasons for abduction are

mostly opportunistic (40%) with only 14% of killers having a prior relationship with the child. He did not specify or provide statistics on how many perpetrators were family members or caregivers.

After the child is killed, the perpetrator often disposes of the body in rural areas (53%) and then conceals the remains in 55.6% - 73% of cases (McKenna, 2006; Häkkänen *et al*., 2007). When the remains are recovered an investigation is launched in order to determine the identity of the victim. In both child and adult cases, where decomposition and mutilation resulted in unidentifiable remains without other evidence, craniofacial approximation/reconstruction may be used in the initial process to achieve identification of skeletal remains.

In Pretoria, the Medico-Legal Laboratory processes almost 3000 unnatural deaths per year of which 10% of the individuals are unidentified. This amounts to 300 bodies which is a serious problem for the legal system (Evert, 2012).

2.5 Craniofacial approximation/reconstruction

Craniofacial reconstruction/approximation is the process in which the face of an unidentified person is recreated from skeletal remains in cases where other techniques to identify him / her such as fingerprinting and DNA sequencing are not possible. Although the reliability of facial reconstruction/approximation techniques has been debated in the literature, many researchers are attempting to set standards for the process as a means to validate their results in forensic cases.

In the following sections a general overview of craniofacial approximation / reconstruction and the problems of craniofacial approximation/reconstruction in children will be provided. A complete and detailed discussion of craniofacial approximation / reconstruction will not be included as craniofacial approximation / reconstruction *per se* is not within the scope of the study. However, tissue thickness will be discussed in detail as it has direct relevance on the study. More information on craniofacial approximation / reconstruction methodology can be found in Işcan and Steyn (2013) and Wilkinson (2012).

2.5.1 General overview

Craniofacial approximation/reconstruction techniques rely on the relation of the soft tissue to the underlying bony landmarks, also known as tissue thickness. In order to produce a craniofacial approximation/reconstruction that family and friends can recognize, the approximation/reconstruction must reflect appropriate characteristics that are based on

ancestry, age and sex (Dumont, 1986; Manhein *et al*., 2000; Williamson *et al*., 2002; Wilkinson, 2002; Utsuno *et al*., 2007). Extensive studies have been conducted on the tissue thickness of adults. Data on the tissue thickness in the South African adult population have been published for Black males (Aulsebrook *et al.*, 1996), Black females (Cavanagh and Steyn, 2011) and a group of Coloured people (Phillips and Smuts, 1996).

Tissue thickness data of children are mainly limited to the Northern hemisphere (Dumont, 1986; Manhein *et al*., 2000; Wilkinson, 2002; Utsuno *et al*., 2007; Codinha, 2009). Data regarding children are almost always based on measurements from homogenous groups. Only some authors have considered skeletal type (facial profile) and dental occlusion as factors that influence tissue depths in adults and children (Dumont, 1986; Utsuno *et al*., 2005, 2007, 2010a, 2010b). The impact of BMI on tissue thickness in adults has been described (de Greef *et al*., 2006; Starbuck and Ward, 2007; Codinha, 2009; Tedeschi-Oliveira, 2010), and both Dumont (1986) and Wilkinson (2002, 2004) have recognized the possible influence of body mass index (BMI) on facial tissue thickness in children. Currently, no information exists on tissue thickness of children of Black and Coloured ancestry in South Africa.

2.5.2 Application and importance of accuracy

Craniofacial approximation/reconstruction aspire to produce an image, 3D or 2D, with close enough resemblance to a living individual so that they can be recognized. Additional supporting evidence can then be used to make a positive identification (Tyrell *et al*., 1997). Authors use different and often confusing terms when referring to facial reconstruction. Stephan (2003) argues that one can never produce the exact face, only a likeness, therefore it is an “approximation”. The debate continues in the literature (George, 1987; Philips and Smuts, 1996; Stephan and Henneberg, 2001; De Greef and Willems, 2005; Domaracki and Stephan, 2006; Stephan, 2006; de Greef *et al.*, 2006; Stephan and Simpson, 2008a, 2008b; Stephan *et al*., 2013, Stephan, 2014).

The methodology of craniofacial approximation/reconstruction has improved since its original description in 1883 (Snow *et al*., 1970; Gatliff and Snow, 1977; Farrar, 1977). The technique has been used to rebuild faces for historical, archaeological and forensic purposes. Several famous cases are described in the literature, which include the Green River serial murder victims (Haglund and Reay, 1991), a 3500-year-old Egyptian mummy (Hill *et al*., 1993), Louis XVII (Puech, 1995), George Buchanan (Hill *et al*., 1996), Antal Simon (Kustár, 2004), the Mayan Red queen (Tiesler, 2005), Johan Sebastian Bach by Dr

Caroline Wilkinson (BBC news, 2008) and Tutankhamen (Handwerk, 2005) to name a few.

The accuracy and success of craniofacial approximation/reconstructions has been widely debated as to whether they contribute to positive identification (Tyrell, 1997; Stephan and Henneberg, 2001, Stephan, 2002; Stephan, 2003a, Wilikinson, 2003, Stephan, 2009). The major concern of Stephan (2003a) is the lack of systematic scientific research in the field. Stephan (2003a) argues that media coverage and contextual information contribute more to positive identification of a victim, than facial approximation/reconstructions being "successful". Thus, interpreting the quoted success rate should be done with caution as many unsuccessful approximation/reconstructions go unpublished (Stephan, 2003a). The American method as practiced by Gatliff (1979, 1984) claims to be 65% successful (Wilkinson, 2001). Stephan and Henneberg (2001) also found American 3D methods more accurate than the American 2D drawing method and American 2D computer method. When using the "face pool" accuracy test they found a 70% false-positive rate for the American methods (Stephan and Henneberg, 2001).

The Manchester method (Prag and Neave (1997) maintained a success rate of 50% - 75% (Prag and Neave, 1997; Wilkinson and Neave, 2001; Wilkinson, 2002). With new advances in the field, the success rate of the Manchester method has improved to 88% (Wilikinson, 2006).

Recognition tests (face arrays) are said to be more robust than case successes and resemblance ratings, as recognition tests can be designed to correspond with real-life blind facial approximation/reconstruction (Stephan, 2009). Several recognition studies have been performed (van Rensburg, 1993; Stephan and Henneberg, 2001; Wilkinson and Whittaker, 2002; Stephan et al., 2005; Stephan and Henneberg, 2006; Cavanagh, 2010; Stephan and Cicolini, 2010) and although recognition rates were above chance rates in each study, the recognition rates varied between 18% – 64%.

Of course an increase in success rates are to be expected as methods are refined as more scientific data becomes available. Changes in methodology and addition of new data on which the approximation/reconstruction is based have to be published, as without such publications an increased success rate could easily be attributed to chance rather than science (Stephan, 2003).

Other factors, not directly associated with the scientific method, may also contribute to successful identification. These external factors include the effort of the investigating

officer makes in advertising the reconstruction in the media and the involvement of the local community leaders**.**

2.5.3 Craniofacial approximation/reconstruction in children

In terms of the facial reconstruction/approximation process, Wilkinson (2004) recommends that the skull of a child be mounted at an upward angle to simulate the angle at which adults are used to seeing faces of children. Therefore the Frankfurt horizontal plane is not recommended. Bony ridges signaling muscle attachments are more delicate on juvenile skulls. Dental occlusion is the only clue as to the shape of the mouth as other bony features of the mouth are of little use in children. In adults, the height of the teeth is used to determine lip thickness, but in children with deciduous teeth or mixed dentition tooth height as indicator of lip thickness will not be accurate (Wilkinson, 2004). Children's faces tend to be round with full cheeks and an undefined jaw line due to the presence of an extended and large buccal fat pad, a remnant from the neonatal period.

Wilkinson and Whittaker (2002) asked volunteers to identify 5 reconstructions of children aged 8 to 18 years from a pool of 10 facial photographs. The volunteers matched the facial reconstruction to the correct photograph 44% of the time, which was 34% above chance rate. The best rating was achieved in assessing the nose and eye areas, while the worst ratings were found when the mouth and age of the child were considered. The results were used to demonstrate that reconstruction of children's' faces was accurate when using correct tissue thickness data (in this case British juvenile data) and the Manchester facial reconstruction/approximation method. However, Stephan (2009) argues that the age rage was too dissimilar and the repeated use of the same face pool assisted volunteers to achieve high recognition rates.

Until recently, facial reconstruction/approximation of children under the age of 8 was not considered to be useful as sex differences among the faces of children are not apparent in this stage. The Nulde case from the Netherlands was the turning point for this theory. In this case, dental development and age were both used to aid in the identification of juvenile skeletal remains. Based on evidence of tooth eruption and dental development, the child had been approximately 5 years of age at time of death. Dr C Wilkinson provided a reconstruction of the face and, in conjunction with a Dutch Police media campaign, the girl was identified. The successful identification of the remains from the reconstruction/approximation demonstrated that juvenile reconstruction/approximation can be applied to forensic cases were the identity of the victim is unknown (Wilkinson, 2004).

In juveniles, the age difference between the available images of the possible victim, which may have been taken several months before death, affect the identification due to changes in the face as a result of growth (Wilkinson, 2004). Furthermore, a lack of knowledge regarding South African juvenile cephalometric facial standards and tissue depths of particular age groups, sex and population affinity is problematic. The use of African-American values to reconstruct faces of Black South African children yields poor results (Capt TM Briers, personal communication).

In order to perform a facial reconstruction/approximation that presents a true reflection of the child in question, information regarding changes to the face during growth is vital. Other factors to take into account are differences in soft tissue at different ages, sexes and ancestry groups. However, some researchers dispute the importance of these features (Stephan 2003, Stephan and Simpson, 2008a, 2008b).

2.6 Tissue thickness

Facial reconstruction/approximation is based on the relationship of soft tissue to the underlying facial skeleton. Tissue thickness at specific bony landmarks is used as a guideline to the shape of the face. Several studies using a variety of methodologies have been conducted to determine tissue thickness at standardized landmarks in order to produce an accurate resemblance of the face. In the following sections, the development of tissue thickness values, modern methods for determining tissue thickness as well as factors that may influence tissue thickness are discussed.

2.6.1 Development of soft tissue thickness values

Welcker in 1883 described the original attempt to measure tissue depth. He inserted a thin blade into the faces of cadavers at selected landmarks and used blade penetration to determine the tissue thickness. From 1895 – 1899, several authors followed this technique and replaced the blade with needles for insertion into the face of the cadaver in order to measure tissue thickness (His, 1895; Kollman, 1899). His (1895) used this method to gather facial tissue thickness measurements and used the data he collected to construct the plaster cast of the famous German composer, Johann Sebastian Bach (1685 – 1750). In 1898 and 1899, Kollman used the same methodology to reconstruct the famous Italian poet Dante (1265 – 1321) and the face of a Stone Age woman from Auvenier in France. Wilkinson (2004) mentioned that this approximation/reconstruction is considered to be the first scientifically valid craniofacial approximation/reconstruction as it was based on the

tissue thickness measurements of more than a 100 women from the same area in which the skull was found. An artist, under the supervision of Kollman, planned and executed the approximations / reconstructions. In the early 1900's other anatomists, anthropologists and palaeontologists such as Merkel, Solger and McGregor followed Kollman's methods. This lead to a range of 2D and 3D approximation /reconstructions of hominid skulls, which included Neanderthal skulls discovered at Le Moustier and La Chapelle-aux-Saints in France (Wilkinson, 2004).

Suk (1935) criticized the use of cadavers for measurement of tissue thickness. Soft tissue deformation due to drying and embalming or putrefaction and bloating as well as misalignment between palpated landmarks and actual landmarks on the skull were the major concerns listed (Suk, 1935). During this time, another method of craniofacial approximation/reconstruction had emerged which was based on anatomy and not tissue thickness.

Gerasimov, a Russian archeologist and anthropologist, began to model approximation/reconstructions of ancient people based on specific muscle anatomy of the face. He later produced many 2D and 3D approximation/reconstructions of modern people and reported positive results for most of these cases. However, no evidence could be found that he based any of the 2D approximation/reconstructions on tissue thickness (Lebedinskaya, 1993; Wilkinson, 2004). In forensic craniofacial approximation/reconstruction, this technique has became known as the Russian method.

In the United States, Krogman (1946) elaborated on the efforts of McGregor (1926) and Wilder (1912) and introduced specific tissue thickness data as a means to establish the accuracy of the method. Together with an artist, Krogman (1946) produced the first approximation/reconstruction based on sex and population specific tissue thickness data (Wilkinson, 2004). Krogman engaged the aid of many artists and thus formed the basis on which Gatliff and Snow (1979) developed the 3D American method. The American method uses an appropriate tissue thickness data set that is followed with an artistic phase to sculpt facial features (Taylor, 2001).

Anatomists such as His, Kollman, Merkel, McGregor and Krogman often engaged the skills of an artist to reconstruct the skull. Today, this practice continues, but several scientists have learned the artistic skills in order to reconstruct the skull themselves and forensic artists base their work on this scientific data.

In Europe, the need to produce accurate approximation/reconstructions motivated Neave to develop a technique in which muscle anatomy of the face and appropriate tissue

thickness are combined, and this is referred to as the Manchester method. Wikinson (2002, 2003, 2004, 2006, 2008) and others (Neave, 1979; Prag and Neave, 1997) have since refined this method to include detailed knowledge of structural craniofacial anthropometry, relationships between facial hard and soft tissue specification as related to age, sex and population.

In summary, facial approximation/reconstruction is generally based either on average soft tissue thickness ("American" methods) or osteology and anatomy of the skull ("Russian" method) or a combination of both. Stephan (2009) argues that the there are no differences between the methods as the "Russian" method is based also includes the use of average tissue thickness, while the "American" method incorporates the anatomical features of the skull.

2.6.2 Current methodology in the measurement of tissue thickness

Most available data on tissue thickness relate to adults and were collected via a variety of methods such as needle puncture (or needle penetration), radiographs, ultrasound, CT and MR scanning. For new data, the use of advanced ultrasound and 3D scanning methods are rapidly increasing in the forensic field (Suzuki, 1948; Rhine and Campbell, 1980; Rhine and Moore, 1982; Helmer, 1984; Aulsebrook *et al*., 1996; Philips and Smuts, 1996; Manhein *et al*., 2000; El-Mehallawi and Soliman, 2001; Wilkinson, 2003; De Greef *et al*., 2005; De Greef *et al*., 2006; Domarcki and Stephan, 2006; Wilkinson *et al*., 2006; Claes *et al*., 2010; Fourie *et al*., 2010; Cavanagh and Steyn 2011; Peckman *et al*., 2013; Ruiz, 2013; Parks *et al*., 2014).

Before 1990, the needle puncture method on cadavers was often used to determine tissue thickness (Welcker, 1883; His, 1895; Kollman, 1899; Suzuki, 1948; Sutton, 1969; Rhine and Campbell, 1980). Helmer (1984) took a different direction and used ultrasound to measure tissue thickness. Ultrasound together with cephalograms (a type of lateral radiograph of the skull to visualize both skeletal and soft tissue profile), became popular due to their non-invasive properties. Measurements taken from radiographs (Dumont, 1986; Aulsebrook *et al*., 1996; Williamson *et al*., 2002; Utsuno *et al*., 2005, 2007, 2010), ultrasound (Hodson *et al*, 1985; Manhein *et al*., 2000; Wilkinson, 2002; El-Mehallawi and Soliman, 2001; Peckman *et al*., 2013) and CT / MRI scans (Philips and Smuts, 1996; Tilotta, 2009; Cavanagh and Steyn, 2011; Ruiz, 2013; Parks *et al*., 2014) are said to be more accurate for the measurement of tissue thickness when compared to needle puncture of cadaver material. The advantages of the imaging methods include the ability to work on

living individuals with minimal distortion of tissue thickness and high resolution of soft tissue with CT scan (Wilkinson, 2002). The disadvantages listed were minimal exposure to radiation when using the radiographic method; inaccurate or improper positioning of the transducer due to inexperience when using the ultrasound; and both high cost and radiation involved in CT and MR scanning (Domaracki and Stephan, 2006). However, in using images already available in a database at a radiology department or the local academic hospital, researchers can circumvent radiation and cost issues of cephalograms, CT scans and MR imaging.

Ultrasound studies are popular as they are not as expensive compared to CT or MR scans, can be used to measure living individuals in the upright position and tissue thickness at lateral landmarks can easily be measured. Furthermore, research indicates that the measurement error in measurements taken by ultrasound is similar to other methods (Stephan and Simpson, 2008a, 2008b). The disadvantage is that the transducer may compress and distort the tissue when pressing too hard on the tissue overlying the bony landmark, which can cause inaccurate measurements (Smith and Throckmorton, 2006; Stephan and Simpson, 2008a; Chen *et al*, 2011). Also, the same (dedicated) machine and operator is needed to ensure repeatability and to reduce observer error. With all these complications, it is not surprising that there had been a re-emergence of the needle puncture method in the literature (Simpson and Henneberg, 2002; Domaracki and Stephan, 2006; Codinha, 2010; Tedeschi-Oliviera *et al*., 2010).

According to Smith and Throckmorton (2006), different methods can render different measurements. They used ultrasound and radiographs obtained at three locations to compare three sets of tissue thickness measurements. They found that the correlation between measurements from the radiographs and ultrasound ranged from poor to excellent and the difference between measured tissue thicknesses ranged from –5.0 mm to +3.0 mm, which they attributed to difficulty in location of specific landmarks and in position of the head (Smith and Throckmorton, 2006). A further analysis of different methods used to collect the tissue thickness data showed that data from cephalograms produced larger values for mid-facial landmarks. The second and third largest values were found in studies that used ultrasound on living individuals and needle puncture on cadaver material, respectively. Both the latter two methods produced comparable results, except at some bilateral landmarks which may be due to positioning of the individual (supine vs upright). CT and MRI values produced the lowest discrepancies (Stephan, 2008a). Therefore caution should be taken when interpreting results obtained from different methods as the

measurements obtained from the different visualization modalities may vary in their comparability (Smith and Throckmorton, 2006).

Yet, the need to evaluate results from different population groups often exceeds concerns for differences in methodology. Researchers tend to use the most accessible method regardless of the advantages and disadvantages. In support of the latter, Stephan and Simpson (2008a) have shown that even though differences in methodology render different values, these values often do not differ significantly in terms of statistical or practical application. In a review, they compared a pooled set of tissue thickness data from different authors and with different methods, such as needle puncture, ultrasound, cephalograms, CT and MRI, to ascertain practical differences. None of these methods, when used by different authors, were shown to produce a consistent result. They concluded that, regardless of the strengths and weaknesses of each method, one method was not superior to the other. They suggested that tissue thickness data be pooled without considering the different methodologies (Stephan and Simpson, 2008a, 2008b, Stephan *et al*., 2013, Stephan, 2014).

Regardless of the method used to measure soft tissue depths, differences in terms of sex and ancestry are expected. The craniofacial approximation/reconstruction expert needs to take this into account when choosing and applying tissue thickness (Wilkinson, 2004; Cavanagh and Steyn, 2011; Peckman *et al.*, 2013; Ruiz, 2013; Parks *et al*., 2014).

2.6.3 Tissue thickness studies in South Africa

The South African Police Service has a dedicated Facial Reconstruction team that specializes in both 2D and 3D reconstruction of faces from skeletal remains. However, only three research studies regarding forensic facial reconstruction/approximation have been published in South Africa (Aulsebrook *et al.*, 1996, Philips and Smuts 1996, Cavanagh and Steyn, 2011). Two of the three South African studies focused on adults from African origin (Aulsebrook *et al*., 1996; Cavanagh and Steyn, 2011), while the study of Philips and Smuts (1996) included Coloured children and adults.

Aulsebrook *et al*. (1996) investigated the soft tissue thickness of Black males aged 20 – 35 years from KwaZulu-Natal (n = 55) using cephalograms. They reported tissue thickness data and specific landmarks, but included no comparison to other datasets. Philips and Smuts (1996) studied the soft tissue thickness on CT scans of a population of Coloured people from the Western Cape aged 12 to 71 years (n = 32). The sample used by

Cavanagh and Steyn (2011) consisted of Black females from 18 to 35 years of age (n = 154). Their soft tissue thickness was measured on CT scans.

The mean average tissue thickness per midfacial landmark as reported by Aulsebrook *et al.* (1996), Philips and Smuts (1996), Cavanagh and Steyn (2011), and Rhine and Campbell (1980) is presented in Table 2.5. Rhine and Campbell (1980) included adults of both sexes from Black and White North Americans.

In general, the tissue thicknesses of the White North American females are the smallest, with the exception of the nasion and pogonion, where the Coloured South African data have the smallest value. However, the South African Coloured sample, although separated into sexes, includes children and adults, which renders the sample composition heterogeneous and as a result makes comparisons with current studies difficult. Philips and Smuts (1996) reported the tissue thickness in Coloured people to not be just an average between Whites and Blacks, but a unique set of values.

A comparison of the South African midline tissue thickness data on Black males (Aulsebrooke *et al*., 1996) and Black females (Cavanagh and Steyn, 2011) to Rhine and Campbell (1980) on African-Americans indicates differences less than 2 mm (Table 2.6). However, Stephan and Simpson (2008a, 2008b) and Stephan *et al.* (2013) questioned whether this difference was practically significant to validate the use of different tissue thickness data sets.

2.6.4 Possible factors influencing tissue thickness

In the following sections the available literature on factors such as sex, ancestry, age and BMI, which may affect tissue thickness in varying degrees, will be described.

2.6.4.1 Sex

In addition to the lack of differences in methods used to determine tissue thickness, Stephan (2006) suggested that no distinguishable difference was present in terms of tissue thickness in sexes and hence the values from males and females could be pooled to increase the population values. Domaracki and Stephan (2006) also found no statistically significant differences between the sexes ($p > 0.05$) when using the needle puncture method on an adult cadaver sample (Australia, n = 33). Since differences were found to be minimal (2.2 mm or less), some authors argue that separate soft tissue depths for males and females are of little practical significance for craniofacial identification (Domaracki and Stephan, 2006). A series of papers by Stephan and Simpson (2008a), Stephan *et al.*

(2013) and Stephan (2014) analyzed all available data on the soft tissue thickness of adults. They maintain their previous standpoint of only having one combined dataset for males and females as the statistical analysis he has conducted on available existing male and female datasets has shown minimal differences between sexes. As an example, Stephan and Simpson (2008a) used mainly studies from Rhine for comparison of the pooled data by sex. The data revealed that males had slightly larger tissue thickness than females at most landmarks except the cheeks. They argued that the mean difference between males and females as determined from the data was 0.4 mm, which is extremely small and has little practical meaning, despite statistical significance. They suggest that male and female data should rather be pooled and weighted.

However, many authors do not agree that sex differences should be ignored and they provide extensive tables that distinguish between males and female tissue thickness measurements as separate subsets. As in the case of Stephan (2008a), most agree that the tissue thickness in females is similar or less comparable to males, except over the cheek area where females have larger tissue thicknesses (Suzuki, 1948; Helmer, 1984; Philips, 1996; Manhein *et al*., 2000; El-Mehallawi, 2001; Wilkinson, 2004; de Greef *et al*., 2006; Utsuno *et al*., 2007; Codinha, 2010; Tedeschi-Oliveira, 2010). Difference in opinions between Stephan (2008a) and others lies in the practical application of the data. While Stephan (2008a) argues that the differences between sexes are not significant and should be ignored in order to simplify tissue thickness datasets, other authors believe these differences increase the accuracy of the craniofacial approximation/reconstructions.

In addition to males having a larger tissue thickness than females, several authors have pin-pointed the landmarks at which these differences are significantly different between the sexes. These include landmarks of the forehead and brow (supra-orbital, glabella), mouth (infra canine) and lower face region of the chin and jaw (mid mandibular border, mid ramus, gonion). Landmarks related to the cheeks where tissue thickness in females is larger than males are as follows: Zygomatic arch, supra-canine, supra-molar and infra-molar. The study of Philips and Smuts (1996) on Coloured people from in and around Cape Town, the Egyptian study of El-Mehallawi and Soliman (2001) and Brazilian study of Tedeschi-Oliveira (2010) all showed that tissue thickness was greater at the forehead landmarks, midphiltrum, chin, and jaw in females compared to males.

In summary, it seems that many publications show that tissue thickness differences exist between males and females, although the practical implications of these relatively small differences have hardly been assessed.

2.6.4.2 Ancestry

Extensive data sets on tissue thickness differences in different population groups have been published (Aulsebrook *et al*., 1996; Manhein *et al*., 2000; Wilkinson, 2003; de Greef *et al*., 2006; Codinha 2010, Tedeschi-Oliveira 2010). Stephan and Simpson (2008a) argued against the aforementioned research with regard to population differences and tissue depth thicknesses. These authors combined data from various studies obtained from a variety of data collection methods and population groups, which were defined in older texts as Caucasoid, Mongoloid and Negroid. Despite these terminologies no longer being in use, Stephan and Simpson (2008a) kept to this classification for comparative reasons. No groups of diverse social designation (previously called mixed ancestry) were included. He found that the data did not cluster, nor was differences statistically significant among Caucasoid, Mongoloid and Negroid groups. Therefore, Stephan and Simpson (2008a) suggested that tissue thickness data could be lumped across populations, or was not population specific. According to Stephan and Simpson (2008a), ancestry has a negligible effect on tissue thickness and differences between authors may be attributed to measurement error, observer error and measurement methodology. The latter, a factor that he himself argued within the same paper of 2008a, should be ignored due to the uncertainty level of more than 2 mm. In effect, this means that Stephan (2008a) suggests that differences or errors up to 2 mm could be made without having an effect on the outcome of the reconstruction/approximation. Chan *et al*., (2011), Chen *et al*., (2011) and Fernandes *et al*. (2012) have since published papers that showed the relevance of population specific tissue thickness data.

Population specific data for South Africans (Aulsebrook *et al.*, 1996; Philips and Smuts, 1996; Cavanagh and Steyn, 2011) are presented in Table 2.7. Although tissue thickness at most landmarks are similar, tissue thickness in the Coloured sample is markedly thinner at the nasion, midphiltrum, lower lip margin and pogonion. A significant practical difference of more than 2 mm was noted at the nasion and lower lip margin.

In summary, most researchers and practioners in the field of craniofacial approximation/reconstruction take ancestry into account so as to minimize error and to improve the possibility for recognition in craniofacial approximation/reconstruction (Wilkinson, 2004). Chan *et al.* (2011) have cautioned against the practice of combining population specific tissue thickness data collected by many different researchers. Reasons offered for this warning include the environmental and cultural differences between groups.

2.6.4.3 Age

Facial tissue thickness changes during all phases of life. These changes are seen during the growth phases in children, as well as in the ageing process in adults. His (1895) described changes in tissue thickness in the aging adult. He suggested that White Europeans increased in tissue thickness with age at nasion, midphiltrum and gonion. More recently, Helmer (1984) and Manhein *et al*. (2000) indicated that tissue thickness in White Europeans and Americans increased with age at glabella, the nose and lower face region, and the cheek areas. A decrease in tissue thickness with age was noted around the mouth (specifically at the midphiltrum and upper lip border), nasion and temporal areas (Helmer, 1984; Manhein *et al*. 2000). This general change in facial appearance is related to a loss in elasticity of facial skin, which causes an increase in tissue thickness over the brows and chin and a decrease over the mouth and cheek area (Wilkinson, 2004).

Data on craniofacial tissue thickness of children are on the increase in the literature, but it mainly involves American children of European (Dumont, 1986; Garlie, 1999; Manhein *et al*., 2000) and African (Manhein *et al*., 2000; Williamson, 2002) descent. Three studies on children from countries other than the USA were found and included Hispanic (Manhein *et al*., 2000), White British (Wilkinson, 2002) and female Japanese children (Utsuno *et al.*, 2005, 2007).

Ancestry, sex and age have been shown to have an effect on tissue depth thickness in children (Tyrell, 1997; Wilkinson, 2004). Williamson *et al.* (2002) reported differences in measurements for African-American children (radiographs) when compared to White American children (tissue thickness measured by ultrasound). The tissue thicknesses of Williamson *et al.* (2002) of their African-American group as measured by radiographs were larger than those reported by Manhein *et al.* (2000) using ultrasound for African American children and larger compared to Hodson *et al.* (1985) who measured tissue thicknesses on radiographs using White American children. Radiographs and ultrasounds are commonly used to gather data on craniofacial tissue thickness in children, and the effect of methodology should be considered when comparing tissue thickness in children from different origin, sex and age groups (Wilkinson, 2002; Dumont, 1986; Aulsebrooke, 1996; Philips and Smuts, 1996; Manhein *et al*., 2000; Williamson, *et al*., 2002; Utsuno *et al*., 2005; Utsuno *et al*., 2007).

Tissue thickness on the facial midline of African-Americans from different geographic locations were examined because of a possibility that geographic differences

may exist between children of the same ancestral group, but no differences were found (Williamson, 2002).

A radiographic study on the facial tissue thickness in Japanese children suggested that soft tissue thickness among Japanese girls (aged 6 – 16 years) differs from Japanese women (< 21 years), with the exception of the gnathion and gonion (Utsuno *et al*., 2005). Upper facial measurements in the Japanese girls were less (Utsuno *et al*., 2005) compared to adults in other studies (Miyasaka, 1995; Aulsebrooke *et al*., 1996) possibly due to the increased expansion of the underlying bone in adults. Furthermore, only American White children (Dumont, 1986) demonstrated larger tissue thickness at all landmarks than Japanese children (Utsuno *et al*., 2005).

Garlie and Saunders (1999), Manhein *et al.* (2000), Williamson (2002) and Dumont (1986) reported significant differences in tissue thickness with sex and age in American and African-American samples. Most increase in tissue thickness was in the early adolescent period (9 to 13 years) and coincided with an increase in growth (Williamson, 2002). Wilkinson (2002), in her ultrasound study of British children aged 11 to 18 years, also showed that tissue thickness in males generally increased with age at all the mid-line facial points and the cheek points (Wilkinson, 2002). In females an increase in tissue depth occurred with age at all the points except the infra-orbital, lateral orbital, mid-zygomatic arch and mid-mandibular points (Wilkinson, 2002).

2.6.4.4 BMI

Facial reconstruction/approximation studies by Dumont (1986), Manhein *et al*. (2000), Williamson (2002), Wilkinson (2002) and Utsuno (2005; 2007) have suggested that BMI should be taken into account. Some authors have considered BMI and tissue thickness in adults (de Greef *et al*., 2006; Starbuck, 2007; Sahni, 2008; Tedeschi-Olivieria, 2008; Codinha, 2009; de Greef *et al*., 2009), but no information on the effects of BMI on childrens' facial tissue thicknesses is readily available. A possible reason may be due to the difficulty in obtaining data of tissue thickness and BMI on the same individual. Another may be that researchers do not believe it has a considerable affect. For example, Stephan and Simpson (2008a, 2008b) did not take BMI into account in his comparative studies of adult and sub-adult tissue thickness data. He argued that body weight cannot be determined from skeletal material**;** therefore he did consider BMI as a co-variant.

De Greef *et al*. (2009) performed multivariate analysis on a large-scale study of Caucasian adults to assess impact of sex, BMI and age on facial tissue thickness. Their

results confirmed that BMI, together with age and sex, significantly influence facial tissue thickness but not equally at all landmarks. Starbuck *et al*. (2007) indicated that the accuracy of recognizing a face also depends on body mass index (BMI). They determined that when people are confronted with three versions of the same face (thin, normal weight and overweight/obese), they tend to distinguish the normal weight version and the overweight/obese version as two different people.

2.7 Cephalometric facial standards and facial growth

Knowledge of craniofacial growth is essential for maxillofacial surgeons, orthodontists and forensic artists. Orthodontists require this knowledge in order to assess and plan treatment programs so as to achieve the most effective result. In this regard, various longitudinal and semi-longitudinal growth studies have shown that linear and angular cephalometrics vary between sex and age groups (Broadbent *et al*., 1975; Vegter and Hage, 2000). Craniofacial indices are often employed to adjust and to predict change in children's faces, specifically in cases where children have been missing for an extended period of time and where comparable photographs are limited (Wilkinson, 2004).

2.7.1 Craniofacial morphology

Craniofacial morphology has intrigued scientists from the earliest times. Aristotle (384–322 BC) described in his book *Physiognomica* the "science" of reading one's character from bodily features. Da Vinci (1452–1519) provided lengthy descriptions of proportions and the manner in which the face (and body) should be ideally shaped.

Jacques Joseph (1865–1934), considered to be the father of modern rhinoplasty, emphasized the importance of the nasal profile for cosmetic surgery. Since the golden proportion was seen in Egyptian architecture, it has been assumed that they were the first to record the 1:1.618 ratio. Pythagoreans and later the Greek geometrician Euclid described the proportion as the ratio between two portions of a line, or the two dimensions of a rectangular plane, in which the lesser of the two is to the greater as the greater is to the sum of both. The Greek letter phi (Φ) is used to indicate the number 1.618. Pacioli (1509) introduced the idea of the "golden proportion" to the scientific community, but it was the publication by Seghers *et al*. (1964) that was noteworthy. Subsequent works by Ricketts (1968; 1981; 1982) popularized the concept. From then onwards, applying the concept of the golden proportion were advocated as it supposedly signifies beauty. The general perception is that the closer the facial features to the golden proportion, the more attractive

the face. However, this is not always achievable and some surgeons prefer other methods, as application of the golden proportion may result in a masculinized female face (Prendergast, 2012). A more practical approach is to keep proportions within normal aesthetic range. Proportions outside of the normal range changes the visual impact of the face, and can be very obvious when affecting the nose, lips, eyes or mouth (Farkas and Munro, 1987). Therefore, facial proportions are important in planning and assessing treatment in orthodontic practice, as well as facial analysis during perioperative assessment in surgical rejuvenation procedures of the face (Vegter and Hage, 2000; Prendergast, 2012).

Broadbent (1894 – 1977) used cephalometric radiology and standard measurements to assess growth changes in the living (Broadbent *et al*., 1975; Vegter and Hage, 2000). Although many studies focused on craniofacial morphology, Farkas published the most extensive works on the subject (Farkas and Munro, 1987; Farkas, 1994, Farkas *et al.*, 2005). These works included revision of the classic canons in terms of facial proportions and comparisons with other available data. Canons are “models” of the face with specific relationships of facial features as determined by the antique Greek sculptors. During the Renaissance, the canons were reformulated according to social expectations of beauty. This modification became known as the neoclassical canons. Due to lack of modern norms, neoclassical canon proportions were used until the 20th century (Farkas and Munro, 1987). Farkas and Munro (1987) determined that the neoclassical canons do not reflect the modern view of attractiveness and should be updated. Later papers on Africans (Porter, 2004) and Asians (Thuy *et al*., 2002) from North America were based on Farkas’ work, and showed that neoclassical canons are not applicable to modern day society.

Farkas also defined the role of anthropometry in assessing and correction of lateral facial dysplasia and the repair of cleft lip and palate (Vegter and Hage, 2000; Farkas *et al*., 2005). Farkas *et al*. (2005) compared data from 25 countries across the world to norms established previously for North American Whites. Farkas is well known for his comprehensive indices consisting of more than 100 dimensions and proportions involving adults and children since the 1980’s (Farkas and Munro, 1987; Farkas, 1994). Although his works considered White North Americans, it forms the gold standard for current and future studies for facial anthropometry and determining modern day facial canons.

2.7.2 Craniofacial indices

The fascination with human variation of physicians and natural scientists such as Camper and Blumenbach in the 18th century spurred the development of quantitative methods in physical anthropology. Direct measurements of the face proved to be problematic due to individual variations in size. Anders Retzius (1796 – 1860), a Swedish anatomist, was the first to use a craniofacial index to explain morphological variation of the skull. He introduced the cranial index, where direct measurements were converted to an index without measurement unit in order to make comparisons possible and eliminate the effect of absolute size. In 1842, he calculated the cranial index as ([maximum head width (eu-eu) / maximum head length (g-op)] x100). Several researchers followed his idea and introduced new indices related to the skull and extended measurements from bones to measurements on the surface of the body (Hajniš, 1985). Aleš Hrdlička (1869 - 1943), a Czech anthropologist, described the index as a relationship between two dimensions. He realized the advantages of indices as opposed to using absolute values when comparing different groups of individuals.

2.7.2.1 Measurements: Live measurements *vs* photoanthropometry

Taking direct measurements of the patient is known as direct anthropometry and is performed by using rulers, sliding or spreading calipers. Direct anthropometry is considered inexpensive and reliable. Farkas and Munro (1987), Farkas (1994) as well as Kolar and Salter (1997) published extensive normative facial indices databases based on the direct method. The direct method is time consuming, measurements cannot be re-taken if a mistake is suspected and the reliability of the measurements also depends on patient compliance which can be problematic, especially when measuring children (Wong *et al*., 2008). As a result of these limitations, some researchers developed alternative two-dimensional methods, namely photoanthropometry (also known as photogrammetry by some authors) and lateral cephalometry.

Both these methods involve the taking of photographs or radiographs which is then later analyzed either by hand or computerized morphometric programmes. Studies have shown several problems with taking measurements from photographs such as measurement errors which may occur due to magnification, varying subject to camera distance, variation of head position between subjects, the angle of the camera, subjective analysis, inexperienced / untrained operators, incorrect landmark identification, and parallax (Farkas *et al.*, 1980; Wong *et al*., 2008; Moreton and Morley, 2011; FISWG

guidelines v1.0, 2012). In fact, these errors may influence measurements to such an extent that the Facial Identification Scientific Working Group (FISWG) have recommended that photoanthropometry not be used when performing facial comparisons under circumstances where photographs were not taken under controlled conditions (FISWG guidelines v1.0, 2012). Despite the controversy in the field of anthropology, some clinicians make use of the method in practice. In this regard, Schaaf *et al*. (2010) compared standard anthropometric cranial measurements to measurements taken from cranial photographs found that photographic images are reliable for quantification of cranial deformities.

However, where conditions are controlled, the advantages outweigh the disadvantages as photoanthropometry provides a fast, non-invasive method for image acquisition, which is relatively low in cost and the images can be archived and re-measured if necessary (Wong *et al*., 2008). Also, the problem of live subjects not remaining still is eliminated (Grayson *et al*., 1988; Al-Omari *et al*., 2005).

In photoanthropometry, measurement errors can be reduced as absolute measurements are not used directly. The direct measurements from photographs is used to calculate facial indices which provides relative relations and although the index values may not be 100% correct, it is still useful specifically to describe facial changes in children (see section “Intrepretation of the index value” later in this chapter).

Some other troublesome aspects of photoanthropometry can be overcome to some extent by standardization of equipment and methodology. The calibration option in measurement programmes such as ImageTool and iTEM®, together with the use of a photo scale may limit measurement errors due to magnification.

Landmark identification is another problem when using photoanthropometry, although is not limited to this particular method (Farkas *et al*., 1980; Wong *et al*., 2008; Moreton and Morley, 2011). Direct anthropometry is time consuming specifically due to landmark identification problems (Wong *et al*., 2008). However, if the researcher taking the photograph in the photoanthropometry method does not notice that a landmark is obscured for example by hair, the landmark is lost and measurements pertaining to the trichion cannot be taken or recovered. Farkas (1994) conducted a study where he compared the measurement errors using the same subjects measured directly and subsequently by photoanthropometry. He concluded that some measurements involving the vertex, trichion and porion are more difficult to locate on photographs due to the presence of hair, which

may result in measurement errors. In addition, it was not possible to perform measurements which involved the contour of the face (Farkas, 1994).

Three dimensional imaging methods, such as the computer-assisted tomography and laser scanning methods have been gaining popularity as they can avoid errors of two dimensional methods (Weinberg *et al*., 2006; Wong *et al*., 2008; Wei *et al*., 2011; Medonca *et al*., 2013). Computer-assisted tomography renders poor resolution, especially regarding facial contours and due to its high cost and radiation risk, is not the first choice in prospective studies. Laser scanning, although expensive and time consuming, provides images with better resolution which aids correct landmark identification. As a result three dimensional stereo photoanthropometry has emerged as another possible method. It involves a three dimensional image being reconstructed by synchronized digital cameras at multiple angles around the subject. The expensive equipment is a disadvantage and sometimes shadows create problem areas where landmarks cannot be identified and hence some measurements cannot be performed. Currently there is no normative database for comparison of results obtained by three dimensional imaging methods. The major advantages of this method, is the instantaneous capture of the image and the ability to manipulate the image to identify the relevant landmarks and calculate measurements. Several studies found the method generally valid and reliable, with the exception of a few measurements involving the lips were landmark location was a problem (Wong *et al*., 2008).

Despite the many concerns regarding the use of photo-anthropometry, the method offers images of high quality for detailed analysis when equipment and conditions are controlled (Davis, 2012).

2.7.2.2 Calculation of indices

An index is created when the value of the numerator is related to the denominator as a percentage (Farkas, 1987; Hajniš, 1985). The calculation of the index is:

Index = [Numerator (smaller measurement) / Denominator (larger measurement)] x 100

Generally, a mean index value is usually provided by authors which is obtained from a representative number of randomly selected subjects with the same age, sex, nutritional status and ancestry. The mean index value is then often referred to as the “index”. In order to counteract the differences in individual indices, samples usually consist of a large

number of individuals per group. The standard deviation (SD) quantifies the normal differences among individuals within the same sample group (Farkas and Munro, 1987). In effect, the standard deviation of the index indicates dispersion of the variation within a group.

2.7.2.3 Interpretation of the index value

The smaller measurement is usually the numerator and divided by the denominator, which is often the larger measurement of the two. If this is the case, the value obtained from the index is less than 100. In some cases, the index value may exceed 100. In children, an index larger than 100 or indices that either increase or decrease are associated with certain ages where growth takes place. The following examples demonstrate these concepts:

Example 1: Head width – craniofacial height index (Figure 2.4)

The formula for the head width – craniofacial height index is as follows:

[Head width / craniofacial height] x 100 (Farkas and Munro, 1987)

OR

HWCHI = [(eu - eu)/(v - gn)] x 100

Where (eu - eu) = Distance between the two euryons (eu); and

(v – gn) = Distance between vertex (v) and gnathion (gn).

For a 6-year old boy (Farkas, 1994):

(eu – eu): 139 mm; (v - gn): 198 mm

HWCHI = [(eu - eu)/(v - gn)] x 100

= [139/198] x 100

= 70

For an 18-year old male (Farkas, 1994):

(eu - eu): 151 mm; (v – gn): 234 mm

FHWHW = [(eu - eu)/(v - gn)] x 100

= [151/234] x 100

= 64

In this case both distances (eu – eu; v - gn) increased, but the increase in length from the top of the cranium to the chin (v – gn) was more than the increase in head width (eu – eu). Therefore the head width – craniofacial height index decreases between the ages of 6 and 18 years, and the face becomes more elongated with age.

Example 2: Forehead - Head width index (Figure 2.5)

The formula for the forehead – head width index is as follows:

[Forehead width / head width] x 100 (Farkas and Munro, 1987)

OR

FHWHW = [(ft -ft)/(eu - eu)] x 100

Where (ft - ft) = Distance between the two frontotemporal points (ft); and

(eu - eu) = Distance between the two euryons (eu).

For a 6-year old boy (Farkas, 1994):

(ft – ft): 104 mm; (eu – eu): 139 mm

FHWHW = [(ft -ft)/(eu - eu)] x 100

= [104/139] x 100

= 74.8

For a 18-year old male (Farkas, 1994):

(ft – ft): 117 mm; (eu – eu): 151 mm

FHWHW = [(ft -ft)/(eu - eu)] x 100

= [117/151] x 100

= 77.5

In this case both distances (ft – ft; eu – eu) increased, but the forehead increased relatively more. Therefore the forehead – head width index increased, indicating that the forehead became broader/wider relative to head width.

2.7.2.4 Index types and categories

Farkas and Munro (1987) identified two types of indices: areal and interareal. Areal indices consisted of measurements or angles taken in one anatomical region. An areal index is useful in determining shape of a facial feature such as the nose. Interareal indices comprised of measurements or angles taken from two anatomical regions. An interareal index describes the relationship between two facial features, such as the nose and face.

Index categories are used to describe the shape of a feature (Martin, 1966; Krogman and Íşcan, 1986; Farkas, 1987). Traditionally these are three categories. For example, a nasal index of 55.0 – 69.9 indicates leptorrhinnea or a narrow nose; whereas index values of 70 – 84.9 indicates a medium or mesorhinneal nose and index values of 85.0 – 99.9 indicates chamaerrhinea, or a wide nose.

2.7.2.5 Normal ranges and disproportions

The mean index value represents the average proportion between measurements for a set of random individuals of comparable age, sex, ancestry and nutritional status. The standard deviation (SD) accounts for the normal variation within the sample. For craniofacial indices, the mean index value is reported ± 2 SD to indicate the range for normal variation within the sample. A mean combined with a small SD indicates a high level of homogeneity for an index, while a large SD implies large differences for that particular index. However, values within ± 2 SD are considered the range for normal variations. When the value falls outside the normal range, the relationship of the measurements and the resultant index is considered to be disproportionate for that sample. However, to determine whether the sample can be extrapolated to the population, one needs to calculate the standard error and the mean.

When the index value is larger than the upper border value of the range (mean plus 2 SD), the index is considered supernormal. Likewise, an index value smaller than the lower border of the range (mean minus 2 SD) is designated as subnormal. The extent of the disproportion is calculated as the percentage that the index value of a patient differs from the upper or lower borders of the range. The disproportion is either reported as mild (difference from range 0.1% – 2.9%), moderate (difference from range 3.0% – 9.9%) or marked (difference from range ≥ 10%) (Farkas and Munro, 1987).

For example, the forehead – head width index of 6-year old boys is 74 ± 3. Therefore, the index range (mean ± 2SD) is 68 to 80. If a boy of 6 years presents with a forehead – head width index value of 65, the difference is 4.4% (Calculated as [(subject index value / normal range)% minus 100] or in this case [(65/68 x100)-100], which is considered to be a moderate disproportion (Farkas and Munro, 1987).

Disproportions are not always obvious, for example, a forehead – head width index with a value 4.4% smaller than the norm results in the 6-year old boy having a narrow forehead in relation to his head width, but this does not necessarily result in the boy having a disproportionate head. In contrast, a 4.4% difference in a 6-year old boy's nasal index is more pronounced because the nose is smaller facial feature. As a result, the boy's nose will either be perceived as very narrow or very wide in relation to nasal height. In addition, the boy's nose may be perceived as disproportionate even though it falls within the normal range as the normal range of the nasal index is usually narrow. Therefore, a small difference from the mean may give the impression of disharmony even though the value

may fall within the range. In these cases, a difference of the index value within 1 ± SD of the mean would be more desirable.

In general, the face is considered balanced when the intercanthal (en – en) distance is the same as the width the alare (al – al). Da Vinci suggested that mouth width (ch – ch) is 1.5 times the distance between the alare (al – al). However, Farkas and Munro (1987) found the mouth width to be more than 1.5 times the nose width in 60.2% of cases and only in 20.4% of cases were the distances of equal size.

Studies on female attractiveness showed that marked differences related to the head and face which are beyond 1 ± SD of the mean, did not affect the perception of attractiveness (Farkas and Munro, 1984; Farkas, 1994). However, indices specifically related to the eyes, lips and nose of moderately attractive faces are within 1 ± SD of the mean. Evidently, statistical differences in craniofacial indices are not always practical and do not change our perception of a person's face (Farkas and Munro, 1987).

2.7.2.6 Asymmetry in the face

Facial asymmetry is often demonstrated by reconstructing a face using stereo-photoanthropometry or computer software for digital images, by reversing the halves of the face e.g., the right half of the face and rejoining it to the same normal (right) half (Burke, 1971). Asymmetry between the right and right halves of the face as well as asymmetry between the size of the paired features of the face has been commonly found in all populations (Dangerfield, 1994).

Quantitative assessment of facial asymmetry is usually made with the head in the Frankfurt horizontal plane in order to minimize errors caused by inclinations and angles. General facial asymmetry is evaluated using a vertical line that bisects the glabella, nasion, and nasal tip, Cupid's bow of the upper lip and chin. Horizontal asymmetry is measured between the vertical facial midline and the two bilateral para-axial landmarks of the face e.g., frontotemporale (ft); ectocanthion (ex); zygion (zy); alare (al); chelion (ch) and gonion (go) (Dangerfield, 1994; Farkas, 1994).

Paired measurements are considered asymmetrical when measurements of the different halves are greater than one millimeter or degrees from the mean ± 2 SD of the population as variance is already included in the range consisting of the mean ± 2 SD. The highest level of asymmetry (55%) has been found in the position of the auricles in relation to the facial midline, possibly due to the difficulty of localizing the tragion (t) on an

anterior view. On lateral view, the ears still proved to be the major source of asymmetry for the sample studied by Farkas (1994). The asymmetrical length of the ears in 22.4% of cases and asymmetrical inclination of the ears (47.5%) were the characteristics contributing to asymmetry. Burke (1971) found that the left maxillary area is generally larger than the right maxillary area.

Faces of adults and children normally display a minor degree of asymmetry (Dangerfield, 1994). Asymmetry is considered to be the result of environmental stressors such as disease, poor nutrition and physical stress (Cheong and Lo, 2011). The asymmetry in children's faces remains consistent during growth (Dangerfield, 1994). The implication is that asymmetry in a child's face will not disappear and the asymmetry will still be visible in adulthood (Dangerfield, 1994).

Asymmetry due to pathology is more prominent (Dangerfield, 1994). It is only in pathological cases that facial asymmetry is more extreme and then a quantitative assessment will be performed (Burke, 1971; Farkas, 1994).

Examples of such pathologies include: 1) Cleft lip which is due to hypoplasia of the first branchial arch creating facial asymmetry in children commonly on the left; and 2) Hemifacial microsomia which involves soft tissue and bone from the first and second pharyngeal arches. It is a progressive type of asymmetry where the mandible becomes asymmetrical due to lack of growth in the midline that results in disfiguration of the lower face as the child grows older (Burke, 1971).

2.7.2.7 Overview of anthropometric data and indices in clinical fields

In reconstructive surgery and orthodontics the surgeon and orthodontist aim to restore or create normal craniofacial features. The objective study of facial morphology relies on quantification of facial features, especially when reconstructive, cosmetic surgery or orthodontic treatment is considered. The appearance of the face is the cumulative effect of distances, inclinations and angles and which can be quantified by a numerical proportional index. Vertical, antero-posterior and transverse disproportions of the viscerocranium are reflected in the overlying soft tissue and dental occlusion. Patients with prominent overjet / overbite often relax their mandibles and / or push the mandible forward in order to mask vertical and antero-posterior discrepancies. Therefore, one of the pronounced effects of vertical discrepancies is a prognathic mandible. Additionally, teeth can cause the mandible to shift into an asymmetrical position since teeth respond to disproportionate relations between the maxilla and mandible in order to maintain dental occlusion. Therefore change

in the inclination of incisors may occur in disproportionate antero-posterior growth of the maxilla and mandible. This dental compensation can prevent repositioning of the mandible / maxilla and must be treated by dentoalveolar surgery or braces. Soft tissue changes secondary to surgery and orthodontic treatment of the underlying hard tissues are not reflected in equal ratios as the tone of the facial muscles as well as skeletal growth patterns differ from patient to patient (Farkas and Munro, 1987).

Anthropometry has proved very useful in evaluation of children with craniofacial deformities (e.g., cleft palate patients). Farkas (1984, 1994) set up a database regarding normal children and data on children on a variety of pre- and post-operative deformities. An inherent difficulty that limits the usefulness of the database is the multitude of coding systems used by different surgeons who specialize in cleft palate repair. Nonetheless, measurements of the viscerocranium affected by age-related morphological changes are clinically useful because these measurements allow pre- and postoperative assessment in growing patients.

Craniofacial anthropometry is also part of the morphometric tools used for objectively describing clinical observations, showing patterns of variation common to specific genetic syndromes and providing comparison between cases with unknown disorders to known genetic disorders. These genetic disorders include Apert syndrome and Crouzon syndrome and a variety of conditions where premature closure of cranial sutures such as unilateral coronal synostosis (anterior plagiocephaly), metopic suture synostosis (trigonocephaly) and sagittal suture synostosis (scaphocephaly) has been corrected (Posnick, 1994). It is also a useful method to describe craniofacial deformities induced by external or environmental factors e.g., fetal alcohol syndrome (FAS), fetal hydatoin effect and fetal warfarin effect (Ward, 1994).

Studies on the prevalence of FAS rely on the diagnosis of FAS using clinical and maternal history, neurocognitive evaluation and facial dysmorphology assessment (May *et al*., 200; Hoyme *et al*., 2005; Urban *et al*., 2008; May *et al*., 2010; Cherisch, *et al*., 2011). Assessment of facial dysmorphology, even for South African studies, is based on the Institute of Medicine in the United States criteria of 1996, based on a White North American sample. These criteria have been evaluated by Hoyme *et al* (2005) and they suggested modifications to accommodate paediatric patients. In 2010, May *et al*. investigated the degree in which normal facial morphology should change in order to be considered as a sign of FAS. They concluded facial features alone cannot be viewed as an indication of FAS. They suggested that facial features of a suspected FAS individual

should always be assessed with normal controls within the same population, in addition to other aspects such as maternal and clinical history and neurocognitive evaluation. It is therefore important to develop a South African dataset of population specific craniofacial measurements and indices for potential use in FAS related clinical research.

2.7.2.8 Application of anthropometric data and indices in Forensic Anthropology

Craniofacial anthropometry is used to obtain measurements either from direct measurements of a skull or living person or by photoanthropometry as a means to provide parameters for facial comparisons and facial reconstruction / approximation. In general, the proportional distances and angles between facial landmarks are calculated. In facial comparisons, it is then used to compare suspects in crime photographs and the suspects apprehended by law enforcement (Davis, 2012). Facial indices are also useful in cases of juvenile age progression. Changes in facial indices are indicative of craniofacial growth in children, and to a lesser extent ageing in adults (Farkas, 1994).

There are many problems around the methodology and legal acceptability of facial comparisons (Kleinberg *et al.* 2007; Davis, 2012). A combination of methods such as photographic video superimposition, morphological comparison analysis and photo-anthropometry is often used for analysis of similarities or differences rather than for identification as required by law (Davis, 2012). Despite limitations it is worthwhile to mention that in terms of photo-anthropometric facial comparisons, several publications have determined some facial measurements and indices to be more reliable in facial comparisons; these include horizontal face width, mouth width, nose width and interpupillary distance (Burton *et al.* 1993; Porter and Doran, 2000).

In juvenile age progression, a child's face is generally aged in accordance to developmental growth stages. For example, the eruption of permanent teeth by the age of 12, except for M3 which appears characteristically between 17 and 21 years, motives the forensic artist to elongate the lower two third of the face in the ageing of children older than 3 years (Mullins, 2012). In general, facial measurements and indices are under-utilized and as a result, juvenile age progression is currently subjective to artist forensic impression (Farkas, 1994, 1995; Taylor, 2001; Mullins, 2012).

The proportion index values can be calculated from facial measurements from an original photograph of a missing child taken at the age of 6 years. If the child were missing for 4 years, the percentage difference of the index values for a child of 10 years can be calculated. The use of percentages negates the need for calibration of the original

photograph which is often not possible. In a digital or printed photograph, measurements are taken from at least three areas: between the orbits (en – en); height of the upper lip (sn – sto) and distance between the base of the columella to the stomion (sn – sto). Farkas (1994) considers these measurements to be the minimum needed on an anterior view. The child's face can be reconstructed with the new values. The reconstruction will reflect the facial growth and a better likeness will be created. Thus, quantitative anthropometric data can be used to estimate growth of a missing child. However, there are two problems with this approach:

- Position of the head:

Very few anterior photographs, such as family snapshots or school photographs are taken with the head in the Frankfurt plane. However, if the photograph is taken at an angle, vertical midline measurements are less affected by the angle, these include sn – st; ls – li, n – sn. It is essential that the reconstructed face should be at the same angle as the photograph in order to prevent distortion of the features. The familiar angle together with the facial character of the child also assists the family in possible recognition as they would be familiar to the face details and angle of the original photograph (TM Briers personal communication, 2010).

- Incorrect identification of landmarks:

Landmark identification poses problems on different levels. The first is the accurate location of the landmark. In this regard, Gordon and Steyn (2012) matched corresponding landmarks on the skull and photographs in order to improve their success rate of their skull-photo superimposition study. Despite the fact that the landmarks were defined using fixed criteria, their success rate did not improve. The thickness of soft tissue overlying landmarks may vary also making the landmark difficult to locate exactly (Işcan and Steyn, 2013). In faces with deformities, landmarks are even more challenging to identify. For example, the subnasale (sn) or subalare (sbal) on a postoperative cleft palate patient or the endocanthion (en) on a Down's syndrome patient with epicanthal folds can be difficult to visualize. Furthermore, incorrect positioning of the head, pursing of the lips, hair obscuring the vertex (v) and euryon (eu) can result in landmark misidentification and result in measurement errors. Some landmarks are inherently difficult to establish such the frontotemporale (ft) and the tragion (t) on an anterior view when using photographs due to presence of hair (Farkas, 1994). When landmarks are to be located on 2D images, the quality of the photograph or source image (e.g., fax, e-mail, photocopy, cell phone image or selfie), possible post-image editing / enhancement, parallax, camera angle and distance

to the face and the expertise of the investigator(s) are to be considered (Ward and Jamison, 1991; Farkas, 1996; Ishii *et al.*, 2011). Oshagh (2013) has shown that enhancement of digital image quality improved landmark identification. Davis *et al.* (2010) described the use of a novel software-assisted photo-anthropometric facial landmark identification system (DigitalFace). Their findings suggest that landmark identification is problematic with an more measurement errors being likely when images were taken in conditions with low-resolution, varying distance from the camera at different viewpoints with facial features hidden. This will result in fewer measurements being useful.

In summary, accurate location of landmarks relies the knowledge and expertise of investigator(s), high-quality images and measuring tools available.

2.7.2.9 Age and sex related changes in craniofacial indices

Craniofacial indices change with age and differ with sex and population group. In practical terms it means that facial areas grow at different rates and therefore some regions develop faster at certain ages, while others seem to slow down. The changes in growth rate are seen as age-related changes in craniofacial indices.

In this regard, Thordarson *et al*. (2006) showed that maxillary prognathism increased in Icelandic boys from 6 to 16. Inclinations of the lower incisors and all cranial base measurements increased. The results of Thordarson *et al* (2006) correlate with results from Farkas and Hreczko (1994). Farkas and Hreczko (1994) addressed age related changes in linear and angular measurements of the craniofacial complex in a healthy sample of North American infants (1 year of age) (n = 18). Linear measurements included measurements of the head (eu – eu; v – n; g – po; v – gn); face (zy – zy; n – gn; sto – gn; t – sn; t – gn; go – go); orbits (en – en; ex – ex; ex – en, l; ps – pi, l); nose (al – al; n – sn; n – prn; sn – prn; ac – prn); lips and mouth (sn – sto; ch – ch; sto – sl). Angular measurement included inclinations of the forehead, nasal tip, nasal bridge, nasal labial angle, lower lip, ear axis and ear protrusion. They found that at age 1, the orbits and the eye had reached 78 - 88% of their adult size, with the nasal width and upper lip height between 80% - 82% of their adult size. Craniofacial regions with high growth in the early years of life also include head width, head height, intercanthal and bi-ocular width, eye fissure height, nasal width and upper lip height. Their results suggest that some areas grow at different ages and at different growth rates. Farkas and Hreczko (1994) argued that on an evolutionary scale these regions and facial features are essential for survival of the species and develop more rapidly than others.

In contrast, areas with slower growth had clear differences between the sexes. For example, the size of the mandible and width of the mouth in 1-year olds were on average 51% of the adult size and the nasal tip protrusion only 4% of the future adult size. These facial features, which developed slower during the first year of life, often displayed accelerated growth in early childhood, and were followed with rapid growth during adolescence. The speed of growth also varied between the sexes. For example, the width of the mouth showed rapid growth in boys between 3 and 4 years of age. However, the width of the mouth of girls moderately increased with age. The mouth width reaches adult size in girls by age 14 and by age 18 in boys (Farkas and Hreczko, 1994).

In general, angular measurements reached adult level at later stages than linear measurements, usually occurring 1 – 4 years earlier in girls than in boys. The nasolabial angle reached adult level at age 10 in girls, but only reached adult level in boys at age 13. The angle of the li – pg line and sn – pg line and vertical profile line, which both effectively involve the mandible, reached adult level at age 14 in girls and age 15 in boys. The only exceptions to this rule were the nasofrontal angle and the angle of ear protrusion which reached adult level in boys at age 6 and later in girls at age 8.

2.7.2.10 Differences in craniofacial indices related to ancestry

Researchers attempted to study the morphological, quantitative and proportional differences between different ancestral groups. The problem with information regarding the differences in craniofacial indices related to ancestry is the pretext of data collection. According to Morris (2003), most data that support differences related to ancestry were collected during a period of racial typological assessment and therefore make the results and interpretations of these studies invalid. In extreme cases, such as studies of Broca and Lombroso, this typological approach was unscientific. For example, Broca believed that intelligence and social development were determined with the cephalic index, whereas Lombroso used anthropometry to identify a “criminal type” of personality. Later research discarded the view of typology and considered environmental influences as contributing to differences between population groups (Boas, 1911; Herskovitz, 1930; Goldstein, 1936).

Kolar (1987) provides valuable insight into the proportional differences in the face in different population groups. Kolar’s sample consisted of 200 young-adult women of Anglo-Saxon, Germanic, Slavic, Latin and mixed ethnicity from North America. Of 155 indices examined, only 14 demonstrated statistically significant differences between the different ethnic groups. The difference between the groups that scored the highest and

lowest mean indices was significant, but the intermediate groups did not significantly differ from any group. In effect this means that there are groups that overlap and that the groups are not clearly separated.

The upper face – face height index ([n–sto/n-gn] x 100) will be used to demonstrate this phenomenon of overlapping of groups. Kolar (1987) found that the Germanic sample had the highest mean index value (63.4) while the Latin group had the lowest mean index value (61.3). The mean index values of the Anglo-Saxon and Slavic groups were the same (62.4). The range of the upper face – face height index for all groups was similar and showed great overlap: Latin: 56 – 66.7; Anglo-Saxon: 58.3 – 66.7; Slavic: 58.5 – 67; and Germanic: 59.3 – 67.6.

Only one index of the orbits (bi-ocular width / face width) was significantly different between groups (ANOVA, $p < 0.05$). Indices related to the nasal tip protrusion also showed significant differences between groups (ANOVA, $p < 0.05$). Indices involving the width and height of the head and face as well as the width of the mandible were statistically significant different between groups (ANOVA, $p < 0.05$). These indices included the cephalic index, calvarium head – face height index, forehead – face width index, skull base width – lower 1/3rd face depth, upper face – face height index, mandibulo – upper face height, mandibulo – face width index and face – skull base width index. The study may be limited by the scope of the sample which includes only women.

Several studies have attempted to shed light on differences in craniofacial morphology and ancestry (e.g., Everekliogl*u et al*., 2002; Ward, *et al.*, 2000; Thordarson *et a.*, 2006). Everekliogl*u et al.* (2002) demonstrated anthropometric variation of indices in a Turkish population for age, sex and population group. They found that intercanthal distance (en – en) for children was lower when compared to a mixed European (Waardenberg, 1951) and Black population (Murphy, 1990).

Thordarson *et al*. (2006) compared a sample of Icelandic children to a similar Norwegian sample and noted small differences in maxillary prognathism, mandibular plane angle and the inclination of the maxilla. Larger differences between the populations were noted regarding the inclination of the lower incisors.

In summary, differences in craniofacial indices related to ancestry are difficult to study even in ideal situations, as age, sex, nutrition and health status play a significant role in craniofacial morphology. However, the majority of studies which compared craniofacial dimensions between populations seem to find both similarities and differences within and

across populations. This means that variation within populations can be substantial. A major contributing factor mentioned by Little *et al*. (2006) is change in diet from coarse to more refined foods. As populations have different food traditions and preferences, it follows that cultural differences may also affect craniofacial dimensions.

2.7.3 Craniofacial growth

Authors do not agree about the exact onset of different growth phases (Bogin, 1999; Tanner, 1999; Bogin, 2009). Bogin's (1999) description of growth events are significant for this study as it provides a clear guideline for analysis of differential craniofacial growth of different age groups used in this study.

In general, Bogin (1999) and Black and Maat (2010) describe growth events in the stages of the human life cycle and categorize "childhood" as ages 3 to 7, and the "juvenile" phase as ages 7 to 10 for girls and 7 to 12 for boys. "Puberty" occurs at the end of the juvenile stage which means that the puberty phase for girls starts at age ± 10/11 and ±12/13 for boys. Puberty is said to be an event of short duration (weeks), but characterized by maximum differentiation between sexes (Bogin, 1999; Black and Maat, 2010). The adolescent growth spurt starts at age 10/11 for girls and 12/13 for boys and involves an increase in height and other physiological and psychological changes that have been well-described (Bogin, 1999).

The association between growth and dental development is well known (Bogin, 1999). Smith (1992) found a link between the eruption of M1 and weight of the brain. They established that the large size of the brain predicts a late M1 eruption in humans (around the age of 6). The replacement of deciduous teeth with permanent teeth (including M1) starts well before 10 years of age and continues until closure of the root apices of M3 between the ages of 18 and 25 (Taylor and Benkin, 2010). According to Bogin (2009), adolescence includes a post pubertal growth. Adolescence for girls ranges between 10 and 18 years and 12 to 21 years for boys (Bogin, 1999; Black and Maat, 2010). These age ranges are generalized as growth and growth spurts may vary significantly between children from different geographical regions due to a variety of reasons e.g., nutrition, SES, altitude and climate (Bogin, 1999). For example, Gillet (1998) and Olze *et al*. (2007) determined that tooth eruption in children from African descent takes place earlier compared to (White) American, Asian, Japanese and German counterparts. This was an unexpected outcome as the low SES of the African children was expected to result in delay

in growth and dental development. In addition, tooth emergence was also faster in African children compared to African American children. One explanation offered was the poor health status of the African children caused early loss of deciduous teeth and subsequent replacement by permanent teeth that presented as “early” tooth emergence. The implications for craniofacial growth are as follows:

- Clear sex differences in the craniofacial complex should be expected from the age of 10 (Bogin, 1999; Black and Maat, 2010);
- Sex differences will become pronounced between girls and boys between the ages of 12 and 14 (Bogin, 1999; Black and Maat, 2010); and
- The eruption of M1and M2 between the ages of ± 6 and ± 12 result in large changes in the craniofacial complex, which coincides with age range of the children in this study (Smith and Garn, 1987; Humphrey, 1998).

Johnston and Zimmer (1989) and Tanner (1999) reported differences in growth for different types of tissue and different body parts. The postnatal growth of the viscerocranium follows a somatic curve, while the neurocranium follows a neural curve. In this context, the neural curve refers to the growth rate of the nervous system and cranium. The somatic curve refers to the growth of the face which is similar to the growth of other tissues. The neurocranium initially grows faster prenatally and in early childhood, but slows down at age 7 although changes still occur until adulthood. Growth of the neurocranium takes place at the sutures. At the sagittal suture, growth leads to an increased width of the cranium, while growth at the temporoparietal suture results in an increased height (Bogin, 1999).

The growth of the viscerocranium is slower than the neurocranium after birth, but its growth rate increases from age 10 to 21. This results in an overall 1:8 growth rate ratio for neurocranium:viscerocranium. Growth of the viscerocranium is seen as a change in the facial height, width and depth. The orbit follows a neural growth curve as it accommodates the eye, which is an extension of the brain. The eye is fully developed to adult size at adolescence. During adolescence an increase in facial height and depth of the face is observed and is confined to the suborbital region, which effects shape changes in the middle to lower face and mandible (Johnston and Zimmer, 1989; Bogin, 1999; Tanner 1999).

In terms of facial growth, the childhood phase is characterized by a general moderate growth rate with a mid-growth spurt (although only occurring in some children) (Tanner, 1999); eruption of the first permanent molar and incisors (Bogin, 1999; Smith and Garn,

1987) and, at the end of this growth stage, a cessation of brain growth (Bogin, 1999). In terms of growth, the juvenile phase has a slower growth rate whereas puberty is characterized by the reactivation of the central nervous system which affects sexual development more than growth (Bogin, 1999).

Upper and middle face changes, in the vertical and sagittal planes, are also due to growth at the sutures. Changes of the facial bones around the erupting teeth play an important role in the lengthwise development of the lower face region, as the alveolar processes are orientated at an angle in the direction of growth (van der Linden, 1986). The eruption of M1 and M2 also changes the craniofacial complex of the middle and lower face regions significantly (Humphreys, 1987; Smith and Garn, 1989).

Broadbent *et al.* (1975) have shown that the craniofacial region of boys continues to grow for a longer period than those of girls. Differences are most apparent in size and shape, which they have ascribed to an increase in the supraorbital ridges, prominence of the nose and chin, and the complete eruption of the permanent incisors.

According to Farkas and Posnick (1992), 10 year old females and 14 year old males have head heights that are equal to adult size. Head height has reached adult size at age 13 for both sexes, and head width equals adult size at age 14 and 15 in females and males, respectively.

Thordarson *et al*. (2006) found differences in size between boys aged 6 and 15/16 in the lower face regions. The degree of maxillary prognathism was shown to increase with age in boys but not in girls. Everekliogl*u et al.* (2002), in a study on craniofacial anthropometry of living children, found that orbital and fronto-occipital measurements increased with age when comparing age ranges of 7 to 9, 10 to 12 and 13 to15. The measurements were also generally larger in males than in females.

Population-specific characteristics are not very apparent in childhood, but obviously develop sometime during growth (childhood, juvenile, puberty). Earlier research papers indicated that craniofacial changes could be used as an indicator of ancestry (Goldstein, 1936; Hauschild, 1937; Tobias, 1958), although St Hoyme and İşcan (1989) stated that differences may not be apparent until adolescence. Steyn and Henneberg (1997) demonstrated that cranial width was a good indicator of population affinity after the age of 5 years. Cranial dimensions are often the part of a larger research focus such as the changes in the craniofacial skeleton over time i.e. secular trends of specific populations (van der Linden, 1986; Steyn and Henneberg, 1996; Steyn, 1997; Everklioglu *et al.*, 2006; Little *et al*., 2006).

2.7.4 Potential problems in growth studies and facial growth studies

Questions regarding the impact of secular trends and the phase at which sex and population specific differences impact on facial growth are difficult to answer. The ideal method to assess facial growth would be to conduct a longitudinal study in order to follow a large group of children over a period of ±15 years. One of the problems in a longitudinal is attrition. Therefore these type of studies need to have a large enough sample to accommodate participant fall-out due to death or migration (Farkas, 1995; Richter *et al*., 2007). In the case of the Birth-to-Twenty study, a 20-year longitudinal South African study involving 78% Black, 6% White, 12% Coloured and 4 % Indian children born in 1990, the attrition was 44% of the original cohort (Richter *et al*., 2007). Adequate tracking mechanisms to follow participants from primary school to high school or migration from one school or area to another is therefore essential in longitudinal studies, as well as incentives for participants to remain part of the study over a long period of time. Due to logistic difficulties and long time needed to collect publishable data from longitudinal studies, cross-sectional studies are conducted more often.

Cross-sectional growth studies can be performed on large scale, in a short time period, data on all variables can be collected once and with little cost to the researchers. It provides a useful base-line assessment as it describes observations at a specific point in time and for specific purpose. There is almost no fall-out of participants compared to longitudinal studies. However, it should be remembered that cross-sectional studies indicate prevalence and not incidence because it does not describe the sequence of events, i.e. cause and effect cannot be determined from cross sectional studies. Other main disadvantages include selection and measurement bias and bias due to low response rates which threatens reliability and validity. However, these threats may be overcome by strict adherence to procedures and data collection (Farkas, 1995; Dawson and Trap, 2004).

2.8 Geometric morphometrics

Human variation can be studied by considering size and shape. Size is easy to measure, but shape is problematic as it is more difficult to quantify. Early studies used indices to study shape, but advances in technology and statistical models such as geometric morphometrics, enabled researchers to also quantify shape and to perform comparisons between groups.

Initial methods of shape analysis by Boas (1905) and Sneath (1967) were based on geometry, but did not generate a lot of interest. It was Bookstein (1978, 1982) who pioneered the biological application of geometric morphometrics (Richtsmeier *et al*., 2002). Development of several programs such as TPS (Rohlf, 2003), Integrated Morphometrics Package or IMP (Sheets, 2001), the Edgewarp series and VECTOR provided statistical tools and imagery to aid the understanding of shape, which greatly improved the usability and application of geometric morphometrics in human biology**.**

2.8.1 Development and biological application

Geometric morphometrics (landmark or outlined-based) distinguishes the shape of an object from the form of an object. The shape is without scale and is recorded as landmarks that are translated into coordinates (Hennesey, 2001). The coordinates provide geometric information that can be analysed in a variety of ways (Richtsmeier *et al*., 2002). The differences between shapes can be studied using several methods that are broadly classified into three categories: superimposition, deformation and distance-based methods.

Superimposition involves the arrangement of landmark data from two shapes in the same coordinate space, one shape known as the reference shape and the other as the target shape (Rohlf and Slice, 1990; Slice, 1996; Richtsmeier, 2002). The displacement of the landmarks in the target shape to the corresponding landmarks in the reference shape is the change in shape (Adams *et. al*., 2004). Procrustean approaches and Bookstein's edge matching are examples of superimposition techniques. Rotation, translation and scaling of shapes are removed by superimposition as these aspects are incorporated into the definition of the shapes as well as the differences between the shapes for any particular analysis. Therefore the parameters are arbitrarily fixed and then ignored during the superimposition process (Richtsmeier, 2002). Superimposition consists of three steps: fixation of the reference object; translation of other shapes to match the reference object based on specific criteria; and analysis of the magnitude and direction of the difference (vector) between the shapes at each landmark (Richtsmeier, 2002). On a mathematical level, superimposition adopts a coordinate system and the differences between the reference shape and the target shape is then graphically demonstrated (Adams *et al*., 2004). A major disadvantage of the superimposition method is that conclusions drawn from superimpositions are the result of chosen criteria that may not correspond with data. The advantage of superimposition is the clear way in which shape differences are graphically illustrated as absolute landmark displacement (Richtsmeier, 2002).

Deformation is another morphometric method used to study shape differences. In this method the area or volume of the reference shape is deformed so that it corresponds with the target shape. The deformation method includes thin plate splines and finite element analysis (Thompson, 1992; Adams *et al.*, 2004).

Thin plate splines map the relative location of landmarks and points between landmarks in the initial configuration to their exact corresponding locations on the target shape. Bending energy is used to predict the location of points between landmarks in the initial shape and the target shape (Bookstein, 1991). The disadvantage of thin plate splines is that the mapping of points from the initial configuration to the final configuration depends on the interpolation function between two sets of coordinate systems. The mapping of points between the landmarks depends on the nature of the interpolation function. Therefore, any change in the function will result in a change in the bending energy and graphic representation of the thin plate spline even though the comparison remains the same (Richtsmeier, 2002). Again, the advantage of the method is the informative graphics in which the results of the comparison are displayed as well as the accessibility of free software programmes on the internet.

Finite-element scaling analysis was initially used in engineering. This method involves the subdivision of landmarks on an object into groups that form elements. A homology function is then used to map the location of landmarks from the initial shape to the target shape. This method differs essentially from other methods as it maps all the mathematically homologous points that are internal to each finite element in the initial shape to a corresponding location on the target shape. The disadvantage of the finite-element scaling analysis is that the method is a generalization and has to adapt to model properties of the object (Rohlf, 1999; Richtsmeier, 2002).

Linear distance-based methods compare linear distances and not landmark coordinate data. In this method, the landmark coordinate matrix is rewritten as linear distances between the pairs of landmarks. A mean shape matrix is then estimated which is robust against translation, rotation and reflection. Each linear distance is then compared to the corresponding linear distance in another shape. Information regarding the difference in length of the linear distances is analysed to determine the absolute difference. The matrix of the linear distance comparisons is analysed to determine the difference in shape. Euclidean distance matrix analysis (EDMA) is an example of a linear distance-based method (Lele and Richtsmeier, 1991). Linear distance-based methods do not require superimposition or adoption of arbitrary rules such as the adherence to minimum bending

energy. A major advantage of the linear distance-based method is that the shape matrix does not change regardless of the location or orientation of the shape in space. The one disadvantage is that the graphic display of the results is not as attractive as other methods. However, Richtsmeier (2002) argues that the mathematics on which a method is based should be more important than the graphic presentation thereof. He determined that the linear distance-based method conveyed valid representations of the change in shape as opposed to other methods that have to make one or more priori assumptions which would influence the display of the results.

2.8.2 Application in forensic anthropology

The characterization of human variability is an old problem. The increasing number of publications using geometric morphometrics in anthropological research to study variability indicates that the method provides useful information regarding shape differences (e.g., O'Higgins and Dryden, 1993; Lynch, 1996; Hennessey *et al*., 1997; Penin and Baylac, 1999; Ross *et al*., 1999; Guy *et al*., 2003; Hennessey and Moss, 2001; Steyn *et al.*, 2004; Oettlé *et al.*, 2005; Pretorius *et al*., 2006; Oettlé *et al*., 2009; Scholtz *et al*., 2010).

Two-dimensional methods such as photographs and radiographs have long been used to study facial shape. Disadvantages include possible magnification errors and inability to capture depth (three-dimensional data) (Bugaighis *et al*., 2010). However, it is easy to keep electronic copies of the photographs and radiographs should any measurement have to be checked. With the advancement of technology, methods of data capturing for shape analysis also improved. It became possible to capture the three-dimensional facial shape accurately and to perform complex statistical calculations in order to obtain more information on shape and shape variation (Ross and Ubelaker, 2009; Bugaighis *et al*., 2010). Three-dimensional methods allow the assessment of differences between groups and the consideration of complexities of asymmetry which is beyond the scope of direct linear measurements on living individuals, the latter a method favoured by Farkas and Munro (1987), Farkas (1994) and Kolar and Salter (1996). More complex characteristics such as fluctuating asymmetry, abnormal growth patterns and specific facial regions that display sexual dimorphism were identified by three-dimensional methods (Claes *et al*., 2011, 2012).

Equipment needed for two-dimensional shape analysis would consist of a X-ray machine or camera and computer with software such as TPS (Rohlf, 2002, 2003), IMP

(Sheets, 2002), MorphoJ (Klingenberg, 2011) or Morphologika (O'Higgins, 2010). Equipment for three-dimensional shape analysis would, for example, require a Microscribe-3DX digitizer or laser scanner (fixed or handheld) (Moss, 2006) and computer with programmes such as MorphoJ (Klingenberg, 2011), Morpheus (Slice, 1998) and ThreeSkull (Ousley, 2004). The Microscribe and laser scanners are expensive while cameras and X-ray equipment are less expensive and are more readily available. Alternatively, data from CT scans are also a popular and less expensive source for three-dimensional data as it provides clear distinction between bone and soft tissue. Improvement of the quality of images obtained by CT scanners and MR machines will provide a broader base for three-dimensional data capturing.

Originally, Mitteröcker and Gunz (2002) described an extension of the sliding landmark method for three-dimensional surfaces. In brief, this method allows compact sampling of three-dimensional points using a standard digitizer and digitizing software. The points are then assigned to a surface mesh that triangulates the points. The advantage is that not only can the method be used on three dimensional objects such as the skull, imaging modalities such as CT scans and MRI can also be used to produce the surface mesh. A representative specimen is chosen and the mesh is statistically cleaned, but still contains the necessary information. The other specimens are then splined onto the reference, allowing the homologous points to slide in a tangential plane to the reference surface while retaining their difference in direction. The dataset is then statistically analyzed (Adams *et al*., 2004). In effect, the method allows for landmark coordinates are directly scaled and aligned for three-dimensional images as opposed to traditional analysis of distances between landmarks for two-dimensional analysis (Moss, 2006). The statistical methods used in the two methods are the similar with the added feature of the mean shape of the sample presented as a three-dimensional graphic (Moss, 2006).

The quantification of size and determination of shape variation by geometric morphometrics offer opportunities for craniofacial growth studies and sub-adult age estimation. O'Higgins and Jones (1998) used geometric morphometrics to describe craniofacial growth in one of the Old World monkey species, *Sooty mangabee*. In 2001, Hennessy and Moss (2001) published a paper that used the three-dimensional method to describe facial growth in three subjects at different ages. Buck and Vidarsdottir (2004) used geometric morphometrics to determine ancestry from sub-adult mandibles. Braga *et al*. (2007) used CT scans of 127 children to construct two three-dimensional landmark configurations, also known as wire frames. They were able use the centroid size of the

facial skeleton as an age-related with a standard error lower or equal to 2.1 years. Franklin *et al*. (2007) was able to predict age in 79 sub-adult mandibles with error rates between ±1.3 and ±3.0 years after 38 bilateral three-dimensional landmarks were acquired using a portable digitizer. Hutchinson *et al*. (2014) used geometric morphometrics to demonstrate that the mandible continues to change in shape and size until the age of 3, while the shape of the tongue remained the same, but increased in size.

Three-dimensional methods are gaining popularity, however accessibility to expensive equipment limits the use of this method. In addition, the use of living subjects, especially children, is problematic as it required them to remain still while being scanned.

Two-dimensional methods are still able to provide adequate information on shape variation (Ross and Williams, 2010). In terms of the current study, two-dimensional geometric morphometrics were used due to time and logistical constraints.

2.8.3 Pitfalls

The advancement of technology such as laptops or desktops that performs at high speed despite massive amounts of data and the development of free and easy-to-use morphometrics software, enables users at any level to perform complicated analyses and statistics without understanding the underlying mathematics. Obviously, lack of understanding the logical basis of geometric morphometrics has profound implications in the interpretation of results (Richtsmeier, 2002; Adams *et al*. 2004). Another pitfall often encountered is orientation. Orientation is necessary for morphometric analysis because it influences the estimation of the mean and variance. When an object undergoes rotation, that is the movement of the object around an axis, its orientation changes. In effect, the relative location of the landmarks on the rotated object remains the same, but the exact coordinates of the landmarks change. Mathematically, rotation of an object multiplies the landmark coordinate matrix making the rotated object unsuitable for comparison. Therefore, objects to be compared should always orientated in the same way (Richtsmeier, 2002; Moss, 2006).

Methodology is another problem in landmarks analysis, since there are many methods available to execute shape comparison. The statistical model adopted in any study is an important choice in the analysis of the data. Often, the statistical model is inherently part of the software program used by the researcher who only has access to the analysis result and not how the landmark data were used. Therefore, the user is unaware of the true implications of the selected model for analysis. A specification model, that attempts to

characterize dimensions, properties or interactions, should be understood and specified followed by choosing an appropriate method for estimating parameters and analysis of the model. The analysis should also consider the accuracy of the method and the validity of the model (Richtsmeier, 2002).

Landmarks are used in two-dimensional and three-dimensional geometric morphometric methods to generate coordinates. Landmarks provide information within the geometric outline, but cannot propose information on variation of shape in the areas between the selected landmarks (Webster and Sheets, 2010). There are different types of landmarks: Type 1 landmarks show the intersection of tissues; type 2 indicates the points of extremity of maximum curvatures; and type 3 specifies the points of inflection (Hennessy and Moss, 2001). Ideally landmarks should be homologous, meaning that they should be defined and correspond on different objects (Zelditch *et al*., 2004; Webster and Sheets, 2010). In biological samples such as the skull vault, there are very few specific landmarks. In this case additional landmarks are defined by relative location.

There are 2 subtypes of landmarks indicating relative position: 1) Semi-landmarks and 2) pseudo-landmarks (Anderson *et al*., 2001). Semi-landmarks are defined relative to other landmarks e.g., halfway between the homologous landmarks, for example between the vertex and inion. Pseudo-landmarks are defined by relative location e.g., at the lowest point of the curved outline between point X and point Y. The sliding semi-landmark method was suggested by Bookstein *et al*. (1997) to accommodate curved surfaces and outlines. The sliding of landmarks occurs along a tangential direction resulting in homologous contours and not homologous landmarks. Perez *et al*. (2006) showed that the way in which sliding semi-landmark data is analysed renders different results in small and large samples. Another way to solve the problem of curved lines in biological shapes is the use of quasi-landmarks. These landmarks are a spatially-dense set of landmarks that maps a predefined template (Claes *et al.*, 2012). It creates an anthropological mask which is fitted for individuals of the sample and the variances are then noted. This method is very complex and requires sophisticated equipment and mathematical models. Differences due to facial expression cannot yet be accommodated by this method (Claes *et al*., 2011).

Repeatability is a concern in the biological application of geometric morphometrics. Observer-induced landmark variation due to imprecise location of landmarks during the digitizing process and landmarks that are not easily identifiable such as semi-landmarks and pseudo-landmarks are sources of potential error. Currently a generalised least square algorithm is used which distributes the landmark error and

variation equally at all landmarks. Chapman (1990) and Webster and Sheets (2010) described this phenomenon as the "Pinocchio effect". Currently no clear-cut method is available to assess landmark precision (von Cramon-Taubadel *et al*., 2007; Claes 2011). Claes *et al*. (2011) have suggested a modified partial Procrustes superimposition of landmark configurations.

2.9 South African studies on growth and SES

The following discussion on South African studies demonstrates the interrelationship of growth and SES.

2.9.1 Growth

South Africa is a developing country in transition due to its fast pace of socio-economic change and urbanization (World Bank, 1998; Vorster *et al*. 2005). Populations in other countries in similar phases of development have shown secular increases in stature and an earlier age for onset of menarche. These changes have been ascribed to increased access to food resources, better healthcare, improved socio-economic status and urbanization (Garn 1987; Bogin 1999). Increased growth rates in females have been correlated with an earlier onset of menarche (Marshall and Tanner 1969, 1970; Marshall 1974). The lack of a similar marker in boys often results in difficulty when assessing and providing scientific evidence for secular trends.

Skeletal maturity can be used as a biological indicator growth, but it is under-utilized due to the lack of similar methods used in older and new studies on secular trends (Hawley *et al*., 2009). Despite the lack of comparable data, Hawley *et al*. (2009) found two previous studies that evaluated skeletal maturity of children aged 9 – 11 years in urban parts of Gauteng (n = 603). They obtained data gathered by the Pretoria National Nutrition Survey (PNNS) from 1962 to 1965, as well as data from the Birth-to-Twenty study in Soweto of children born between 1990 and 2001. Hawley *et al*. (2009) found that skeletal maturity of White males and females in 2001 occurred 3.4 months earlier in boys and 2.0 months earlier in girls than in 1962. However, Black males and Black females reached skeletal maturity significantly earlier (9.7 months and 15.8 months for boys and girls respectively) in 2001 as opposed to 1962. The Black urban children also increased significantly in stature and weight. An increase in fat mass has been shown to contribute to advances in skeletal maturity (Beunen *et al*. 1982; Malina *et al*. 2004). A significant

improvement in lifestyle in the SES of the Black urban population in Gauteng is offered to explain the magnitude of secular increase in skeletal maturity in the Black population.

2.9.2 Growth and SES

Henneberg and Louw (1998) conducted a longitudinal growth study of South African children between 1987 and 1994. They specifically analysed growth and maturation of urban and rural "Cape Coloured" boys aged 6 to 19 years from Cape Town (designated as "urban") and the Little Karoo area (designated as "rural") in South Africa (n = 600) and took SES into account. They found that SES was negligible in terms of child growth in urban areas. In contrast, they found that children (of high and low SES) from the rural region were not as tall and were not as "fat" as children of the same SES in the urban area. Henneberg and Louw (1998) concluded that the immediate environment, such as more readily availability of food in urban areas and low food supply in rural areas, disease patterns and physical activity influenced the growth of "Cape Coloured" boys. Similarly, Kimani-Murage *et al.* (2010) found a high incidence of poor nutrition of boys between 9 and 12 years of age in a Black rural community from the Agincourt district, Mpumalanga Province, South Africa. The area is geographically isolated and has limited food resources as household plots are too small to cultivate enough food to sustain a family. Therefore people of the Agincourt district rely on purchased food, but due to the low SES of the community only low quality food was purchased and resulted in under nutrition.

Several authors have concluded that the prevalence of under nutrition in boys in rural areas delayed the normal pubertal growth spurt when compared to their counterparts in urban areas (Cameron, 1993; Henneberg and Louw, 1998; Sedlemeyer, 2002; Kimani-Murage *et al.* 2010). This delayed maturation should be taken into account in any growth study, also when it comes to facial growth.

In addition, Kimani-Murage *et al.* (2010) found that growth of 20% of children aged between 1 and 4 years was stunted due to poor nutrition and disease. The stunting of growth during infancy and early childhood followed by an increase in weight and BMI in later years due to poor nutrition were also noted by researchers using the cohort of the extensive Birth-to-Twenty study involving children born in 1990 in the Soweto-Johannesburg area (Cameron and Demearth, 2002; Cameron, 2007; Jones *et al.*, 2008; Willey *et al.*, 2009). These findings regarding growth stunting followed by obesity have been confirmed by similar trends seen in other communities described by Monyeki *et al.*

(2008) (Ellisras Longitudinal study in Limpopo Province) and Kimani-Murage *et al.* (2010) (Agincourt district, Mpumalanga Province).

Table 2.1: Number of actual cases of crimes against children younger than 18 years 2006/2007 – 2012/2013 (SAPS annual report 2012/2013)

Province	2006 / 2007	2007 / 2008	2008 / 2009	2009 / 2010	2010 / 2011	2011 / 2012	2012 / 2013
Eastern Cape	430	382	358	356	346	268	264
Free State	370	420	404	450	347	343	311
Gauteng	1144	1035	1000	1057	973	787	723
KwaZulu-Natal	467	448	490	455	372	302	306
Limpopo	269	232	235	218	245	242	239
Mpumalanga	203	166	170	164	139	140	118
North West	221	213	281	270	256	232	218
Northern Cape	240	232	213	197	128	93	103
Western Cape	914	978	883	847	667	542	476
Total	**4258**	**4106**	**4034**	**4014**	**3473**	**2949**	**2758**

Table 2.2: Number of cases of crime committed against children 6 to 17 years of age (SAPS annual report, 2008/2009)

Crime category	Age group											
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Murder	12	8	12	9	9	5	14	24	33	77	152	234
Attempted murder	13	10	13	16	11	17	23	30	44	97	162	207
All sexual offences	656	684	744	688	804	815	1164	1781	2429	2683	2727	2549
Common assault	123	176	243	326	356	483	677	973	1515	2208	3100	3855
*GBH Assault	88	121	143	210	222	255*	376	571	1035	1767	2925	4114
TOTAL	**892**	**999**	**1155**	**1249**	**1402**	**1575**	**2254**	**3379**	**5056**	**6832**	**9066**	**10959**

*GBH: Grievous Bodily Harm

Table 2.3: Percentage increase from 2008 to 2009 of crimes committed against children (aged 6 to 17 years) (SAPS annual report, 2008/2009)

Crime category	Age group											
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Murder	1.4	0.9	1.4	1.1	1.1	0.6	1.7	2.8	3.9	9.1	18.0	27.8
Attempted murder	1.7	1.3	1.7	2.0	1.4	2.2	2.9	3.8	5.6	12.4	20.7	26.5
All sexual offences	3.3	3.4	3.7	3.4	4.0	4.0	5.8	8.8	12.1	13.3	13.5	12.7
Common assault	0.8	1.2	1.7	2.2	2.4	3.3	4.7	6.7	10.4	15.2	21.3	26.5
*GBH Assault	0.7	1.0	1.2	1.7	1.8	2.1	3.0	4.6	8.3	14.2	23.5	33.1
Mean	**1.6**	**1.6**	**1.9**	**2.1**	**2.1**	**2.4**	**3.6**	**5.4**	**8.1**	**12.9**	**19.4**	**25.3**

*GBH: Grievous Bodily Harm

Table 2.4: Percentage child abduction murders per age (US report, 2006)

Victim's age group	%
1 - 5 years	10.1
6 - 9 years	21.5
10 - 12 years	20.7
13 - 15 years	25.5
16 - 17 years	22.2
Total	**100**

Table 2.5: Summary of adult South African tissue thickness data and North American tissue thickness data

Landmark	[a]SA Black Males	[b]SA Black Females	[c]SA Coloured Males	[c]SA Coloured Females	[d]US Black Males	[d]US Black Females	[d] US White Males	[d] US White Females
Supraglabella	5.21	4.70	5.36	4.88	4.75	4.50	4.25	3.50
Glabella	5.76	6.30	5.47	5.64	6.25	6.25	5.50	4.70
Nasion	7.03	6.00	4.00	4.68	6.00	5.75	6.50	5.50
End nasal	3.08	2.70	2.88	2.78	3.75	3.75	3.00	2.75
Midphiltrum	12.10	10.30	12.25	10.13	12.25	11.25	10.00	8.50
Mid upper lip margin	14.61	13.30	13.16	13.63	14.00	13.00	9.75	9.00
Lower lip margin	16.38	14.70	10.48	12.45	15.11	15.50	11.00	10.00
Supramentale	12.87	12.20	12.02	11.70	12.00	12.00	10.75	9.50
Pogonion	11.66	10.60	8.94	9.57	12.25	12.25	11.75	10.00
Under chin	7.26	6.70	6.61	6.47	8.00	7.50	7.25	5.73

[a] Aulsebrook et al. (1996)
[b] Cavanagh and Steyn (2011)
[c] Philips and Smuts (1996)
[d] Rhine and Campbell (1980)

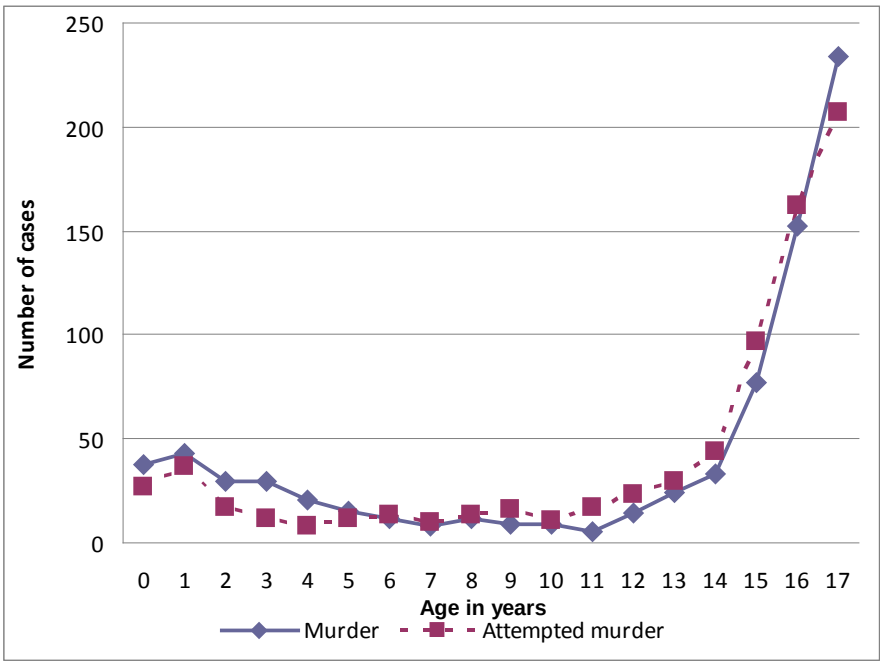

Figure 2.1: Number of cases recorded for murder and attempted murder against children under the age of 18 years during 2008/9 based on data from the SAPS annual report, 2008/2009.

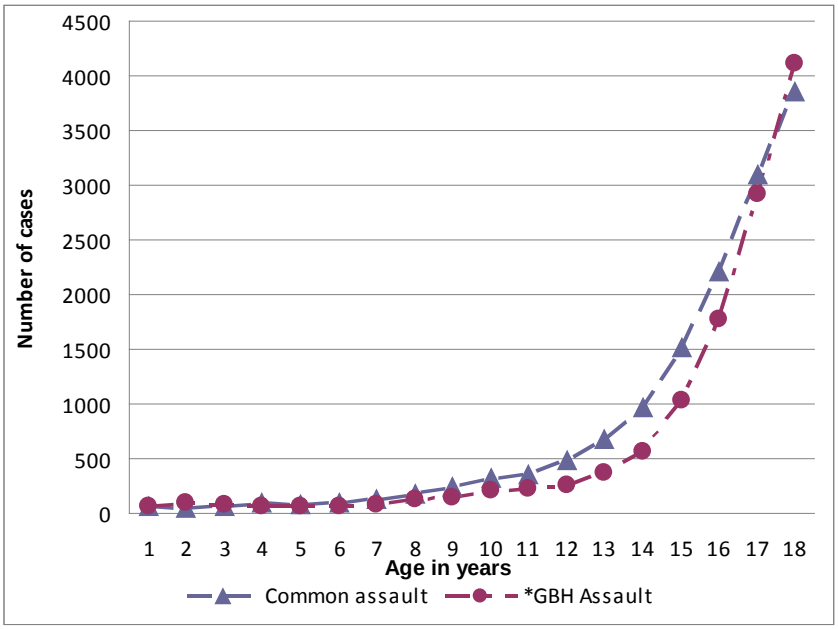

Figure 2.2: Number of cases recorded for common assault and assault to cause grievious bodily harm (*GBH) against children under the age of 18 years during 2008/9 based on data from the SAPS annual report, 2008/2009.

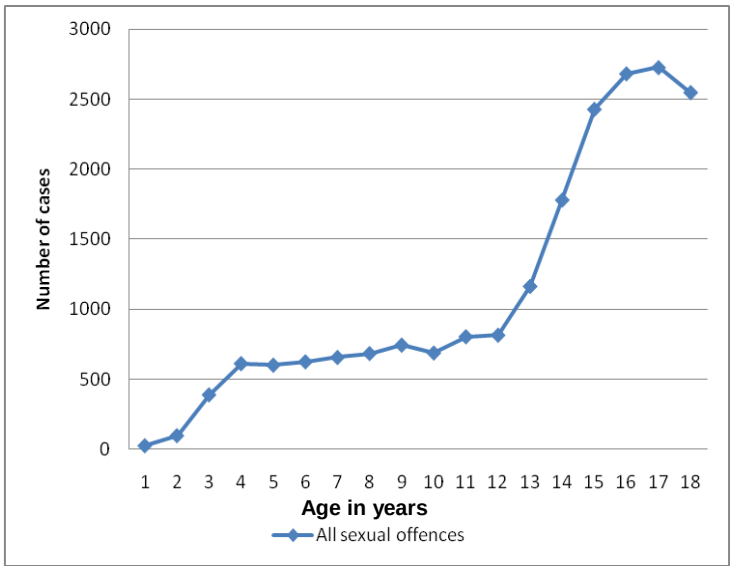

Figure 2.3: Number of cases recorded for all sexual offences against children under the age of 18 years during 2008/9 based on data from the SAPS annual report, 2008/2009.

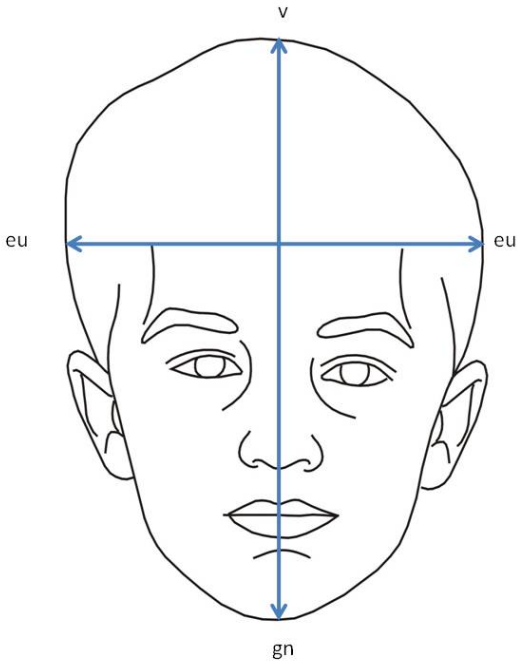

Figure 2.4: Schematic presentation of the measurements and formula for example 1, the head width – craniofacial height index: [(eu - eu)/(v - gn)] x 100

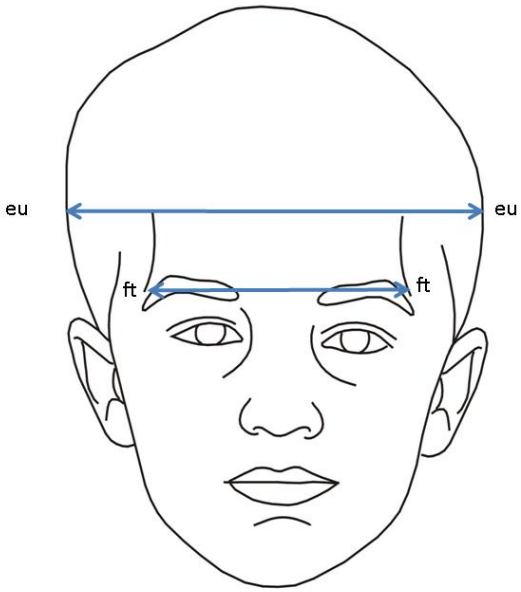

Figure 2.5: Schematic presentation of the measurements and formula for example 2, the forehead – head width index: [(ft -ft)/(eu - eu)] x 100

Chapter 3: Materials and Methods

3.1. Materials

For this study, a cross-sectional, descriptive study design was used, in order to collect data from children of different ancestry (African/Black and Coloured). Although a variety of different techniques and methods are available for measurement of tissue thickness and facial dimensions, this study made use of cephalograms (a type of lateral radiograph) for measuring midline facial tissue thickness and facial photographs (anterior and lateral view) for anthropometry and calculation of indices. The motivation for each choice will be discussed at the appropriate sections. In addition, the changes in craniofacial morphology at different age levels were assessed using geometric morphometrics, also using facial photographs.

3.1.1. Sampling rationale

The communities where the children were sampled from were selected based on three criteria:

- Relethford's geographical cluster axiom (Relethford, 2009) which was developed from work by Sforza-Cavelli (1994) and Liebermann and Kirk (2004);
- Communities most affected from crime that involved children; and
- Compliance of communities and schools.

Relethford's (2009) axiom dictates that geographical clusters express the correlation between genetics and geography and that the geographical distances between clusters should exceed the geographical distance within a cluster. In practical terms, schools within the Western Cape and Gauteng provinces were identified to participate in the project as the geographical distance between these two provinces is 1200 km. As described in Chapter 2, the Coloured people in the Western Cape are descendants of the Khoesan, Malaysian slaves brought in by the Dutch, local African people, while the Black people in Gauteng are descendants of the people who migrated and dispersed from the northern parts of Africa.

Furthermore, the SAPS annual crime statistics of the last 5 years have shown that the greatest frequency of cases regarding neglect and ill treatment of children occurred in Gauteng (26.7%) and the Western Cape (18.3%) (SAPS annual report 2011/2012; SAPS annual report 2012/2013). As separate statistics on child murder, child kidnapping or missing children are not available from the SAPS or other sources, the above-mentioned

provinces were used as they were considered to be a reflection of crime in the country. Schools in communities with low socio-economic status were targeted as children in such circumstances often tend to run away from home or become victims of crime. Children from age 6 to 13 were included in the study as SAPS statistics indicates that children below the age of 14 are more affected by social contact crime.

Thus, a need exists to develop standards for craniofacial indices and soft tissue thickness for Black and Coloured children, aged 6 to 13 years, in order to assist in presumptive identification.

3.1.2. General ethical considerations and procedures

Ethical guidelines required that permission be obtained from:

- The Oral and Dental Hospitals of the University of Pretoria and the Western Cape;
- Heads of the relevant community dentistry departments;
- Departments of Education of the Western Cape and Gauteng;
- Principals of selected schools; and
- Parents / guardians and children at selected schools.

Ethical clearance was obtained from the Main Ethics and Research Committee, Faculty of Health Science, University of Pretoria (85/2007) prior to commencement of this study. Specific ethical procedures were required when engaging directly with living children at the schools. These specific issues formed part of the procedure and will be elaborated upon in the section relating to craniofacial indices. For tissue thickness only patient images and data already on file were reviewed and captured. In terms of ethics regulations in 2008, consent were only required from the curator of the archive and not the parents / guardians or children.

3.1.3. Sample for tissue thickness

3.1.3.1. Source

Cephalograms were used to measure tissue depth thickness. After obtaining the required permission, the researcher captured these images from patient files at the Oral and Dental Hospitals in the Western Cape and Gauteng respectively.

A cephalogram, a specific type of lateral radiograph of the face that shows both the skeletal profile and soft tissue outline of dental patients, were used to measure tissue thickness. Although some researchers use ultrasound (Manhein *et al*., 2000; Wilikinson,

2002) or CT scans (Cavanagh and Steyn, 2010), both methods have disadvantages. In terms of the ultrasound, an experienced ultrasonographer or radiologist is required as well as time in order to determine tissue thickness without compression of the soft tissue overlying the bony landmark which can cause inaccurate measurements (Smith and Throckmorton, 2006; Stephan and Simpson, 2008a; Chen *et al*, 2011). Children may also not be as compliant as adults. The possibility to obtain paediatric CT scans was investigated. However, due to the relative high radiation dose, a prospective study would create ethical problems and was not deemed feasible. Retrospective CT scans of children were considered, but availability of head CT scans of paediatric patients without trauma was not available to meet sample size requirements. The cephalograms were more readily accessible by the researcher and offered the best solution due to limited time and resources available. A cephalogram is a type of lateral radiograph of the skull to visualize both skeletal and soft tissue profile. It is normally used in the field of dentistry to assess the degree of dental occlusion.

A total of 388 cephalograms from children aged 6 to 13 years of Black and Coloured ancestry were obtained from oral and dental hospitals in the Western Cape and Gauteng**.**

Experienced radiographers had taken these images using a standard position and as part of a standard patient examination. In addition to the cephalogram, the following demographic information of the participants was recorded: sex, age, ancestry, as reported on file by the child's parent or guardian, and, when available, weight and height. The exclusion criteria for this study included:

- Patients not within the specified age range;
- Images or plates with incorrect positioning of the head;
- Radiographs that were taken after orthodontic treatment; and
- Patients with any form of maxillofacial deformities such as cleft palate.

While these children are not the same individuals as the children used to determine craniofacial indices, they are of the same ancestry (Black or Coloured South Africans). No information on their SES was available and they can be assumed to represent the broader South African community.

3.1.3.2. Sample size

The sample size was constructed so that standards for tissue thickness with respect to age, sex and ancestry could be established. Dumont (1986), Manhein *et al*. (2000), Williamson (2002), Wilkinson (2002) and Utsuno (2005, 2007) used sample sizes that ranged from 112 and 551 to estimate tissue thickness in children. They observed coefficients of variation of less than 10%. Due to the large sample size of this study, a similarly small coefficient of variation was anticipated. In a pilot study of limited size, it was determined that when comparing ancestry groups, sample sizes of 23 for each sex and age category were capable of detecting fairly small differences. For example, in the pilot study, tissue thickness at the pogonion, which is the most variable of all measurable tissue thickness, had a difference of 2 mm between groups and is detectable with a 90% power using a standard deviation of 4.63 mm derived from the pilot study. Therefore, statistically, a sample size of 23 per sex-age group was determined as an adequate number.

Tissue thickness standards constituted the mean ± 1 standard deviation in the two childhood populations between the ages of 6 to 13 years and with respect to differences between the sexes. This approach was taken in order to conduct meaningful comparisons with other authors who reported their results in a similar format. In addition, tables that include the mean, standard deviation (SD) and confidence intervals are included.

3.1.4. Sample for craniofacial indices and face shape

3.1.4.1. Source

Digital photogrammetry was used to collect data, followed by measuring distances between landmarks by a measuring programme. While some researchers prefer direct anthropometric measurements (Farkas, 1987, 1994) or 3D laser technology (Wong *et al*., 2008), the cross-sectional nature of the current study dictated the methodology. Direct anthropometry is time consuming and children are not as compliant as adults. Due to the high cost of 3D scanners and 3D cameras as well the relatively long time required to scan a subject, 3D laser technology was not deemed a feasible option.

Permission to approach children via schools was obtained from the Departments of Education of the Western Cape and Gauteng. After obtaining approval from the Departments of Education in the Western Cape and Gauteng, 22 schools were contacted. Six schools had declined to participate. Three schools which had initially agreed later decided not to participate and they did not state a reason for their final decision. One school in the Western Cape suffered storm damage a week before data collection was due

to take place and as a result retracted their consent in order to repair the school. The data of one school had to be discarded as the teachers refused the request from the researcher for children to remove their shoes, despite this fact being brought to the principal's attention during initial negotiations with the school. In addition, the parents received and signed a parental/guardian consent form that explained the procedure in full, thus all role players were aware that the children were required to remove their shoes. The teachers still insisted that would be impractical and the matter was not pursued further. In summary, data from 11 schools were collected, but data from only 10 schools were entered into the database. The location of the schools is presented in Figure 3.6.

After the principals of the various schools had agreed to participate, consent forms were either couriered (Western Cape) or hand delivered (Gauteng) to these schools. In general, principals appointed a teacher or the vice-principal to coordinate the distribution and collection of forms from parents and guardians and to arrange a date and venue with the researcher. On the day of data collection, teachers brought only the children whose parents had agreed in writing in the appropriate section on the consent form to the research venue. Before entering the venue, the researcher explained the procedure to each child and then asked the child whether they would like to participate in the study. This procedure was in accordance with the ethics committee's requirement of obtaining assent from children below the age of 18. If the child indicated that they would like to participate, it was recorded on the form and the child entered the research venue. If the child did not want to participate, despite their parents having given permission, the child's assent (or non-consent) was considered paramount to their parents. In these cases, the teachers asked the child to return to class or to wait until the other children were done with the process.

When necessary, the teacher translated the procedures and consent questions into the child's native language which was either Tswana or Pedi (Gauteng). In the Western Cape, most children spoke either Afrikaans or English and the researcher was able to translate the process, the assent and consent questions. The researcher invited parents and teachers to observe the research process.

The Research Ethics Committee of the Faculty of Health Science, University of Pretoria requires that all cross-sectional studies be designed to protect the identity of the participants. For this reason, each school and all the children who participated were assigned an unique, but non-identifying, number**.** Children who were interested in their weight, height and BMI were provided with a card with these details as well as some

information regarding normal BMI ranges, risks, benefits and ways to maintain a healthy lifestyle. This was done so that each learner could benefit directly from information obtained in the study.

In addition, the schools and the Gauteng and Western Cape education departments have requested feedback on the results of the BMI of their children. The reason is that most of these schools provide a feeding programming to their learners and they want to determine the nutritional status of these children. For these schools, the unique number can be traced to the identity of the school in order to give the requested feedback. However, the identity of the children cannot be traced as the consent and assent forms that contain the names of the learners were kept separate from the numbers and the participant numbers were not noted on the form. These procedures were in accordance with the regulation of the Research Ethics Committee, UP.

Although data regarding the weight, height and BMI of the children are available, it does not form part of the primary objectives of the current study and will therefore not be discussed in detail.

3.1.4.2. Sample size

The sample size was constructed so that standards for facial indices with respect to age, sex and ancestry could be established. As in the benchmark database by Farkas and Munro (1987), standards were derived from mean values ± 2 standard deviations. Farkas and Munro (1987) and Farkas (1994), used sample sizes ranging between 21 and 50 to determine indices in their North American sample of white children. They observed coefficients of variation less than 10%. Due to the large sample size of this study, a similarly small coefficient of variation is anticipated.

A pilot study of limited size was conducted in order to determine the adequate sample size. When comparing the ancestry, sample sizes of 35 per sex, age and population category were capable of detecting fairly small differences, e.g., for the lip index being the most variable of indices, a difference of 5 mm between groups was detectable with a 90% power using a standard deviation of 11.08 mm derived from the pilot study. Therefore, a sample size of 35 per group was found to be adequate for the calculation of craniofacial indices. However, it was attempted to obtain 50 children per group per age, sex and ancestry in order to match the sample sizes of Farkas and Munro (1987) and Farkas (1994).

In terms of geometric morphometrics, the sample comprised of 800 lateral facial photographs of the children used in the craniofacial index part of the study. Fifty lateral facial photographs of children from each age, sex and ancestry group were randomly selected for geometric morphometrics.

3.1.5. Determination of socio-economic status

Although socioeconomic status (SES) was not of primary importance, it was included as a broad descriptor of the children who were included in the sample.

SES often features as a variable in studies regarding child health and growth. It is a multidimensional characteristic which is difficult to describe and quantify (Sheppard *et al*., 2009). In previous studies, the social elements of SES have been determined by parental education level and marital status, while the quality of household dwellings and household expenditure are usually used as descriptors of the economic element of SES (Sheppard *et al*., 2009). In this study, the measurement of SES focused on the economic element. Expenditure regarding school fees was used as a descriptor of SES. In order not to impose further on the privacy of participants who may be sensitive to their SES, the annual school fee of each school was used to provide a rough guideline of SES. Schools representing higher or low SES, from rural or urban areas were randomly selected. In South Africa, parents pay school fees for 11 months from January to November. Socio-economic status, based on the following criteria, was described in 3 arbitrary categories:

- Low: school fees less than a R500 pm (< R5500 p.a.)
- Middle: school fees of R501 to R1000 pm (R5501 to R11 000 p.a.)
- High: school fees more than R1000 pm (> R11 000 p.a.)

Exclusion criteria for schools were as follows:

- Schools attended by more than 40% white or Indian South African children
- Schools that were unable to accommodate the researchers on specific dates due to other activities at the school, e.g., tests
- Schools that were non-compliant in terms of distribution of consent and assent forms

In 2007, 40% of South African schools were declared as “no-fee” schools. These schools are part of the 20% poorest areas in the country. One school (included in this study) in Gauteng fell in this category. For other schools, the fees were taken as an indication of socio-economic status. Comparison of the SES of the schools from the Western Cape and Gauteng shows that the average school fees of schools in the Western

Cape is R1650-00 per annum or R15-00 per month and in Gauteng R3340-00 per annum or R320-00 per month. Despite these low fees, only 52.4% of parents in the Western Cape are able to pay school fees and 63% of parents in Gauteng pay school fees (Statistics SA annual report, 2011; Personal communication with school principals). A summary of the SES of participating schools in Gauteng and the Western Cape is provided in Tables 3.1 – 3.3.

Based on the categories explained in the section above, all schools except one fell into the low SES category. The exception was a privately owned school in Gauteng with a monthly fee of R1200 pm at the time the data was collected. The school therefore was classified as being in the high SES category. This school was the control group for the study.

In summary, the study mainly included children from low SES as children from underprivileged background are often involved in gangs, especially in the Western Cape (SAPS annual report 2011/2012). They are also more often the victims of crime or run away from home to eventually end up on the missing children's list (Benoit-Bryan, 2011).

3.2. Methodology

3.2.1. Tissue thickness

3.2.1.1. Choice of method for tissue thickness

Computer tomography imaging (CT) was initially considered as a method to record tissue thickness, but a preliminary assessment of the number of paediatric patients who presented at the local academic hospital revealed that all had either traumatic injuries or tumours involving the head or face. In 96% of cases soft tissues of the face were distorted and therefore unsuitable for the purpose of the study. Ultrasound was not an option due to lack of a portable ultrasound machine and an expert operator needed when travelling into rural areas. Currently the cadaver collection at the Department of the Anatomy, UP also does not contain sufficient paediatric cadavers in order to conduct a needle puncture study. Cephalograms were the only viable option as they are often used in dental practice to assess occlusion in dental patients. Cephalograms differ from lateral radiographs which are usually requested by medical practitioners to assess the paranasal sinuses. The radioactive dose a patient receives with cephalograms is generally less (dose: 0.02mSv) and poses little health risk, especially for a child (Buch, 2003), compared to the radioactive dose received when a radiograph of the paranasal sinuses is taken (dose: 0.005 – 0.06mSv). The reason for this lies in the penetration depth of the radiation required. More radiation is

needed to penetrate deeply in order to demonstrate deep structures such as the paranasal sinuses. Also, multiple views of skull radiographs are necessary to determine the full extent of the trauma or infection. Less radiation is required to visualize both the skeletal and soft tissue profile of dental patients on cephalograms (Wall, 1997; Poppe, 2007).

3.2.1.2. Measurement of tissue thickness

Several measurement programmes are available for example ImageTool (Dove, 2002), iTEM (ResAlt Technologies, 2009) and ImageJ (Ferreira and Rasband, 2012) software. It was decided to use the iTEM measuring programme, which is often used in cell biology, but can also measure distance and angles. The programme can also measure distances in millimetres and larger units. As a means to calibrate the measuring programme, all cephalograms were digitized with a scale. Tissue thickness measurements were taken at the midline as cephalograms are a type of lateral radiograph and only the midline tissue thicknesses are visible. Cephalograms are life size and orthodontists directly measure distances and angles from the cephalograms to determine a treatment plan for patients with no correction factor added. Therefore it was not necessary to use a correction factor.

Measurements were taken at 10 mid-facial landmarks using the iTEM measuring program. Landmarks on the skull were located and digitally marked. Table 3.4 shows a list of homologous landmarks. The computer's cursor was first placed on the bony landmark on the skull and then at the visible edge of the tissue following a line perpendicular to the bony landmark. This method simulated the angle of a tissue marker used in facial reconstruction/approximation and is similar to methods by Aulsebrooke *et al.* (1996) and Cavanagh and Steyn (2011) (See Figure 3.1). The distance was automatically registered on a spreadsheet.

The use of this method has an advantage over ultrasound methods as bony landmarks are visually located and as a result, more easily identified on cephalograms. The distance from the bone (known parameter) is then measured to the skin's outline (variable parameter). When using ultrasound, the transducer is placed on the soft tissue (variable parameter) and then the operator attempts to find the bony landmark (known parameter) before taking the measurement. This inverted method of using the "unknown" parameter to locate the "known" parameter may result in measurement error due to incorrect location of landmarks. The ultrasound image also covers a smaller visual field as opposed to cephalograms where the whole face is visible, marking landmark identification difficult.

3.2.1.3. Facial profile

One of the aims on this study was to assess whether the facial profile had a significant effect on soft tissue thickness. Utsuno refers to the facial profile as “skeletal type” (Utsuno, 2005, 2007, 2010). Both Utsuno (2005, 2007, 2010) and Dumont (1986) argued that skeletal type and dental occlusion reflects the visual appearance of the face.

According to Utsuno (2005, 2007), an angle he called ANB describes the facial profile or skeletal type. Utsuno described the relationship of the mandible to the maxilla and referred to it as an angle “ANB”. “A” refers to the deepest point on the line between the anterior nasal spine and the prosthion. “B” refers to the deepest point from the line between the infradentale (the apex of the alveolar bone between the right and left lower first incisors) and the pogonion. “N” is the nasion, positioned on the suture between the frontal and nasal bones (Figure 3.2).The skeletal type of the patient and can be classified into 3 classes (see Figure 3.3): In class I the angle ANB is between 2 and 5 degrees, which is desirable and considered normal as it presents a straight facial profile. In Class II, the angle ANB is greater than 5 degrees causing a convex facial profile. The ANB angle in class III is less than 2 degrees resulting in a concave facial profile. This method was used to determine the facial profile or skeletal type of each child.

Dumont (1986) considered dental occlusion in their soft tissue thickness study. Dumont (1986) describes 3 classes of dental occlusion: Class I is considered as normal occlusion and describes the paracone of the 1st maxillary molar occluding the buccal groove of the 1st mandibular molar. Class II causes overbite as the metacone of the 1st maxillary molar occludes the buccal groove of the 1st mandibular molar. This situation results in the mandibular molar being found posterior to the maxillary molar. Class III causes underbite as the paracone of the 1st maxillary molar occludes the distobuccal groove of the 1st mandibular molar. As a result the mandibular molar is anterior to the maxillary molar.

However, Utsuno (2010) argued that the two terms do not have the same meaning. This author argues that angle ANB indicates the convexity or concavity of the face while dental occlusion only refers to the position of the teeth which does not take the specific relation of the mandible and maxilla into account. In effect, it means that a patient with additional teeth in the maxilla may be classified as having class II dental occlusion, but the position of the mandible and maxilla remains class I in terms skeletal type. It will be more correct use the skeletal type as that would represent the visual appearance of the reconstruction more accurately than dental occlusion.

For the purpose of this study, it was decided to use skeletal type, as angle ANB could be accurately measured with the iTEM programme.

3.2.2. Craniofacial indices and shape analysis

3.2.2.1. Choice of method for craniofacial indices

As explained before, it was decided to use photo-anthropometry for data collection as opposed to live measurements. The first reason for using photo-anthropometry is that a large number of children (around 200 per day) had to be processed under 5 hours as the school schedule had to be adhered to. Secondly, it provides a permanent record which could be accessed again should the need arise, for example to re-check a measurement or to conduct additional measurements. In contrast, live measurements are time consuming, especially were young children are concerned and more importantly, the measurement cannot be performed again. However, much controversy exist on the accuracy of photo-anthropometry (Kleinberg *et al*., 2007), therefore no direct measurement was used, but were utilized in the form of indices only.

The procedure for taking of the photographs were similar to procedures described by others which amounted to the head being oriented in the Frankfurt horizontal plane, a ruler being included on all photographs for calibration and mounting the camera a constant distance from the camera (Guyot *et al*., 2003; Fernández-Riverio, 2002; Faraiby, 2006; Dimaggio *et al*., 2007; Han *et al*., 2010; Catteneo *et al*., 2012). The distance of the camera varied between authors. Guyot *et al*. (2003) mounted the camera 3 meters away from the subject, while in the studies by Dimaggio *et al*. (2007) and Catteneo *et al*. (2012), the subject was placed 1.5 meters from the camera. The subjects in Han *et al*. (2010) were 1 meter from the camera. From these studies it is clear that although there are no prescribed standard distance used by all authors, the distance was always constant and the same camera were used in all cases.

In this study, digital photographs of the anterior and lateral facial profiles were taken of 1749 children. All images were taken with the head in the Frankfurt horizontal plane. The children were in a seated position in front of a standard grey background, a standard distance of 1.2 m from the camera with a calibrated scale 5 cm lateral to the face included on each photograph.

3.2.2.2. Measurements

Each image was calibrated and 22 standard craniofacial biometric landmarks were identified, from which linear facial measurements were recorded using the iTEM programme. Each image was calibrated before commencing with the actual measurement of distances on the face. The iTEM programme contains a calibration function which requires the measurement on a known distance on the photograph. For this reason, two rulers (in mm), one in the vertical and one in the horizontal plane was attached to a laboratory stand by clamps. The stand was placed in the same plane as the child and photographed together with the child and subject number. This enabled the operator to calibrate the image and to eliminate any magnification due to distance from the camera.

For measurements, the cursor was placed on a landmark of the face. A line was drawn between two landmarks and the linear distance was automatically recorded. See Table 3.7 for a description of the biometric landmarks involved. The corresponding linear measures that were used to create 37 facial indices, according to previous work by Farkas and Munro (1987) and Roelofse (2006), can be found in Tables 3.8 and 3.9.

3.2.2.3. Facial shape changes

Geometric morphometrics were used to assess shape changes in facial morphology as seen on lateral profiles with respect to age, sex and ancestry. Lateral profiles provide more information as it enables visualization of shape changes regarding the forehead, nose mouth and chin as well as the degree of prognathism.

Geometric morphometrics using the TPSpline v3.2 (Rohlf, 2003) was performed to measure shape differences between age groups. In effect, the mean shape of an age group was compared to the mean shape of the previous age group on the lateral images of the face. From these comparisons, shape changes over the 8 year period were plotted. The mean shape of age groups per sex and ancestry was also determined and compared for shape changes between groups.

Lateral profiles were used to assign landmarks for geometric morphometric analysis. Standard orientation was not a problem as the photographs had been taken with the childrens' head in the Frankfurt horizontal plane. According to Webster and Sheets (2010), the number of landmarks should provide an accurate summary of the morphology of the object. In addition, they suggest that landmarks should be homologous anatomical positions, consistently replicable with a high degree of accuracy, must be on the same plane and should be in the same topological location relative to other landmarks. These

aspects prompted a pilot investigation into landmark selection in order to determine which landmarks and how many landmarks would adhere to the criteria by Webster and Sheets (2010). Fifteen lateral facial photographs of children of the same age, sex and ancestry was digitized. In the first effort, 13 landmarks were assigned to the lateral facial profile. Two landmarks, pogonion and under chin, varied greatly in position by different operators and for the same operator (Goodall's F-test: $p=0.0100$; Hotteling's T^2-test: $p=0.0330$). No significant differences were found at any of the other 11 landmarks.

The pogonion and under chin landmarks were discarded as they could not be located with a high degree of accuracy and thus had a low rate of repeatability. As a result, 11 homologous landmarks were assigned to each lateral profile on digital photographs via a computer.

The landmarks corresponded to standardized landmarks in determining tissue thickness which ensured easy and reliable identification of the landmarks on each face (Figure 3.4). The chosen landmarks also represented the lateral profile of the face adequately and are the same landmarks presented in Table 3.7.

The homologous landmarks were digitized with tpsDig, part of the tps programme series (version 1.03) by Rohlf (2002). The tpsDig programme marked the location of the landmarks and noted the image file name, often in numerical format as assigned when the image was taken. The data were saved in tps format files that are compatible with tpsSpline and tpsRelw which were used to determine consensus between groups, compare landmarks in different individuals and determine general trends in shape.

Consensus configurations of groups were compared with tpsSpline (version 1.03) (Rohlf, 2002). In general, tpsSpline compares the same landmarks in several different individuals by means of thin plate spline transformations as well as warps (principal and partial).

The tpsSpline component was able to generate deformation grids and graphic presentations in the vector mode. This function was used to determine: 1) average facial shape of each group; and 2) specific landmarks that were responsible for variation between groups.

TpsRel (version 1.03) was used to determine general trends in shape (Rohlf, 2002). The tpsRel component of the tps programme series performs statistical analysis and presents results on a 4-axis graph without labels. The graph can be set to show either the distribution of individuals within a group, which also enables the investigator to visualize

intra-sample variation, or the variation between different groups. Variation is without unit and the scale is thus not important, therefore labels are absent from the axes of the graph.

The Integrated Morphometrics Package or IMP was used to perform advanced statistical analysis with regard to changes in facial shape. The IMP consists of three parts: CoordGen, Canonical Variates Analysis (CVAGen6) and TwoGroup6. The first part of IMP, namely CoordGen, converted the tps data file generated by the digitization of landmarks using tpsDig to a set of shape coordinates known as the Bookstein Coordinates (BC). The BC rescaled and repositioned the object and then fixed the landmarks in a coordinate system, e.g., Landmark 1 = (0,0).

In the next step, CVAGen6 generated a plot to indicate similarities or dissimilarities between the groups. The CVAGen6 generated plots presented data as clusters and also indicated the mean shape. Some clusters may overlap which can be used to indicate differences. Statistically significant differences were determined and a p-value was obtained. The CVA also assigned individuals to a group, as it performed discriminant function analysis. The accuracy with which the CVA performs this task indicates whether the variation between objects was significant to the extent that it could be assigned to different groups such as sex, ancestry and age group.

The BC files were used by TwoGroup6 to compare any two groups by superimposing clusters of landmarks of the two groups on a plot. Usually different colours are assigned to each group in order to improve readability and visual presentation of the plot. The clustering of the landmarks or lack of clustering indicated similarities or dissimilarities of the groups, respectively.

3.3. Statistical analysis

Standard descriptive statistics (including means, standard deviations) were calculated per age group, sex and ancestry. An analysis of variance (ANOVA) was used to assess differences in tissue thickness and craniofacial indices between age groups, sexes and ancestry. Results from the current study were compared to results from other studies regarding tissue thickness and facial indices. Details of these comparisons are outlined in the sections below.

3.3.1. Tissue thickness

Tissue thickness measurements were pooled into different age groupings. The reasons for structuring the data in this way were the following:

1) There is not enough data per single age group, specifically for the younger children. The younger groups are therefore under represented and statistical analysis cannot be performed with these small sample sizes unless they are pooled;
2) The exact age of a child cannot not be determined from skeletal remains with great certainty, therefore it makes more sense to use age ranges rather that exact ages in juvenile cases were facial approximation/reconstruction are to be performed;
3) The multiple ways in which tissue thickness data is pooled into age groups in the literature made it necessary to determine how tissue thickness data should be pooled in order to provide a workable dataset for forensic artists;
4) These age groupings are similar to that used by other authors such as Dumont (1986), Williamson *et al.* (2002), Utsuno *et al.* (2007, 2010), Manhein *et al.* (2000), Wilkinson (2002) and Stephan and Simpson (2008b) which enable comparison of results;
5) Stephan and Simpson (2008b) analyzed tissue thickness data from five published studies in the literature on children and found that between 1 and 18 years, most measurements increased by fewer than 3 mm. They therefore suggest that two age groups for sub-adults should be used as more than two age groups are unlikely to hold any advantage.

For the first round of analysis, tissue thickness measurements were pooled into three age groupings: Ages 6 to 9 years were compiled as one group representing the young individuals. Similarly, the results for the 10 & 11 year olds were grouped as the middle age group, and the 12 & 13 year olds were compiled as the older age group. This age grouping is the same as age divisions by Dumont (1986), Williamson *et al.* (2002), Utsuno *et al.* (2007, 2010).

Following the first analysis, a second was performed where tissue thickness measurements were pooled into two age groupings: Children aged ages 6 to 8 year represented the young children, while children aged 9 to 13 were part of the older age group. This age grouping is the same as age groupings used by Manhein *et al*. (2000) and Wilkinson (2002)

Thirdly, tissue thickness measurements pooled into two age groupings with the division at age 11 as suggested by Stephan and Simpson (2008b). Measurements taken from children aged 6 to 11years were pooled as the young age grouping and measurements from children aged 12 and 13 years were pooled as the older age grouping.

After stratifying the data, 2-way and 3-way ANOVA with Bonferroni comparisons were performed taking the factors sex, population and age categories into account. The

Bonferroni comparison, also known as Dunn's multiple comparison procedure, was selected in order to avoid Type I error, which is the probability that significance is obtained by chance rather than real statistical difference (Dawson and Trapp, 2004). Stephan *et al*. (2013) also employed the Bonferroni correction in their analysis of multiple sets of tissue thickness data.

In terms of ancestry, tissue thickness results were compared to the results of studies performed on white American (Dumont, 1986; Manhein *et al*., 2000), white British (Wilkinson, 2002), female Japanese (Utsuno, 2005; Utsuno, 2007), and African American children (Manhein *et al*., 2000; Williamson, 2002) as well as the generalized pooled sub-adult datasets of Stephan and Simpson (2008b).

3.3.2. Craniofacial indices

Thirty-one standard facial indices were calculated (Farkas, 1987; Farkas, 1994; Starbuck and Ward, 2007; Roelofse *et al*., 2008). A list of these indices and their corresponding formulae are supplied in Tables 3.8 (23 anterior indices) and 3.9 (8 lateral indices). Craniofacial measurements and indices were summarized by age, sex and ancestry. Data are presented as the mean and two standard deviations from the mean for each index per age, sex and ancestral group, similar to the reports provided by Farkas and Munro (1987). In addition, tables that include the mean, standard deviation (SD) and 95% confidence intervals are included. In terms of craniofacial indices, results were compared to studies on white North American children conducted by Farkas (1987, 2004) as currently there are no craniofacial index data available for children of African descent.

3.3.3. Analysis of variance

Analysis of covariance (ANOVA) was performed at the 0.05 level of significance. For tissue thickness, facial profile was considered as co-variant along with demographic variables of age, sex, ancestry for craniofacial indices.

3.3.4. Intra-and inter observer repeatability

The intra-observer reliability for the measurements was calculated using the intra-class correlation (ICC). In order to test intra-observer reliability, 27 cephalograms for tissue thickness and 20 photographs of different age groups and sex were chosen for facial measurements and indices. Both sets of cephalograms and photographs did not contain any landmarks. Landmarks had to be identified again according to definitions as presented

in Tables 3.4 and 3.5 in order to check correct landmark placement. The primary researcher re-measured the tissue thickness and linear facial distances. Intra-observer error was calculated as the intra-cluster correlation.

Similarly, inter-observer error was performed on the same 27 cephalograms and 20 photographs for facial measurements and indices. In these instances, another person, familiar with the field of facial identification, was asked to locate landmarks on cephalograms and photographs according to definitions provided in Tables 3.4 and 3.5. This strategy ensured correct landmark placement before taking measurements. Measurements of the tissue thickness and linear facial distances were taken and recorded.

These values were then compared and the reliability was determined by using the inter-rater agreement. Both the intra-observer and inter-observer error are restricted to one. This means that a value close to 1 indicates a high reliability. The statistical packages STATA (version 10) and SPSS (version 11.5) were used in data analyses.

3.3.5. Face shape changes

The similarities/dissimilarities between groups were determined by means of TwoGroup analyses, and the programme also determined whether the dissimilarities were significant by means of Goodall's F test and Hotteling's T^2-test. Goodall's F test indicates overall shape difference between groups since it compares the Procrustes distance between the means of the two samples. It also computes the average shape of each group by calculating the least squares Procrustes analysis. Therefore is quantifies the magnitude of differences between the groups. Hotteling's T^2- test compared the difference between the mean vectors and as a result determines the significance of shape differences between groups.

Table 3.1: Summary of socio-economic status of participating government schools in the Western Cape

Western Cape Schools	School fees pm (ZAR)	School fees pa (ZAR)	% Parents that pay school fees*	SES
W1	R 10.00	R 1 100.00	35	Low
W2	R 10.00	R 1 100.00	14	Low
W3	R 30.00	R 3 300.00	24	Low
W4	R 15.00	R 1 650.00	23	Low
W5	R 10.00	R 1 100.00	35	Low
Average	**R 15.00**	**R 1650.00**	**52.4**	**Low**

*Estimation by the principal
W1: Western Cape school 1
W2: Western Cape school 2
W3: Western Cape school 3
W4: Western Cape school 4
W5: Western Cape school 5

Table 3.2: Summary of socio-economic status of participating schools in Gauteng

Gauteng Schools	School fees pm (ZAR)	School fees pa (ZAR)	% Parents that pay school fees*	SES
G1**	No fee	No fee	Not applicable	Low
G2***	R 350.00	R 3 580.00	55	Low
G3**	R 260.00	R 2 860.00	49	Low
G4***	R 350.00	R 3 580.00	85	Low
Average	**R320.00**	**R 3 340.00**	**63.0**	**Low**

*Estimation by the principal
**Government school
***Privately owned school
G1: Gauteng school 1
G2: Gauteng school 2
G3: Gauteng school 3
G4: Gauteng school 4

Table 3.3: Details of participating privately owned high SES school in Gauteng

Gauteng School	School fees pm (ZAR)	School fees pa (ZAR)	% Parents that pay school fees*	SES
G5	R 1 200.00	R 13 200.00	80	High

*Estimation by the principal
G5: Gauteng school 5

Table 3.4: List of landmarks and their definitions of hard and soft tissue landmarks used in the tissue thickness part of this study (Knußmann, 1988; Aulsebrook *et al*., 1996; Kolar and Salter, 1996; Manhein *et al*., 2000; Stephan and Simpson, 2008b)

No	Skeletal landmark	Symbol	Description	Soft tissue landmark	Symbol	Description
1	Supraglabella	sg	Point at the deepest part of the curvature on the frontal bone	Supraglabella	sg’	Midline soft tissue point directly overlying hard tissue of the supraglabella
2	Glabella	g	The most prominent point between the supraorbital ridges in the midsagittal plane	Glabella	g’	Most anterior midline soft tissue point overlying the glabella
3	Nasion	n	The midpoint of the suture between the frontal and the two nasal bones	Nasion	n’	Midline soft tissue point directly overlying hard tissue at the nasion
4	End nasal / Rhinion	en / rhi	The anterior tip of the nasal bone OR Midline point at the inferior free end of the internasal suture	End nasal / Rhinion	en' / rhi'	Midline soft tissue point directly overlying the hard tissue at the end of the nasal point / rhinion
5	Midphiltrum (point A)	mp / A	The deepest midline point on the indentation between the nasal spine and the supradentale. Also known as point A	Midphiltrum	mp'	Midline point midway between soft tissue subnasale and the vermilion border of the upper lip in the groove of the philtrum
6	Upper lip border (Labiale superius)	ls	The apex of the alveolus in the midline between the maxillary central incisors (also the alveolare or prosthion)	Upper lip border (Labiale superius)	ls’	Midline soft tissue point at the vermilion border of upper lip
7	Lower lip border (Labiale inferius)	li	The apex of the alveolus in the midline between the mandibular central incisors	Lower lip border (Labiale inferius)	li'	Midline soft tissue point at the vermilion border of lower lip
8	Labiomental groove or mentolabial sulcus (point B)	mls / B	Deepest midline point in the groove superior to the mental eminence. Also known as point B	Labiomental groove or mentolabial sulcus	mls'	Deepest soft tissue point on the midline of the groove just superior to the chin
9	Pogonion	pg	The most anterior point in the midline on the mental protuberance	Pogonion	pg'	Most anterior midline point on the eminence of the soft tissue chin
10	Beneath chin (menton)	me	Most inferior midline point at the mental symphysis of the mandible (also considered the most causal point in the outline of the mental symphysis on radiographs)	Beneath chin (menton)	me’	Midline soft tissue point directly overlying the hard tissue menton

Table 3.5: Standard biometric landmarks used for anthropometric measurements (Farkas and Munroe, 1987; Farkas, 1994; Kolar and Salter, 1996; Farkas *et al*., 2005) with the head in the horizontal Frankfurt plane

Name	Symbol	Description
Trichion	tr	Midpoint of the hairline
Glabella	g	Prominence between the eyebrows in the facial midline
Nasion	n	Midpoint of the suture between the frontal and two nasal bones
Endocanthion	en	The point where the upper and lower eyelids meet on the medial side
Ectocanthion	ex	The point where the upper and lower eyelids meet on the lateral side
Alare	a	The extreme lateral point of the alar wing
Subnasale	sb	The point in the midline where the lower border of the nasal septum meets the upper lip
Labiale superius	ls	The midpoint of the upper lip
Stomion	sto	The point where the facial midline crosses the line between the 2 cheilions
Labiale inferius	li	The midpoint of the lower lip
Cheilon	ch	The outer border of the meeting of the upper and lower lips when the non-smiling mouth is lightly closed and the molars occluded
Gnathion	g	The midpoint between the most anterior point of the chin (pogonion) and lowest point of the chin (menton)
Zygion	zy	Most lateral point on the zygomatic arch that indicates the widest part of the face
Vertex	v	Highest point of the cranium I midline. It may be difficult to pinpoint due to the presence of hair
Euryon	eu	The most lateral point of the head.
Frontotemporale	ft	The most medial point on the temporal crest of the frontal bone
Gonion	go	The most lateral point of the mandible at the angle of the mandible
Tragion	t	The point at the notch above the tragus of the ear where the upper edge of the cartilage becomes part of the skin of the face
Palbebrale superius	ps	The highest point in the middle of the margin of the upper eyelid
Palbebrale inferius	pi	The lowest point in the middle of the margin of the lower eyelid
Maxillofrontale	mf	The anterior lacrimal crest of the maxilla at the frontomaxillary suture
Porion	po	The most superior point on the upper margin of the external acoustic meatus

Table 3.6: List of anterior anthropometric craniofacial indices, calculation of formulae and reference source for each index

Index	Formula	Reference
Anterior indices related to head width		
Head width - craniofacial facial height index	[eu - eu / v-gn] x 100	Farkas and Munro (1987) p170
Forehead - head width index	[ft – ft / eu – eu] x 100	Farkas and Munro (1987) p167
Skull base - head width index	[zy - zy / eu – eu] x 100	Farkas and Munro (1987) p268
Forehead width – face width index	[ft – ft / zy - zy] x 100	Farkas and Munro (1987) p255
Anterior index related to head and face height		
Auricular head height - skull base width index	[(v - po, 1) / t – t] x 100	Farkas and Munro (1987) p172
Facial index	[n – gn / zy – zy] x 100	Farkas and Munro (1987) p179; Roelofse (2006) p77
Upper face index	[n – sto / zy – zy] x 100	Farkas and Munro (1987) p181
Anterior indices related to the mouth		
Lip index	[ls – li / ch –ch] x 100	Roelofse (2006) p88
Upper lip thickness index	[ls – sto / ls – li] x 100	Roelofse (2006) p93
Lower lip thickness index	[li – sto / ls – li] x 100	Roelofse (2006) p95
Mouth width index	[ch – ch /ex –ex] x 100	Roelofse (2006) p97
Upper lip height – mouth width index	[sn-sto/ch-ch] x 100	Farkas and Munro (1987) p233
Anterior indices related to the mandible		
Mandibular index	[sto – gn / go – go] x 100	Farkas and Munro (1987) p183
Mandible width - face width index	[go – go / zy – zy] x 100	Farkas and Munro (1987) p180
Mandible width - face height index	[go – go / n – gn] x 100	Farkas and Munro (1987) p182
Anterior indices related to the nose		
Nasal index	[al – al / n – sn] x 100	Farkas and Munro (1987) p212 Roelofse (2006) p81
Nasofacial index	[n – sn / gn –n] x 100	Roelofse (2006) p84
Nose – face width index	[al –al / zy –zy] x 100	Roelofse (2006) p86
Anterior indices related to the eyes		
Intercanthal index	[en – en / ex – ex] x 100	Farkas and Munro (1987) p208 Roelofse (2006) p79
Eye fissure index	[(ps - pi, 1) / (ex - en, 1)] x 100	Farkas and Munro (1987) p211
Bi-ocular face width index	[ex – ex / zy – zy] x 100	Farkas and Munro (1987) p280
Intercanthal width - upper face height index	[en – en / n – sto] x 100	Farkas and Munro (1987) p281

Table 3.7: List of lateral anthropometric craniofacial indices, calculation formulae and reference source

Index	Formula	Reference
Lateral indices related to face height		
Head - craniofacial height index	[n – gn / tr –gn] x 100	Farkas and Munro (1987) p186
Fore-head - head height index	[trn – n / v – n] x 100	Farkas and Munro (1987) p176
Upper face - face height index	[n - sto / n – gn] x 100	Farkas and Munro (1987) p187
Lower face - face height index	[sn - gn / n – gn] x 100	Farkas and Munro (1987) p188
Mandibulo - face height index	[sto – gn / n – gn] x 100	Farkas and Munro (1987) p189
Mandibulo - lower face height index	[sto – gn / sn – gn] x 100	Farkas and Munro (1987) p191
Lateral indices for face depth		
Upper middle third face depth index	[t - n, l / t - sn, l] x 100	Farkas and Munro (1987) p198
Lower middle third face depth index	[t - sn, l / gn - t, l] x 100	Farkas and Munro (1987) p199

Table 3.8: List of soft tissue landmarks and their definitions of the facial profile used in the geometric morphometric part of this study (Knußmann, 1988; Aulsebrook *et a*l., 1996; Kolar and Salter, 1996; Manhein *et al*., 2000; Stephan and Simpson, 2008b)

No	Soft tissue landmark	Symbol	Description
1	Trichion	tr'	Midline point of the hairline
2	Supraglabella	sg’	Midline soft tissue point directly overlying hard tissue of the supraglabella
3	Glabella	g’	Most anterior midline soft tissue point overlying the glabella
4	Nasion	n’	Midline soft tissue point directly overlying hard tissue at the nasion
5	Nasal tip / pronasale	prn'	Furthest protrusion of the nasal tip
6	Subnasal	sn'	The junction between the lower border of the nasal septum and the cutaneous border of the upper lip at the apex of th nasiolabial angle
7	Midphiltrum	mp'	Midline point midway between soft tissue subnasale and the vermilion border of the upper lip in the groove of the philtrum
8	Upper lip border (Labiale superius)	ls’	Midline soft tissue point at the vermilion border of upper lip
9	Stomion	st'	Midpoint of the labial fissure when the lips are closed naturally
10	Lower lip border (Labiale inferius)	li'	Midline soft tissue point at the vermilion border of lower lip
11	Labiomental groove	mls'	Deepest soft tissue point on the midline of the groove just superior to the chin

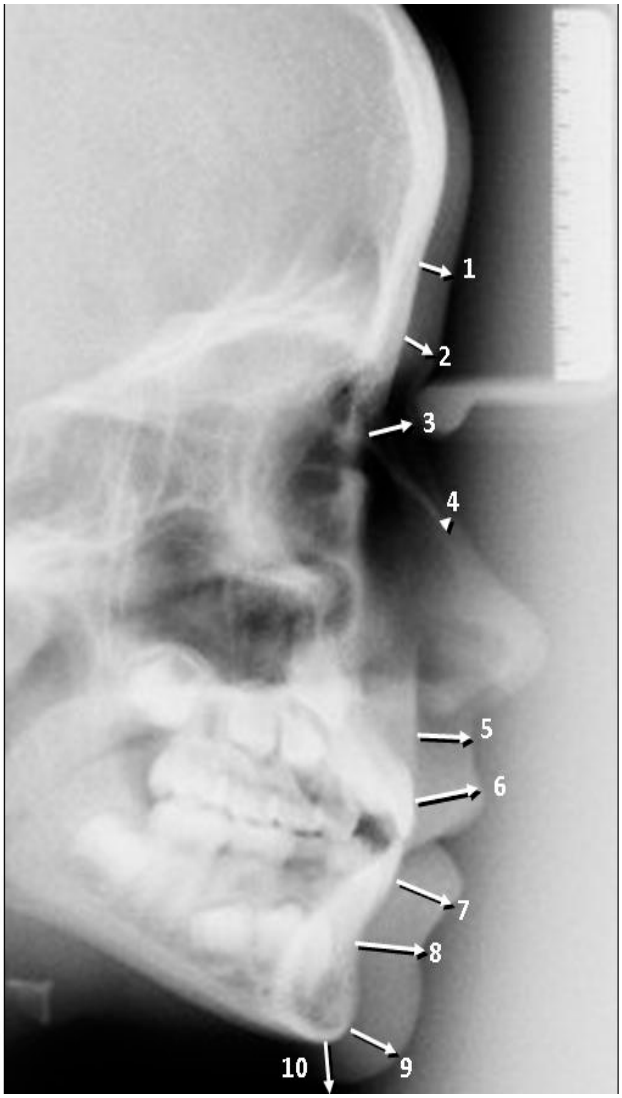

Figure 3.1: Cephalogram indicating the landmarks at which tissue thickness was measured.

Key:
Landmark 1: Supraglabella
Landmark 2: Glabella
Landmarks 3: Nasion
Landmark 4: End nasal
Landmark 5: Midphiltrum
Landmark 6: Labiale superius
Landmark 7: Labiale inferius
Landmark 8: Labiomentale
Landmark 9: Pogonion
Landmark 10: Menton

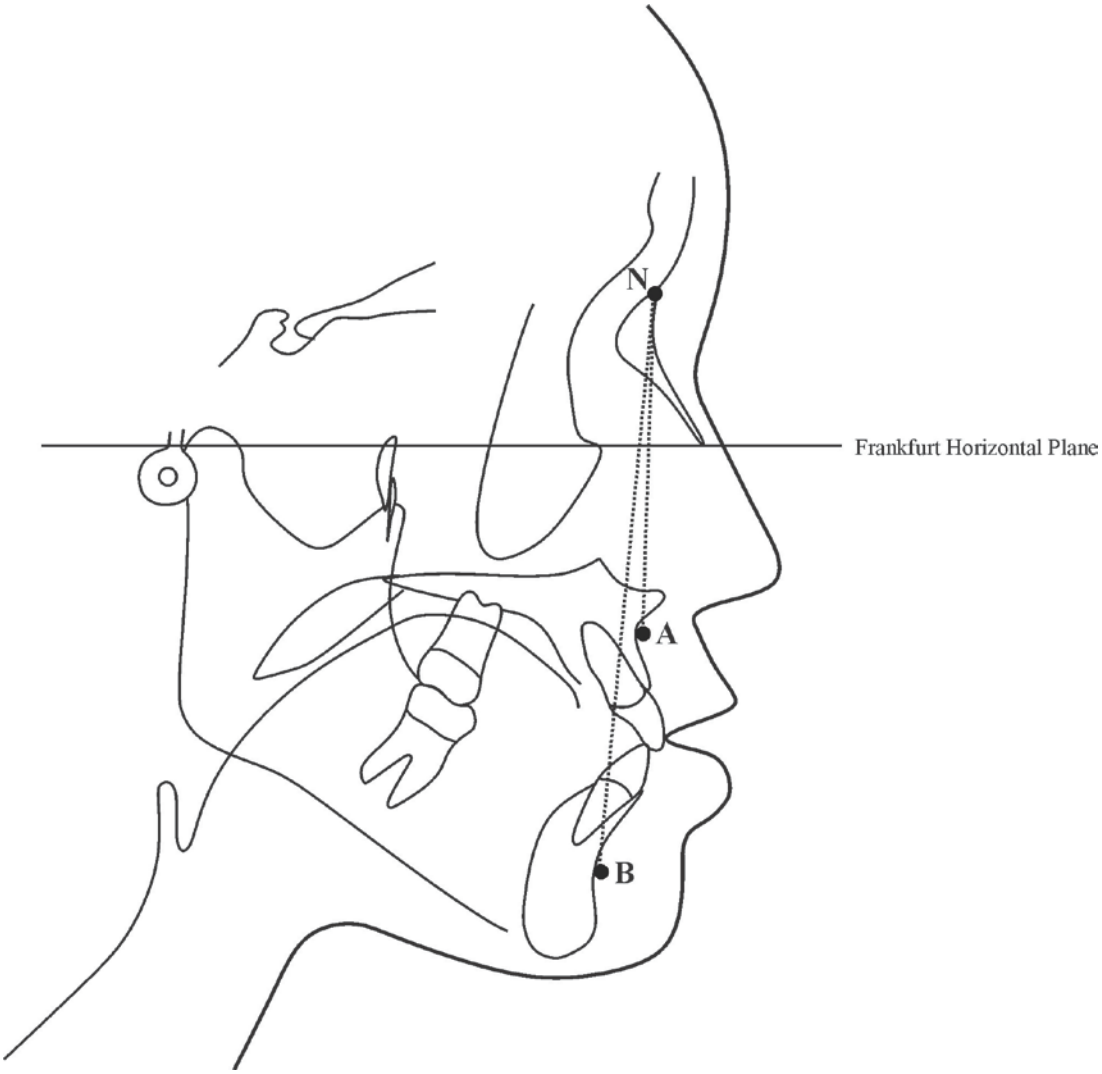

Figure 3.2: Schematic presentation of the relationship of the mandible to the maxilla, also known as angle “ANB”. “A” refers to the deepest point on the line between the anterior nasal spine and the prosthion. “B” refers to the deepest point from the line between the infradentale (the apex of the alveolar bone between the right and left lower first incisors) and the pogonion. “N” is the nasion, positioned on the suture between the frontal and nasal bones.

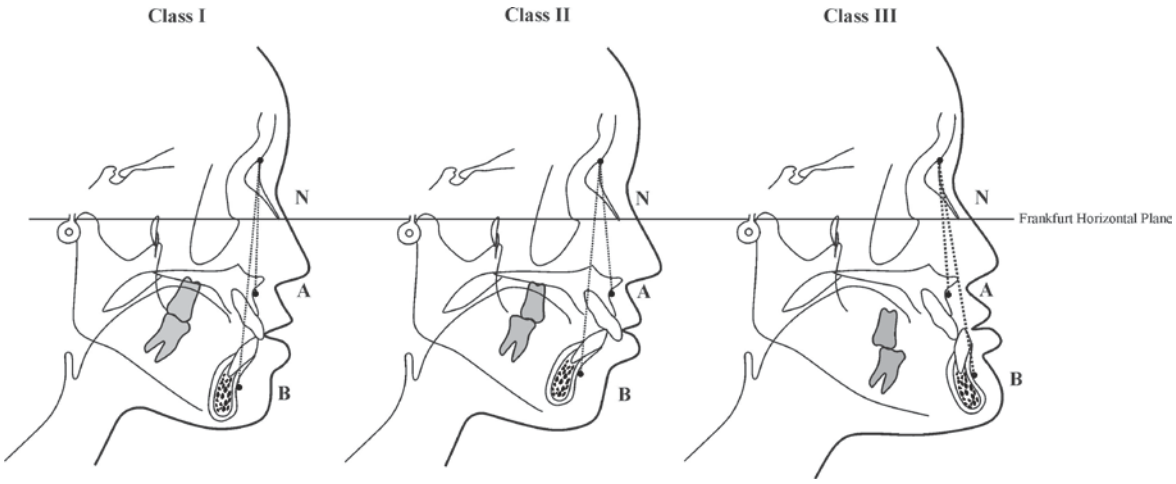

Figure 3.3: Schematic presentation of the 3 classes of skeletal type (Utsuno, 2005, 2007).

Class I: ANB 2 – 5 degrees; straight facial profile

Class II: ANB > 5 degrees; convex facial profile

Class III: ANB < 2 degrees; concave facial profile

Figure 3.4: Location of the schools in Gauteng (G1 – G5) and in the Western Cape (W1 – W5) that participated in the study. Regulations of the Research Ethics Committee, Faculty of Health Sciences (UP) require the schools to remain anonymous, therefore schools were coded.

Figure 3.5: Lateral facial profile of a 8 year old female to demonstrate the landmarks used for geometric morphometrics

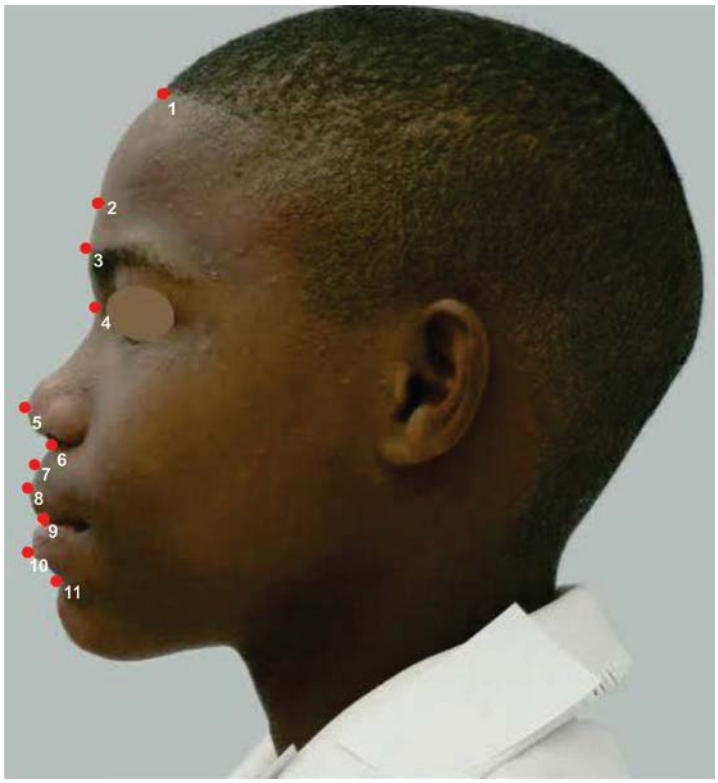

Figure 3.6: Lateral facial profile of a 12 year old male to demonstrate the landmarks used for geometric morphometrics

Chapter 4: Results of tissue thickness

4.1. Introduction

In this section the standards for tissue thickness for South African children aged 6 to 13 are presented per age, sex and ancestry as mean ± SD. Comparisons between age groups, sex and ancestral groups are also shown. The tissue thickness data were collected retrospectively from files containing cephalograms. The files did not contain information regarding the weight and height of the children. Therefore, the effect of BMI on tissue thickness could not be assessed. However, it was possible to assess whether facial profile (skeletal type) had a significant effect on soft tissue thickness.

4.2. Tissue thickness sample composition

The sample for tissue thickness comprised of a total of 388 individuals. From Tables 4.1 and 4.2, it can be seen that 76.8% (298/388) of the sample comprised of Coloured children who presented for oral and dental assessment and treatment. In comparison, only 23.2% of the sample consisted of Black children (90/388). According to a consultant at the Oral and Dental Hospital where the data were collected, patients from the Black South African community are only now starting to present for dental assessment due to an increase of dental awareness campaigns. Furthermore, the consultant stated that prognathism, a feature that is more prevalent in the Black population, ensures enough space for permanent teeth. Therefore, crowding of teeth is not a major problem in the Black population (Dr Hogan, personal communication, 2009).

Tables 4.3 and 4.4 provide information of the sample per age, sex and ancestry when children from various age groups were pooled into large age cohorts, as explained in the "Materials and Methods". It can be seen that 42% of the sample comprised of children aged 12 - 13 years. According to Dr Hogan, the mean age of the patients presenting at the Oral and Dental Hospital is 12 years. Females seem to present earlier between the ages of 10 and 11, reaching peak numbers around 12 and 13 years of age. Usually patients are referred for dental assessment and treatment after eruption of most permanent teeth between 11 and 13 years, which explains the smaller number of patients in the young age categories (Dr Hogan, personal communication, 2009). Table 4.4 shows that almost equal numbers of Black patients (23.2%) were present in all three age categories. Subsequent analyses were therefore in pooled groups as they each have meaningful sample sizes.

4.3. Intra- and inter-observer repeatability

In order to test intra-observer reliability for tissue thickness, 27 cephalograms were selected at random and the linear distances were re-measured. Intra-observer repeatability was calculated as the intra-cluster correlation, which is restricted to 1. A value close to 1 indicates a high reliability. Similarly, inter-observer repeatability was performed on the same 27 cephalograms. In this instance, another person, familiar with the field of facial identification, was asked to take the measurements. The values were then compared and the reliability was determined by using the inter-rater agreement, which is restricted to 1. A value close to 1 indicates a high correlation.

The intra-observer reliability for the measurements was calculated using the intra-class correlation (ICC), which is restricted to one (Table 4.5). Therefore, a value closer to one will indicate a high level the reliability. The ICC for both measuring events by the author and the other person, values varied between acceptable levels of 0.9924 and 0.9999. Measurements that showed the least reliability were the thickness at the end nasal landmark. The most reliable measurements were the upper lip border and the supraglabella.

4.4. Approach to tissue thickness data

This section explains how the data are presented in the rest of this chapter. Due to the current debate in literature whether to and how to subdivide tissue thickness data according to ancestry, sex and age, attention was given to each of these aspects in subsequent subsections.

Stephan and Simpson (2008b) argues that, as in the case of adult data, tissue thickness difference among sub-adults based on ancestry and sex is of little practical use, and can therefore be disregarded. This theory was tested by firstly pooling the tissue thickness data in ancestral groups with sex and age combined (see section 4.4.1).

Secondly, tissue thickness data from the current study were pooled into male and female groups with ancestry and age combined (see section 4.4.2).

Thirdly, the possible influence of age on tissue thickness data was assessed (see section 4.4.3). Comparisons were made by pooling children into age groups as explained in the “Materials and Methods” section. In brief, children aged 6 - 9 years, 10 & 11 years, 12 & 13 years were pooled for comparison with Dumont (1986), Williamson *et al.* (2002) and Utsuno *et al.* (2007, 2010). See section 4.4.3.1 for results of the three age group analysis as well as further subsections where tissue thickness per age group was subdivided by

ancestry (sexes pooled) (section 4.4.3.1.1) and age groups subdivided by sex (ancestry pooled) 4.4.3.1.2) as well as subdivision of age per ancestry and sex (section 4.4.3.1.3). These subdivisions were necessary as these aspects were also considered by the authors listed above.

Other authors prefer to divide their sample into two age groups rather than three for a variety of reasons such as increasing the sample size (see section 4.4.3.2). However, authors often do not use similar age groupings. Therefore, the data of the current study were subdivided in four different ways: Children of ages 6 - 8 years and 9 - 13 years were pooled for comparison with Manhein *et al*. (2000) and Wilkinson (2002) (see section 4.4.3.2.1). Children aged 6 - 11 years and 12 & 13 years were pooled for comparison with Stephan and Simpson (2008b) (see section 4.4.3.2.2). Another age category division was added based on the results from the craniofacial indices from the current study. Tissue thickness data of children aged 6 - 9 and 10 -13 years were pooled (see section 4.4.3.2.3) as data from the craniofacial indices indicated that significant changes occur in craniofacial dimensions at age 10 which may be reflected on soft tissue level as well. A detailed discussion on this aspect is provided in Chapter 6. Within each of these sections (4.4.3.2.1 - 4.4.3.2.3), groups were analyzed according to age (ancestry and sex pooled); age subdivided by ancestry (sexes pooled) and age subdivided by sex (ancestry pooled). These subdivisions were necessary as these aspects were also considered by other authors in the field.

In the last part of this chapter, the possible effect of the facial profile is presented. It will be done in two ways. First, all the data will be pooled to assess whether tissue thickness differences are apparent between the facial profiles (section 4.4.4.1). Then data will be arranged in similar fashion to that of Utsuno (2007) for comparison to Japanese children (section 4.4.4.2).

4.4.1. Mean tissue thickness in ancestry groups (sex and age combined)

In Table 4.6, the tissue thickness (mean, SD, 95% CI and p-value for the *t*-test) is provided for Black and Coloured children. Comparison between the Black and Coloured children, with sex and age combined, showed that the tissue thickness between Black and Coloured children were significantly different at seven out of ten landmarks, i.e., glabella, nasion, end nasal, midphiltrum, labiale inferius, labiomentale and beneath the chin. The tissue thickness was larger at these landmarks in Coloured children compared to the Black children, except at the end nasal landmark, where the tissue thickness in the Black children

was larger. The difference in tissue thickness between Black and Coloured children varied between 0.02 mm and 2.12 mm. The largest difference occurred at the midphiltrum. The difference was smaller than 1 mm at most landmarks, except at the labiomentale where the tissue thickness in the Coloured children was 1.03 mm larger compared to the Black children, and at the midphiltrum where the tissue thickness was 2.12 mm larger in the Coloured children.

4.4.2. Mean tissue thickness per sex (age and ancestry groups combined)

The tissue thickness per sex (mean, SD, 95% CI and p-value for the *t*-test) is presented in Table 4.7. In general, tissue thickness at most landmarks were larger in females compared to the male children. However, the only significant differences were seen at the pogonion and beneath the chin. The difference in tissue thickness between males and females varied between 0.01 mm and 0.62 mm. The largest difference occurred at the pogonion and beneath the chin. Both these values are smaller than 1 mm (pogonion: 0.62mm and beneath the chin: 0.42 mm) which has little practical value as suggested by Stephan and Simpson (2008b).

4.4.3. Mean tissue thickness per age (sex and ancestry combined)

Tables 4.8 to 4.10 summarize the descriptive statistics (mean, SD, upper and lower confidence intervals and p-values of ANOVA) when comparing age groups when sex and ancestral groups are combined. Significant differences were seen between groups at the glabella, labiale superius, labiale inferius and pogonion. After Bonferroni correction, statistical differences were seen between 9 and 10 year old age groups at the supraglabella, glabella and labiomentale. Tissue thicknesses at all three landmarks were larger for the 9 year old group compared to the 10 year old group. The differences of the means were as follow when the mean tissue thickness of the 9 year olds were subtracted from the 10 year olds: Supraglabella: -0.69 mm; glabella: 0.81 mm and labiomentale: -1.32 mm. Significant differences were seen between the 10 year old and 13 year old groups at the labiale inferius and labiomentale. Tissue thickness at these landmarks was larger in the 13 year old group compared to the 10 year old group. The differences between the means were 1.25 mm at the labiale superius and 1.47 mm at the labiomentale. At the labiomentale a significant difference was also seen when comparing the 7 year old group (mean: 10.44 mm) and the 13 year old group (mean: 12.29). The means of these 2 age groups for the labiomentale differed by 1.85 mm. The tissue thickness mean of the 7 year old group (5.10

mm) also differed significantly from the mean tissue thickness of the 11 year old group (6.42 mm). The difference between the means was 1.32 mm. These differences are all less than 2 mm and the practical value of such small differences have been questioned (Stephan & Simpson, 2008a, 2008b; Stephan *et al*., 2013; Stephan, 2014).

4.4.3.1. Three age groups (Ages 6 - 9 years, 10 & 11 years, 12 & 13 years)

In Tables 4.11 to 4.13 tissue thickness data (mean, SD, and 95% CI) are presented as 3 sets of age groups: 6 - 9 year old group (n=98), 10 & 11 year old group (n=127) and 12 & 13 year old group (n=163). As mentioned previously in the Materials and Methods section, this strategy enlarged the sample size of the younger groups to enable comparison between groups with specific reference to age. An ANOVA with Bonferroni correction (Table 4.14) showed significant differences at landmarks around the forehead (supraglabella and glabella) and lower face landmarks (labiomentale and beneath chin). At the supraglabella all age groups were significantly different from one another (6 - 9 year olds *vs* 10 & 11 year olds; 10 & 11 year olds *vs* 12 & 13 year olds). At the glabella, tissue thickness was significantly different between 6 - 9 year old groups and the 10 & 11 year old group. Tissue thickness at the labiomentale differed significantly between the 10 & 11 year old groups and the 12 & 13 year old group. A significant difference was seen at the landmark beneath the chin between the youngest age group (6 - 9 year olds) and older age group (12 & 13 year olds), but not the middle age group when compared to the younger or older group.

Bar charts (Figures 4.1 - 4.10) of the mean tissue thickness of the 3 different age groups per landmark show that tissue thickness does not necessarily increase with age. Linear trends were seen at the midphiltrum (Figure 4.5), labiale inferius (Figure 4.7), pogonion (Figure 4.9) and beneath the chin (Figure 4.10). At the supraglabella (Figure 4.1), glabella (Figure 4.2), nasion (Figure 4.3), labiale superius (Figure 4.6) and labiomentale (Figure 4.8) tissue thickness of the middle age group (10 & 11 year olds) were less than in the youngest age group (6 - 9 year olds). This downward trend, which was significant at the supraglabella and glabella, was followed by an increase in tissue thickness between the middle age group and the eldest age group which was significant at the supraglabella and labiomentale. The exception was at the end nasal landmark where an increase in tissue thickness was seen between the youngest and middle age groups, followed by a decrease between the middle and older groups. The differences at the end

nasal landmark was not significant. In practical terms, the difference is ± 1 mm, which is negligible in practical terms.

Due to these differences, the question arose whether one could estimate at what age groups ancestral and sex difference could be detected. In this regard, the three age groups were subdivided into Black and Coloured young, middle and oldest age groups and male and female young, middle and oldest age groups (sections 4.4.3.1.1 and 4.4.3.1.2).

In section 4.4.3.1.3, the three age groups are again further subdivided to form the following groups: young Black male group; middle Black male group; oldest Black male group; young Black female group; middle Black female group; oldest Black female group; young Coloured male group; middle Coloured male group etc.

4.4.3.1.1. Mean tissue thickness of three age groups per ancestry (sexes pooled)

Tissue thickness (mean, SD, and 95% CI and ANOVA p value) for each of the three age groups are presented in Tables 4.15 to 4.17 in terms of ancestry. Results of the ANOVA with Bonferroni corrections are shown in Tables 4.18 and 4.19. Significant differences were seen at the end nasal and midphiltrum landmarks (Table 4.18) among all three Black and Coloured age groups. At the labiomentale significant differences were seen 6 - 9 year old and 12 & 13 year old Black and Coloured groups. No significant difference was seen at the same landmarks between the 10 & 11 year old Black and Coloured groups. Significant differences were also seen at the glabella between the young Coloured and middle age Black group and the young and middle Coloured age groups. Tissue thickness at the labiale inferius and beneath the chin differed significantly between the 6 - 9 year old Black age group and the 12 & 13 year old Coloured age group (Table 4.19). At the supraglabella a significant difference in tissue thickness was seen between the 6 - 9 year old and 10 & 11 year old Coloured age groups.

A decline in tissue thickness was seen at the supraglabella (Figure 4.11), glabella (Figure 4.12), labiale superius (Figure 4.16) and labiomentale (Figure 4.18) when comparing the Black and Coloured middle age groups (10 & 11 year olds) to the youngest Black and Coloured age groups (6 - 9 year olds). Again this downward trend was followed by an increase in tissue thickness between the Blacks and Coloured children of the middle age group and the eldest Blacks and Coloured children at the landmarks listed above. A similar trend was seen in Coloured children at the nasion (Figure 4.13) and labiale inferius (Figure 4.17) as well as in Black children at the midphiltrum (Figure 4.15). At several landmarks (nasion (Figure 4.13), end nasal (Figure 4.14), pogonion (Figure 4.19) and

beneath the chin (Figure 4.20) an increase in tissue thickness was seen between the youngest and middle age groups of Black children, followed by a decrease between the middle and eldest age groups of Black children. This trend was seen only at the midphiltum in Coloured children. Upward linear trends, which indicate an increase in soft tissue thickness between the youngest to the eldest children, were seen at the labiale inferius (Figure 4.17) of Black children as well as the pogonion (Figure 4.19) and beneath the chin (Figure 4.20) in Coloured children. The only downward trend where a decrease in tissue thickness was seen with increasing age, was at the end nasal landmark (Figure 4.14) in Coloured children.

4.4.3.1.2. Mean tissue thickness of three age groups per sex (ancestry groups pooled)

Tables 4.20 - 4.22 show tissue thickness (mean, SD, and 95% CI) for males and females in the 3 age groups: 6 - 9 year old group, 10 & 11 year old group and 12 & 13 year old group. The only significant difference was found between the 6 - 9 year old females and 10 & 11 year old males for the supraglabella (Tables 4.23 and 4.24).

For the supraglabella (Figure 4.21), glabella (Figure 4.22) and nasion (Figure 4.23), the females in the two young age groups had thicker tissue thickness than the males. However, this trend switched around in the 12 & 13 year old group where the males had the highest value.

Bar charts showed a decrease in tissue thickness at the labiale superius (Figure 4.26), labiale inferius (Figure 4.27), labiomentale (Figure 4.28) and pogonion (Figure 4.29) tissue thickness when comparing males of the middle age group (10 & 11 year olds) to the youngest males (6 - 9 year olds). Again this downward trend was followed by an increase in tissue thickness between the males of the middle age group and the eldest males at the landmarks listed above. A similar trend was seen in females at the supraglabella (Figure 4.21), glabella (Figure 4.12), nasion (Figure 4.23), labiale superius (Figure 4.26) and labiomentale (Figure 4.28). At some landmarks (end nasal (Figure 4.24), midphiltrum (Figure 4.25) and pogonion (Figure 4.29) an increase in tissue thickness was seen between the youngest female and middle age female groups, followed by a decrease between the middle and eldest female groups. This trend was not seen in any of the male age groups. Linear increase of tissue thickness was seen in males from age 6 - 9, 10 & 11 and 12 &13, at the end nasal (Figure 4.24), midphiltrum (Figure 4.25) and beneath the chin (Figure 4.30). In females a similar linear trend was seen at labiale inferius (Figure 4.27) and beneath the chin (Figure 4.30).

4.4.3.1.3. Mean tissue thickness per three age groups subdivided by sex and ancestry

Tissue thickness values (mean, SD, and 95% CI) per age (6 - 9 year olds, 10 & 11 year olds and 12 & 13 year olds), sex and ancestry are presented in Tables 4.25 to 4.27 for Black children and Tables 4.28 to 4.30 for Coloured children. The p-values generated by ANOVA with Bonferroni comparisons for landmarks that displayed significant differences between groups, are presented in Tables 4.31 to 4.33. Significant differences were found at the supraglabella between 10 & 11 year old Black females and the same age group of Coloured males, as well as the 6 - 9 year old and 10 & 11 year Coloured females (Table 4.31). At the end nasal landmark (Table 4.32) a significant difference was found between the 10 & 11 year old Black females and 10 & 11 year old Coloured males. All other significant differences were seen mostly at the midphiltrum (Table 4.33) between young and middle age group Black females and the Coloured children (male and female). Despite significant differences at three landmarks, no unidirectional trends e.g. constant increase in tissue thickness as age increase or *vice versa* could be seen

4.4.3.2. Two age groups

The difficulty in practical application of many subsets of tissue thickness has been described by Stephan (2008). In addition, tissue thickness values that do not follow linear trends are problematic in terms of conceptualization for the forensic artist who has to reconstruct / approximate facial features based on tissue thickness data. In order to make the data more useful and because few significant differences were found when subdividing the dataset into three age groups, the number of age groups were reduced to two.

4.4.3.2.1. Ages 6 - 8 years and 9 - 13 years

The division between ages and 8 and 9 corresponds to other authors (Manhein *et al*., 2000 and Wilkinson, 2002) which will enable comparison of results to their data as the data ranges are the same.

Tissue thickness values (mean, SD, 95% CI and ANOVA p-value) for children aged 6 - 8 years and 9 - 13 years olds per ancestry are presented in Tables 4.34 and 4.35. Comparisons between groups by means of ANOVA *post hoc* Bonferroni tests showed significant differences at four landmarks (end nasal, midphiltrum, labiomentale and beneath the chin (Tables 4.34 and 4.35). Bar charts (Figures 4.41 to 4.50) show soft tissue thickness at each landmark for 6 - 8 year old and 9 -13 year old groups.

Tables 4.36 and 4.37 present tissue thickness (mean, SD, 95% CI and ANOVA p-value) per age group (6 - 8 years and 9 - 13 years) and sex. Significant differences between sexes were seen in the lower face at the labiomentale, pogonion and beneath the chin.

The tissue thickness data for 6 - 8 year olds and 9 - 13 year olds were then further analyzed in terms of both ancestry and sex (Tables 4.38 to 4.41). Comparisons between groups by means of ANOVA *post hoc* Bonferroni tests showed significant differences at end nasal, midphiltrum, labiomentale and beneath the chin (Tables 4.42 and 4.45). Significant differences were seen mostly between young and older Coloured males at the end nasal and midphiltrum. Significant differences were noted between 9 - 13 year Black and Coloured females at the midphiltrum, while the older Black and Coloured males differed significantly at the labiomentale. The older Black male group differed significantly from the older Coloured females beneath the chin. No specific trend could be identified between and within groups even at landmarks where significant differences were seen such as end nasal (Figure 4.44), midphiltrum (Figure 4.45), labiomentale (Figure 4.47) and beneath chin (Figure 4.50).

A possible reason for the absence of trends as seen in previous sections lies in the ages that were pooled. In terms of development, it would make sense to group 6 to 8 year old children together. However, pooling 9 year olds with ages up and including 13 is problematic as pubertal changes are bound to set in from age 11 onwards. As a result, the 9 to 13 year old group is too heterogonous for comparison, obscuring trends in tissue thickness values.

4.4.3.2.2. Ages 6 - 11 years and 12 & 13 years

The division of the age groups between 11 and 12 is based on a paper by Stephan and Simpson (2008b). They motivated the division at this age as their data density was high at this particular point.

In the current study, tissue thickness data were also subdivided at this point and the tissue thickness data for children aged 6 - 11 years and 12 & 13 years were pooled with ancestry and sex combined. Tissue thickness were larger in the older group compared to the younger group, except at the end nasal landmark (Table 4.46). The results show that significant differences exist between these age groups at the midphiltrum, labiale inferius, labiomentale and beneath the chin (Table 4.46). However, the differences in mm were small (0.5 - 1 mm).

When taking age (6 - 11 years and 12 & 13 years) and ancestry into account, differences were also seen at the same landmarks as above, but with the addition of the end nasal landmark (Table 4.47 and 4.48). The actual differences in mm at the end nasal were less than 0.4 mm between groups. At the midphiltrum difference between the Black and Coloured groups were between 1.5 and 2.6 mm with tissue thickness at this landmark being larger in the Coloured children compared to the Black children. At the labiale inferius and labiomentale the tissue thickness of the Coloured group were 1.0 - 1.5 mm larger than in the Black group.

Tables 4.49 and 4.50 present the results of the 6 - 11 year old group and 12 & 13 year old group when considering sex. Significant differences were only seen at the labiomentale and beneath the chin. However, at both these landmarks the differences were less than 1 mm.

4.4.3.2.3. Ages 6 - 9 and 10 -13 years

Age groups were pooled with the division at age 10, creating a 6 - 10 year old group and an 11 to 13 year old group. Tissue thickness values (mean, SD, and 95% CI) per age group (6 - 10 year olds, 11 - 13 year olds) are presented in Table 4.51. Significant differences between the 6 - 10 year olds and 11 - 13 year olds were seen at the labiale inferius, pogonion and beneath the chin. None of the differences were more than 0.76 mm.

In Tables 4.52 and 4.53, the age groups (6 - 10 years and 11 - 13 years) per ancestry significant differences were noted at seven of the ten landmarks. These included the glabella, end nasal, midphiltrum, labiale inferius, labiomentale, pogonion and beneath the chin. The difference in mm at the end nasal and glabella was less than 1 mm, while the differences at the labiale inferius, labiomentale, pogonion and beneath the chin ranged between 1.0 and 1.6 mm. The largest difference was seen at the midphiltrum where the tissue thickness in the Coloured group was almost 2.7 mm larger compared to the Black group.

In Tables 4.54 and 4.55 comparison of the 6 - 10 year old group and 11 - 13 year old group per age showed significant differences at five of the ten landmarks. Significant differences were seen mostly in the lower face region at the midphiltrum, labiale inferius, pogonion and beneath the chin. Only at the pogonion was the actual difference more than 1 mm at the other landmarks, the differences were less than 1 mm.

Tissue thickness data per age group (6 - 10 year old group and 11 - 13 year old group) per sex and ancestry are presented in Tables 4.56 to 4.59.

Comparisons between groups by means of ANOVA with Bonferroni corrections showed significant differences at the midphiltrum, labiale inferius, labiomentale, pogonion and beneath the chin (Tables 4.60 to 4.64).

At the midphiltrum, several significant differences were seen between the groups (Table 4.60). Young Black females differed significantly from both young Coloured males and young Coloured females. Older Black females also differed significantly from both older Coloured males and older Coloured females.

Only the young Black females and older Coloured males differed significantly at the labiale inferius (Table 4.61) young Coloured females and older Black females showed a significant difference at the pogonion (Table 4.64). At the labiomentale differences were seen between the young Black males and Coloured groups (young Black males *vs* young Coloured males; young Black males *vs* older Coloured males; young Black males *vs* older Coloured females), the exception being the young Coloured females where no significant difference were detected compared to young Black males (Table 4.62). At the landmark beneath the chin significant differences were seen between the young Black males and older Coloured females as well as between the young and older Coloured females (Table 4.64).

A general trend for an increase in tissue thickness between 6 - 10 year old groups, compared to the 11 -13 year old groups, regardless of ancestry and sex, could be seen at most landmarks in the lower face region (midphiltrum, labiale inferius, pogonion, beneath chin). A decrease in tissue thickness was seen in the Coloured females aged 11 - 13 years in the upper face region, specifically at the supraglabella, glabella, nasion and end nasal landmarks.

4.4.4. Comparison of tissue thickness of South African children to North American children, British children and generalized pooled datasets

Williamson *et al.* (2002) reported tissue thickness values for African-American children in different age groups (6 - 9 years, 10 - 12 years, ≥13 years). Tables 4.65 to 4.67 present the results of the comparison of Black male and female children to Williamson *et al*. (2002). In addition, results of Williamson *et al*. (2002) were also compared to Coloured children per age and sex (Tables 4.68 - 4.70). Tissue thickness of South African Black males in the 10 - 12 year old and ≥13 year old groups were generally smaller and differed significantly from their American counterparts. The tissue thickness in Black females in the 10 - 12 year old group were smaller and differed at more landmarks from Williamson

et al. (2000) compared to the other age groups. In the 10 - 12 year old category all Black South African children Black were significantly different from American children regardless of sex. When the Coloured children were compared to the American children, the least number of differences were seen in the young age group (6 - 9 years). Tissue thickness at almost all landmarks was significantly less between Coloured children ages 10 to 13 and the American children of the same ages, regardless of sex. In the 6 to 9 year old groups the tissue thickness at the glabella of Coloured females was significantly larger than values of Williamson *et al*. (2002). Tissue thickness values measured at the supraglabella and midphiltrum were also larger in the Coloured females in the young age group, however the differences were not significant.

In Tables 4.71 to 4.74 tissue thickness data of Black and Coloured children were compared to White British children. The data were pooled per age, sex and ancestry. The following age categories were used: 6 to 8 year olds and 9 to 13 year olds. When comparing Black males and female aged 6 - 8 years, differences in tissue thickness were seen at most landmarks, the exceptions being the landmarks at the chin in Black males; and nasion and midphiltrum in Black females which were larger compared to White males and females respectively. In Coloured children the same pattern emerged and the tissue thickness values for Coloured children were generally larger than the White group from Wilkinson (2002). For age group 9 - 13, the tissue thickness at most landmarks was larger in the South African sample and differed at most landmarks from the White British children. Manhein *et al*. (2000) used similar age categories as Wilkinson (2002) to report their African American data. Comparison of the South African data to Manhein *et al.* (2000) is presented in Tables 4.75 to 4.78. Again the tendency of the South African data to be larger than their American counterparts was observed for all ages regardless of sex.

Age has been identified by Williamson *et al.* (2002) as the principal factor that affects tissue thickness. Differences in tissue thickness between the different age groups within the same sex and same ancestry were noted mainly in the middle and lower face region (Figures 4.31 to 4.34). Significant increases occurred in Black males between the middle and oldest age groups, specifically related to the midphiltrum (Figure 4.31). In the case of the Black females, significant increases were also seen in the same age groups and facial region of the males, but the increase in tissue thickness also concerned the labiomentale (Figure 4.32). In the Coloured male children some landmarks in the midface region (midphiltrum, labiale superius and labiale inferius) also showed an increase in thickness between the middle and oldest age groups (figure 4.33). In Coloured children,

tissue thickness at the labiomentale did not increase with age progression. In the Coloured male group it decreased and in the female group, it first increased and then decrease with ageing (Figure 4.34). Tissue thickness at the nasion also did not progressively increase with age. In Black children there was first an increase between the younger groups, followed by a decrease between the older 2 groups. In Coloured females, there was a general decrease of tissue thickness over the nasion with age. Changes in tissue thickness with age progression were more pronounced in the Coloured children at the forehead landmarks (supraglabella and glabella), compared to the Black children.

Differences between males and females were seen at the midphiltrum of the 6 - 9 year old Black children (Figure 4.35). In the 10 & 11 year old males and females the tissue thickness at the midphiltrum was still larger in males compared to females (Figure 4.36). In contrast, tissue thickness at the glabella and at the pogonion was larger in females than in males. This tendency could also be seen in the 12 & 13 year old group, where the tissue thickness in females was larger than the males at even more landmarks which included the supraglabella, glabella, labiale superius, labiale inferius, labiomentale and pogonion (Figure 4.37). The tissue thickness at the midphiltrum was larger in males than in females at this older age group (Figure 4.37). Sex differences within the same age group were not apparent in the 6 - 9 year old and the 10 & 11 year old Coloured children (Figures 4.38 and 4.39). However, differences were noted at the midphiltrum, labiale superius and labiale inferius between the males and females of the 12 & 13 year old group of Coloured children (Figure 6.9).

Wilkinson (2006) states that the ancestry of adolescent skulls can be determined with a success rate of 80%. The question is whether facial soft tissue thickness is also distinct between groups of different ancestry. In the current study, tissue thicknesses were consistently larger in Coloured males compared to Black males regardless of age group (Figures 4.41 to 4.43). Differences between Black and Coloured children in the 6 - 9 year old and 10 & 11 year old age groups were noted at the glabella, midphiltrum, labiale inferius and labiomentale. In the 12 & 13 year old group, tissue thickness in the Coloured males was larger at landmarks of the forehead (supraglabella, glabella and nasion) as well as middle face and lower face landmarks. The exception was the end nasal where no difference between the groups was seen. When comparing females of the same ages, but of different ancestry, it was observed that the tissue thickness of Coloured females was also consistently larger compared to Black females in the 6 - 9 year old group (Figures 4.44 to 4.46). Landmarks where differences were seen included the glabella, nasion, midphiltrum,

labiale inferius and labiomentale. In the 10 & 11 year old group, differences between Black and Coloured females were seen at the midphiltrum, labiale inferius and labiomentale (Figure 4.45). At the pogonion the tissue thickness in Black females were larger compared to Coloured females in this age group. Tissue thickness in Black females aged 12 & 13 years were larger compared to Coloured females at the pogonion, labiale superius, labiale inferius and glabella (Figure 4.46). At the midphiltrum, the tissue thickness value of Coloured females remained larger compared to the Black females. In general tissue, thickness were larger in Coloured males compared to Black males as well as in Coloured females compared to Black females aged 6 - 9 years and at most landmarks in the 10 & 11 year old groups, with the exception of the pogonion. In the older age group (12 & 13 year old) tissue thickness in Black females increase and as a result tissue thickness at more landmarks was larger in Black females than in Coloured females.

Prof Stephan has published several papers in which he suggests that that tissue thickness data be pooled into two age groups without considering differences in terms of sex, ancestry and methodologies (Stephan and Simpson, 2008a, 2008b, Stephan *et al*., 2013, Stephan, 2014). Table 4.79 provides a comparison between tissue thickness values of Stephan and Simpson (2008b) and the current study. Differences between the younger age groups of Stephan and Simpson (2008b) and the current study are less than 2 mm. Comparison of the older age groups of the two studies showed differences between 2 mm and 3 mm. According to Table 4.79, tissue thickness differences were as follow: labiale inferius: 2.1 mm; labiale superius: 2.2 mm; nasion: 2.9 mm; and midphiltrum: 3.0 mm. These differences were less than 3 mm, which is considered of little practical value (Stephan and Simpson, 2008a, 2008b, Stephan *et al*., 2013, Stephan, 2014). However, if the percentage difference is taken into account, the values of Stephan and Simpson (2008b) are 25% larger at the midphiltrum and 56% larger at the nasion. These large differences in percentages indicate that differences of between 2 mm and 3 mm might still have practical value, despite being perceived as too small to have any practical impact.

4.4.5. Facial profile and tissue thickness differences

Tissue thickness data were analyzed per facial profile, also known as “skeletal type” (Utsuno, 2005, 2007, 2010, 2014). This term describes the relationship of the mandible to the maxilla and can be determined by measuring angle “ANB” which enables the researcher to divide the sample into three classes: Class I (ANB = 2 to 4 degrees, which

presents a straight facial profile); class II (ANB > 4 degrees, results in convex facial profile) and class III (ANB < 2 degrees, results in a concave facial profile).

Although the sample consisted of a total of 388 children, subdividing the sample in classes per age, sex and ancestry was not possible as each subcategory then only consisted of a very small number of children and statistical analysis could not be perform on such small samples.

Therefore, in the followings sections, tissue thickness data were analyzed in terms of classes with age, sex and ancestry combined (section 4.4.4.1). In section 4.4.4.2 tissue thickness data were subdivided into class and age (sex and ancestry pooled), while in section 4.4.4.3 tissue thickness data were subdivided into class and ancestry (age and sex pooled). In the last section (4.4.4.4) tissue thickness data per sex was considered.

4.4.5.1. Differences between class I, II, III (age, sex and ancestry combined)

Tissue thickness values of the sample (age, sex and ancestry combined) per three different classes (mean, SD, 95% CI and ANOVA p-value) are presented in Table 4.80. Significant differences were seen between the classes at the nasion, midphiltrum and labiale superius. Table 4.81 indicates the differences in mm between the different classes. At the nasion the difference between class I and class III was 1.08 mm, at the midphiltrum, the difference between class I and class II was 1.81 mm and between class I and class III the difference was 1.06 mm. All other differences between classes were less than 1 mm.

4.4.5.2. Differences between class I, II, III per age (sex and ancestry combined)

Tissue thickness data per class and age (6 - 10 years and 11 - 13 years) are presented in Tables 4.82 and 4.83. Significant differences were seen at five landmarks: Nasion, midphiltrum, labiale inferius, labiomentale and beneath the chin. The class I 6 - 10 year old group and class I 11 - 13 year old group differed with more than 1 mm at the midphiltrum, labiomentale and beneath the chin.

4.4.5.3. Differences between class I, II, III per ancestry (age and sex combined)

Significant differences were seen at more landmarks when class per ancestry was considered (Tables 4.84 and 4.85). These included the nasion, end nasal, midphiltrum, labiomentale and beneath the chin. Tissue thickness difference in mm was the largest between Black and Coloured class I and class III children (class I difference: 4.34 mm; class III difference: 2.89 mm) (Table 4.84). Differences in tissue thickness of more than 1

mm were seen at the labiomentale between class II Black and Coloured children and beneath the chin between class I Black and Coloured children (Table 4.85). Tissue thickness differences at the nasion and end nasal landmarks were less than 1 mm despite the fact that the differences at these landmarks were determined as being significant by ANOVA.

4.4.5.4. Differences between class I, II, III per sex (age and ancestry combined)

In Tables 4.86 and 4.87 descriptive statistics, ANOVA p-value and difference in mm of tissue thickness of classes per sex are presented. Significant differences were seen at only at the nasion and midphiltrum. Only between class III males and class III females at the midphiltrum (Table 4.86) and pogonion (Table 4.87) were the difference in mm more than 1 mm.

4.4.5.5. Summary of differences between classes

In summary, differences were seen in facial profile classes (age, sex and ancestry combined) at three landmarks (nasion, midphiltrum and labiale superius), however the actual differences were less than 2 mm. When age was added as a variable, five landmarks (nasion, midphiltrum, labiale inferius, labiomentale and beneath the chin) showed differences between classes, most being in the lower face region. Differences of more than 1 mm was seen between class I children at the midphiltrum, labiomentale and beneath the chin. When classes are subdivided by ancestry differences at five landmarks in the upper and lower face regions (the nasion, end nasal, midphiltrum, labiomentale and beneath the chin) were seen with large tissue thickness differences (2 mm - 4.5 mm). Subdividing classes by sex showed differences only at two landmarks (nasion and midphiltrum), but differences were less than 2 mm.

4.4.6. Comparison of tissue thickness between South African and Japanese children

In Tables 4.88 to 4.90 the results of the current study are compared to that of Utsuno (2005) in terms of age groups (6 - 9 years; 10 & 11 years; and 12 & 13 years) per ancestry. Significant differences between class I Black females and Japanese females were seen in the 6 - 9 year old group at the labiomentale. A comparison between the class II Black females and class II Japanese females showed significant differences at the glabella and nasion, labiale inferius and labiomentale. Class III Black females differed significantly from class III Japanese females at the nasion, labiale superius and beneath the chin.

Comparison of tissue thickness values of the 10 & 11 year old age group between Black females and Japanese females showed differences at most landmarks in class I (glabella, midphiltrum, labiale superius, labiale inferius, labiomentale and beneath the chin), less differences in class II (midphiltrum, labiale superius, labiale inferius and labiomentale), and only beneath the chin in class III. Black females in class I of the 12 & 13 year old group differed significantly from Japanese females of the same age and class at the midphiltrum and labiomentale. Tissue thickness at the nasion, end nasal, upper and lower lip and labiomentale were significantly different between Black females and Japanese females in the 12 & 13 year old age group of class III.

In summary, tissue thicknesses at several landmarks were different in Class I and Class II Black females and Japanese females in the 10 & 11 year old group. In general, the tissue thickness in class II Black females was different compared to the Japanese females in all age groups.

In Coloured females differences were seen at most landmarks regardless of age and class when compared to Japanese females (Tables 4.91 to 4.92). Comparison of the 6 - 9 year old group could not be performed as there was only one Coloured female in the group. Class III Coloured and Japanese females differed in the upper face region (nasion, end nasal, midphiltrum) in the 10 & 11 year old age group and from nasion to labiale inferius in the 12 & 13 year old age group. In class II individuals, differences were seen at the glabella, end nasal, lips, labiomentale of the Black and Japanese female 6 - 9 year old and 10 & 11 year groups. In class I, tissue thickness differed significantly at all landmarks except the chin (pogonion and beneath the chin).

More differences were seen when comparing the Coloured females to Japanese females regardless of age and sex, as opposed to the Black females where differences were seen at fewer landmarks, mostly at older age groups.

Table 4.1: Summary of the sample composition for tissue thickness

Sex	Black children	Coloured children	Total (n)	
Male	43	110	153	(40%)
Female	47	188	235	(60%)
Total (n)	**90 (23%)**	**298 (77%)**	**388 (100%)**	

Table 4.2: Details of the sample composition for tissue thickness per age, sex and ancestry

Age group	Black		Coloured		Total
	Male	Female	Male	Female	
6	2	0	0	0	2 (0.5%)
7	5	4	5	5	19 (4.8%)
8	2	6	8	6	22 (5.7%)
9	4	6	21	24	55 (14.2%)
10	11	6	10	26	53 (13.7%)
11	7	9	21	37	74 (19.1%)
12	5	11	22	52	90 (23.2%)
13	7	5	23	38	73 (18.8%)
Total	**43 (11%)**	**47 (12%)**	**110 (28%)**	**188 (49%)**	**388 (100%)**

Table 4.3: Composition of tissue thickness sample per age group and sex

Sex	Age groups			Total
	6 to 9 years	10 & 11 years	11 & 12 years	
Male	47	49	57	153 (39%)
Female	51	78	106	235 (65%)
Total	**98 (25%)**	**127 (33%)**	**163 (42%)**	**388 (100%)**

Table 4.4: Composition of tissue thickness sample per age group and ancestry

Ancestry	Age groups			Total
	6 to 9 years	10 & 11 years	11 & 12 years	
Black	29	33	28	90 (23%)
Coloured	69	94	135	298 (77%)
Total	**98 (25%)**	**127 (33%)**	**163 (42%)**	**388 (100%)**

Table 4.5: Intra- and interobserver repeatability for tissue thickness measurements (n=27)

Landmark	Intraobserver repeatability	Interobserver repeatability
Supraglabella	0.999	0.999
Glabella	0.999	0.979
Nasion	0.999	0.995
End nasal	0.999	0.998
Midphiltrum	0.999	0.999
Upper lip border	0.999	0.999
Lower lip border	0.998	0.884
Labiomentale	0.954	0.997
Pogonion	0.998	0.999
Beneath chin	0.995	0.991
Angle ANB	0.998	0.997

Table 4.6: Tissue thickness for Black and Coloured children with age and sex combined

Landmark	Group	N	Mean	SD	95% Confidence Interval		T-test, p-value	Difference in mm (Black minus Coloured)
Supraglabella	Black	90	4.88	0.96	4.679	5.079	0.878	0.02
	Coloured	298	4.86	1.24	4.716	4.999		
	Total	388	4.86	1.18	4.745	4.980		
Glabella	Black	90	5.74	1.06	5.518	5.961	0.034	-0.35
	Coloured	298	6.08	1.43	5.921	6.247		
	Total	388	6.00	1.36	5.869	6.140		
Nasion	Black	90	4.96	1.16	4.718	5.205	0.015	-0.41
	Coloured	298	5.37	1.46	5.204	5.538		
	Total	388	5.28	1.41	5.136	5.417		
End nasal	Black	90	2.54	0.64	2.411	2.678	0.000	0.34
	Coloured	298	2.21	0.70	2.128	2.287		
	Total	388	2.29	0.70	2.216	2.355		
Midphiltrum	Black	90	10.63	2.50	10.105	11.151	0.000	-2.12
	Coloured	298	12.74	3.17	12.384	13.106		
	Total	388	12.25	3.15	11.939	12.569		
Labiale superius	Black	90	12.47	1.98	12.055	12.883	0.774	0.08
	Coloured	298	12.39	2.29	12.132	12.653		
	Total	388	12.41	2.22	12.189	12.632		
Labiale inferius	Black	90	12.83	2.10	12.392	13.271	0.040	-0.55
	Coloured	298	13.38	2.27	13.126	13.643		
	Total	388	13.26	2.24	13.033	13.479		
Labiomentale	Black	90	10.83	1.68	10.482	11.184	0.000	-1.03
	Coloured	298	11.86	2.11	11.623	12.104		
	Total	388	11.62	2.06	11.419	11.830		
Pogonion	Black	90	10.91	2.09	10.478	11.352	0.694	0.12
	Coloured	298	10.80	2.64	10.495	11.096		
	Total	388	10.82	2.52	10.572	11.074		
Beneath chin	Black	90	5.56	1.29	5.292	5.832	0.003	-0.57
	Coloured	298	6.13	1.67	5.942	6.323		
	Total	388	6.00	1.60	5.840	6.160		

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)

Table 4.7: Tissue thickness for male and female children with age and ancestral groups combined

Landmark	Group	N	Mean	SD	95% Confidence Interval		T-test, p-value	Difference in mm (Male minus Female)
Supraglabella	Male	153	4.81	1.16	4.623	4.992	0.462	-0.09
	Female	235	4.90	1.20	4.744	5.052		
	Total	388	4.86	1.18	4.745	4.980		
Glabella	Male	153	5.99	1.25	5.788	6.188	0.853	-0.03
	Female	235	6.01	1.43	5.831	6.198		
	Total	388	6.00	1.36	5.869	6.140		
Nasion	Male	153	5.23	1.39	5.008	5.451	0.599	-0.08
	Female	235	5.31	1.42	5.124	5.489		
	Total	388	5.28	1.41	5.136	5.417		
End nasal	Male	153	2.26	0.67	2.153	2.368	0.565	-0.04
	Female	235	2.30	0.72	2.210	2.394		
	Total	388	2.29	0.70	2.216	2.355		
Midphiltrum	Male	153	12.42	3.25	11.902	12.940	0.400	0.28
	Female	235	12.15	3.09	11.747	12.543		
	Total	388	12.25	3.15	11.939	12.569		
Labiale superius	Male	153	12.48	2.27	12.119	12.843	0.612	0.12
	Female	235	12.36	2.19	12.083	12.645		
	Total	388	12.41	2.22	12.189	12.632		
Labiale inferius	Male	153	13.27	2.37	12.894	13.650	0.910	0.03
	Female	235	13.25	2.15	12.969	13.522		
	Total	388	13.26	2.24	13.033	13.479		
Labiomentale	Male	153	11.62	2.14	11.280	11.962	0.976	-0.01
	Female	235	11.63	2.01	11.368	11.886		
	Total	388	11.62	2.06	11.419	11.830		
Pogonion	Male	153	10.45	2.29	10.081	10.813	0.017	-0.62
	Female	235	11.07	2.63	10.730	11.406		
	Total	388	10.82	2.52	10.572	11.074		
Beneath chin	Male	153	5.74	1.59	5.491	5.998	0.011	-0.42
	Female	235	6.17	1.60	5.961	6.372		
	Total	388	6.00	1.60	5.840	6.160		

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)

Table 4.8: Tissue thickness per age group (sex and ancestral groups combined) for the supraglabella, glabella, nasion and end nasal landmark

Landmark	Age	N	Mean	SD	95% Confidence Interval		ANOVA, p-value
	6	2	5.01	1.46	2.697	7.329	
	7	19	5.00	0.98	4.494	5.504	
	8	22	4.83	0.97	4.393	5.257	
	9	55	5.13	1.77	4.656	5.611	
Supraglabella	10	53	4.44	0.75	4.237	4.650	0.089
	11	74	4.72	1.19	4.443	4.993	
	12	90	5.00	1.10	4.769	5.228	
	13	73	4.91	1.01	4.678	5.148	
	Total	388	4.86	1.18	4.745	4.980	
	6	2	5.85	1.43	3.574	8.126	
	7	19	6.07	1.42	5.340	6.803	
	8	22	6.22	1.66	5.482	6.951	
	9	55	6.43	1.92	5.908	6.947	
Glabella	10	53	5.62	1.03	5.331	5.900	0.063
	11	74	5.92	1.07	5.671	6.165	
	12	90	5.84	1.37	5.551	6.126	
	13	73	6.19	1.10	5.931	6.443	
	Total	388	6.00	1.36	5.869	6.140	
	6	2	3.84	0.80	2.570	5.115	
	7	19	5.15	1.21	4.523	5.767	
	8	22	5.18	1.05	4.710	5.645	
	9	55	5.55	1.46	5.153	5.945	
Nasion	10	53	5.31	1.25	4.960	5.650	0.259
	11	74	5.04	1.49	4.700	5.390	
	12	90	5.32	1.51	4.998	5.632	
	13	73	5.37	1.38	5.053	5.697	
	Total	388	5.28	1.41	5.136	5.417	
	6	2	1.93	1.23	-0.024	3.889	
	7	19	2.24	0.52	1.978	2.512	
	8	22	2.44	0.81	2.077	2.797	
	9	55	2.30	0.83	2.072	2.521	
End nasal	10	53	2.24	0.62	2.065	2.407	0.740
	11	74	2.38	0.77	2.205	2.562	
	12	90	2.25	0.65	2.115	2.387	
	13	73	2.24	0.60	2.100	2.381	
	Total	388	2.29	0.70	2.216	2.355	

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)

Table 4.9: Tissue thickness per age group (sex and ancestral groups combined) for the midphiltrum, labiale superius, labiale inferius and labiomentale

Landmark	Age	N	Mean	SD	95% Confidence Interval		ANOVA, p-value
	6	2	10.72	2.20	7.225	14.211	
	7	19	11.18	2.86	9.712	12.657	
	8	22	12.48	3.20	11.062	13.896	
	9	55	11.94	2.64	11.229	12.656	
Midphiltrum	10	53	11.42	3.16	10.546	12.289	0.167
	11	74	12.77	2.98	12.079	13.460	
	12	90	12.53	3.20	11.862	13.202	
	13	73	12.50	3.60	11.657	13.335	
	Total	388	12.25	3.15	11.939	12.569	
	6	2	13.51	1.92	10.454	16.561	
	7	19	12.53	1.90	11.551	13.506	
	8	22	12.46	2.45	11.379	13.547	
	9	55	12.45	2.35	11.812	13.084	
Labiale superius	10	53	11.92	2.30	11.288	12.556	0.762
	11	74	12.38	1.97	11.920	12.831	
	12	90	12.48	2.13	12.035	12.927	
	13	73	12.58	2.44	12.013	13.150	
	Total	388	12.41	2.22	12.189	12.632	
	6	2	13.89	5.52	5.106	22.679	
	7	19	13.03	2.55	11.716	14.334	
	8	22	12.60	2.22	11.609	13.581	
	9	55	13.02	2.40	12.375	13.674	
Labiale inferius	10	53	12.48	2.39	11.820	13.137	0.045
	11	74	13.53	2.21	13.020	14.044	
	12	90	13.42	1.69	13.069	13.777	
	13	73	13.73	2.20	13.214	14.240	
	Total	388	13.26	2.24	13.033	13.479	
	6	2	9.40	1.56	6.910	11.885	
	7	19	10.68	1.57	9.874	11.490	
	8	22	11.06	1.69	10.315	11.814	
	9	55	12.14	2.35	11.505	12.777	
Labiomentale	10	53	10.82	1.86	10.306	11.332	0.000
	11	74	11.54	2.14	11.042	12.034	
	12	90	11.73	1.86	11.341	12.120	
	13	73	12.29	2.01	11.820	12.757	
	Total	388	11.62	2.06	11.419	11.830	

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)

Table 4.10: Tissue thickness per age group (sex and ancestral groups combined) for the pogonion and beneath chin landmark

Landmark	Age	N	Mean	SD	95% Confidence Interval		ANOVA, p-value
	6	2	9.54	1.65	6.916	12.164	
	7	19	10.42	1.49	9.654	11.188	
	8	22	10.14	1.81	9.335	10.944	
	9	55	10.64	2.73	9.899	11.376	
Pogonion	10	53	10.24	2.36	9.591	10.892	0.107
	11	74	11.33	2.71	10.704	11.962	
	12	90	11.23	2.60	10.689	11.780	
	13	73	10.73	2.45	10.160	11.302	
	Total	388	10.82	2.52	10.572	11.074	
	6	2	3.67	1.48	1.317	6.023	
	7	19	5.43	1.49	4.667	6.197	
	8	22	5.92	1.43	5.281	6.549	
	9	55	5.67	1.56	5.249	6.095	
Beneath chin	10	53	5.53	1.21	5.200	5.869	0.001
	11	74	6.42	1.72	6.020	6.819	
	12	90	6.19	1.58	5.863	6.526	
	13	73	6.21	1.66	5.820	6.595	
	Total	388	6.00	1.60	5.840	6.160	

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)

Table 4.11: Tissue thickness for children aged 6 to 9 years

Landmark	6 - 9 years (n=98)			
	Mean (mm)	SD	95% Confidence Interval	
Supraglabella	5.04	1.48	4.740	5.332
Glabella	6.29	1.75	5.943	6.647
Nasion	5.33	1.35	5.055	5.597
End nasal	2.30	0.79	2.145	2.463
Midphiltrum	11.88	2.80	11.321	12.442
Upper lip border	12.51	2.26	12.055	12.963
Lower lip border	12.96	2.52	12.458	13.470
Labiomentale	11.53	2.18	11.097	11.972
Pogonion	10.44	2.32	9.978	10.909
Beneath chin	5.60	1.56	5.291	5.915

Table 4.12: Tissue thickness for children aged 10 & 11 years

Landmark	10 & 11 years (n=127)			
	Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.60	1.03	4.422	4.785
Glabella	5.79	1.06	5.606	5.978
Nasion	5.15	1.40	4.908	5.399
End nasal	2.32	0.71	2.196	2.447
Midphiltrum	12.21	3.12	11.658	12.752
Upper lip border	12.19	2.11	11.815	12.558
Lower lip border	13.09	2.34	12.682	13.503
Labiomentale	11.24	2.05	10.877	11.599
Pogonion	10.88	2.62	10.418	11.338
Beneath chin	6.05	1.59	5.771	6.329

Table 4.13: Tissue thickness for children aged 12 & 13 years

Landmark	12 & 13 years (n=163)			
	Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.96	1.05	4.797	5.123
Glabella	5.99	1.27	5.799	6.191
Nasion	5.34	1.45	5.117	5.566
End nasal	2.25	0.63	2.149	2.343
Midphiltrum	12.52	3.37	11.994	13.038
Upper lip border	12.53	2.27	12.176	12.877
Lower lip border	13.56	1.93	13.260	13.858
Labiomentale	11.98	1.94	11.680	12.281
Pogonion	11.01	2.54	10.616	11.402
Beneath chin	6.20	1.61	5.951	6.450

Table 4.14: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) with sex and ancestry combined

Landmark	Group	6 - 9 years	10 & 11 years	12 & 13 years
Supraglabella	6 - 9 years	1.000	0.019	1.000
	10 & 11 years	0.019	1.000	0.031
	12 & 13 years	1.000	0.031	1.000
Glabella	6 - 9 years	1.000	0.017	0.247
	10 & 11 years	0.017	1.000	0.611
	12 & 13 years	0.247	0.611	1.000
Nasion	6 - 9 years	1.000	1.000	1.000
	10 & 11 years	1.000	1.000	0.778
	12 & 13 years	1.000	0.778	1.000
End nasal	6 - 9 years	1.000	1.000	1.000
	10 & 11 years	1.000	1.000	1.000
	12 & 13 years	1.000	1.000	1.000
Midphiltrum	6 - 9 years	1.000	1.000	0.349
	10 & 11 years	1.000	1.000	1.000
	12 & 13 years	0.349	1.000	1.000
Labiale superius	6 - 9 years	1.000	0.841	0.349
	10 & 11 years	0.841	1.000	0.588
	12 & 13 years	0.349	0.588	1.000
Labiale inferius	6 - 9 years	1.000	1.000	0.112
	10 & 11 years	1.000	1.000	0.233
	12 & 13 years	0.111	0.233	1.000
Labiomentale	6 - 9 years	1.000	0.842	0.264
	10 & 11 years	0.842	1.000	0.007
	12 & 13 years	0.264	0.007	1.000
Pogonion	6 - 9 years	1.000	0.599	0.112
	10 & 11 years	0.599	1.000	1.000
	12 & 13 years	0.112	1.000	1.000
Beneath chin	6 - 9 years	1.000	0.112	0.011
	10 & 11 years	0.112	1.000	1.000
	12 & 13 years	0.011	1.000	1.000

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)

Table 4.15: Tissue thickness for Black and Coloured children aged 6 to 9 years

Landmark	Black (n=29)				Coloured (n=69)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.88	0.94	4.518	5.233	5.10	1.65	4.706	5.500
Glabella	5.70	1.20	5.245	6.156	6.54	1.89	6.090	7.000
Nasion	4.82	0.99	4.450	5.200	5.54	1.43	5.192	5.881
End nasal	2.40	0.57	2.184	2.619	2.26	0.87	2.054	2.472
Midphiltrum	10.35	2.53	9.388	11.312	12.53	2.66	11.885	13.165
Upper lip border	12.60	1.91	11.874	13.326	12.47	2.41	11.891	13.049
Lower lip border	12.14	2.37	11.236	13.036	13.31	2.52	12.706	13.917
Labiomentale	10.52	1.65	9.897	11.152	11.96	2.25	11.419	12.498
Pogonion	10.45	1.56	9.857	11.044	10.44	2.59	9.819	11.062
Beneath chin	5.33	1.33	4.819	5.834	5.72	1.64	5.326	6.112

Table 4.16: Tissue thickness for Black and Coloured children aged 10 & 11 years

Landmark	Black (n=33)				Coloured (n=94)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.76	0.74	4.494	5.020	4.55	1.11	4.321	4.778
Glabella	5.61	0.93	5.281	3.61	5.85	1.10	5.630	6.079
Nasion	5.18	1.22	4.747	5.609	5.14	1.46	4.846	5.444
End nasal	2.70	0.79	2.416	2.977	2.19	0.64	2.060	2.321
Midphiltrum	10.03	2.39	9.186	10.880	12.97	2.99	12.355	13.580
Upper lip border	12.25	1.35	11.774	12.732	12.16	2.33	11.686	12.640
Lower lip border	12.71	1.64	12.133	13.295	13.23	2.53	12.707	13.743
Labiomentale	10.61	1.50	10.079	11.142	11.46	2.18	11.012	11.905
Pogonion	11.14	2.26	10.334	11.938	10.79	2.74	10.226	11.348
Beneath chin	5.74	1.45	5.223	6.248	6.16	1.63	5.827	6.494

Table 4.17: Tissue thickness for Black and Coloured children aged 12 & 13 years

Landmark	Black (n=28)				Coloured (n=135)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	5.03	1.18	4.569	5.486	4.95	1.03	4.771	5.122
Glabella	5.93	1.05	5.521	6.339	6.01	1.31	5.785	6.231
Nasion	4.85	1.26	4.358	5.338	5.44	1.47	5.194	5.695
End nasal	2.51	0.45	2.339	2.689	2.19	0.64	2.081	2.301
Midphiltrum	11.62	2.38	10.694	12.539	12.70	3.52	12.103	13.302
Upper lip border	12.59	2.62	11.575	13.603	12.51	2.20	12.139	12.887
Lower lip border	13.69	2.06	12.893	14.487	13.53	1.91	13.206	13.858
Labiomentale	11.42	1.80	10.716	12.114	12.10	1.96	11.765	12.431
Pogonion	11.13	2.33	10.232	12.037	10.98	2.59	10.542	11.424
Beneath chin	5.60	1.03	5.203	5.998	6.32	1.69	6.038	6.612

Table 4.18: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the supraglabella, glabella, nasion and midphiltrum landmarks

Landmark	Group	Black			Coloured		
		6 - 9 years	10 & 11 years	12 & 13 years	6 - 9 years	10 & 11 years	12 & 13 years
Supraglabella	Black 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Black 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Black 12 & 13 years	1.000	1.000	1.000	1.000	0.881	1.000
	Coloured 6 - 9 years	1.000	0.046	1.000	1.000	1.000	1.000
	Coloured 10 & 11 years	0.046	1.000	0.881	1.000	1.000	0.181
	Coloured 12 & 13 years	1.000	1.000	1.000	1.000	0.181	1.000
Glabella	Black 6 - 9 years	1.000	1.000	1.000	0.068	1.000	1.000
	Black 10 & 11 years	1.000	1.000	1.000	0.016	1.000	1.000
	Black 12 & 13 years	1.000	1.000	1.000	0.612	1.000	1.000
	Coloured 6 - 9 years	0.068	0.016	0.612	1.000	0.018	0.105
	Coloured 10 & 11 years	1.000	1.000	1.000	0.018	1.000	1.000
	Coloured 12 & 13 years	1.000	1.000	1.000	0.105	1.000	1.000
Nasion	Black 6 - 9 years	1.000	1.000	1.000	0.348	1.000	0.465
	Black 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Black 12 & 13 years	1.000	1.000	1.000	0.428	1.000	0.609
	Coloured 6 - 9 years	0.328	1.000	0.428	1.000	1.000	0.105
	Coloured 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Coloured 12 & 13 years	0.465	1.000	0.609	0.105	1.000	1.000
End nasal	Black 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Black 10 & 11 years	1.000	1.000	1.000	0.045	0.004	0.003
	Black 12 & 13 years	1.000	1.000	1.000	1.000	0.433	0.357
	Coloured 6 - 9 years	1.000	0.045	1.000	1.000	1.000	1.000
	Coloured 10 & 11 years	1.000	0.004	0.433	1.000	1.000	1.000
	Coloured 12 & 13 years	1.000	0.002	0.357	1.000	1.000	1.000
Midphiltrum	Black 6 - 9 years	1.000	1.000	1.000	0.019	0.001	0.003
	Black 10 & 11 years	1.000	0.633	1.000	0.002	0.000	0.000
	Black 12 & 13 years	1.000	0.633	1.000	1.000	0.579	1.000
	Coloured 6 - 9 years	0.019	0.002	1.000	1.000	1.000	1.000
	Coloured 10 & 11 years	0.001	0.000	0.579	1.000	1.000	1.000
	Coloured 12 & 13 years	0.003	0.000	1.000	1.000	1.000	1.000

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)

Table 4.19: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the labiale superius, labiale inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	Black			Coloured		
		6 - 9 years	10 & 11 years	12 & 13 years	6 - 9 years	10 & 11 years	12 & 13 years
Labiale superius	Black 6 - 9 years	x	1.000	1.000	1.000	1.000	1.000
	Black 10 & 11 years	1.000	x	1.000	1.000	1.000	1.000
	Black 12 & 13 years	1.000	1.000	x	1.000	1.000	1.000
	Coloured 6 - 9 years	1.000	1.000	1.000	x	1.000	1.000
	Coloured 10 & 11 years	1.000	1.000	1.000	1.000	x	1.000
	Coloured 12 & 13 years	1.000	1.000	1.000	1.000	1.000	x
Labiale inferius	Black 6 - 9 years	1.000	1.000	0.127	0.255	0.317	0.033
	Black 10 & 11 years	1.000	1.000	1.000	1.000	1.000	0.869
	Black 12 & 13 years	1.000	1.000	1.000	0.127	1.000	1.000
	Coloured 6 - 9 years	0.255	1.000	1.000	1.000	1.000	1.000
	Coloured 10 & 11 years	1.000	1.000	1.000	0.317	1.000	1.000
	Coloured 12 & 13 years	0.033	0.869	1.000	1.000	1.000	1.000
Labiomentale	Black 6 - 9 years	1.000	1.000	1.000	0.020	0.433	0.002
	Black 10 & 11 years	1.000	1.000	1.000	0.024	0.557	0.002
	Black 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
	Coloured 6 - 9 years	0.020	0.024	1.000	1.000	1.000	1.000
	Coloured 10 & 11 years	0.433	0.557	1.000	1.000	1.000	0.269
	Coloured 12 & 13 years	0.002	0.002	1.000	1.000	0.269	1.000
Pogonion	Black 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Black 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Black 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
	Coloured 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Coloured 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Coloured 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
Beneath chin	Black 6 - 9 years	1.000	1.000	1.000	1.000	0.202	0.033
	Black 10 & 11 years	1.000	1.000	1.000	1.000	1.000	0.835
	Black 12 & 13 years	1.000	1.000	1.000	1.000	1.000	0.418
	Coloured 6 - 9 years	1.000	1.000	1.000	1.000	1.000	0.150
	Coloured 10 & 11 years	0.202	1.000	1.000	1.000	1.000	1.000
	Coloured 12 & 13 years	0.033	0.835	0.418	0.150	1.000	1.000

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)

Table 4.20: Tissue thickness for male and female children aged 6 to 9 years

Landmark	Male (n=47)				Female (n=51)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.82	1.41	4.407	5.234	5.23	1.52	4.805	5.663
Glabella	6.27	1.66	5.781	6.758	6.32	1.85	5.798	6.838
Nasion	5.24	1.30	4.856	5.620	5.41	1.40	5.012	5.801
End nasal	2.24	0.80	2.006	2.475	2.36	0.79	2.140	2.585
Midphiltrum	12.04	3.05	11.144	12.937	11.74	2.56	11.015	12.455
Upper lip border	12.57	2.21	11.923	13.221	12.45	2.33	11.794	13.106
Lower lip border	13.11	2.78	12.295	13.926	12.83	2.28	12.186	13.471
Labiomentale	11.55	2.38	10.852	12.246	11.52	2.01	10.956	12.086
Pogonion	10.55	2.30	9.874	11.223	10.35	2.37	9.681	11.012
Beneath chin	5.52	1.83	4.981	6.055	5.68	1.27	5.324	6.038

Table 4.21: Tissue thickness for male and female children aged 10 & 11 years

Landmark	Male (n=49)				Female (n=78)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.47	0.88	4.214	4.721	4.69	1.11	4.438	4.939
Glabella	5.61	0.93	5.348	5.879	5.90	1.12	5.650	6.157
Nasion	5.01	1.40	4.608	5.413	5.24	1.40	4.929	5.558
End nasal	2.25	0.61	2.074	2.423	2.37	0.77	2.194	2.542
Midphiltrum	12.13	2.76	11.336	12.923	12.25	3.34	11.500	13.005
Upper lip border	12.05	2.09	11.451	12.654	12.27	2.14	11.789	12.752
Lower lip border	12.98	2.46	12.271	13.682	13.17	2.27	12.653	13.677
Labiomentale	11.13	1.87	10.598	11.671	11.30	2.17	10.813	11.792
Pogonion	10.21	2.24	9.563	10.848	11.30	2.76	10.676	11.923
Beneath chin	5.69	1.41	5.282	6.093	6.28	1.66	5.904	6.651

Table 4.22: Tissue thickness for male and female children aged 12 & 13 years

Landmark	Male (n=57)				Female (n=106)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	5.09	1.07	4.807	5.373	4.89	1.05	4.689	5.092
Glabella	6.08	1.02	5.808	6.349	5.95	1.38	5.683	6.216
Nasion	5.41	1.44	5.029	5.793	5.30	1.46	5.023	5.587
End nasal	2.29	0.62	2.122	2.452	2.22	0.63	2.103	2.346
Midphiltrum	12.99	3.73	11.996	13.976	12.26	3.15	11.656	12.870
Upper lip border	12.78	2.43	12.130	13.421	12.39	2.17	11.974	12.810
Lower lip border	13.66	1.86	13.165	14.153	13.51	1.98	13.125	13.886
Labiomentale	12.10	2.08	11.546	12.651	11.92	1.87	11.557	12.277
Pogonion	10.57	2.35	9.947	11.195	11.24	2.62	10.740	11.748
Beneath chin	5.98	1.51	5.579	6.381	6.32	1.66	5.999	6.639

Table 4.23: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the supraglabella, glabella, nasion, end nasal and midphiltrum

Landmark	Group	Males			Females		
		6 - 9 years	10 & 11 years	12 & 13 years	6 - 9 years	10 & 11 years	12 & 13 years
Supraglabella	Males 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 10 & 11 years	1.000	1.000	0.096	0.017	1.000	0.546
	Males 12 & 13 years	1.000	0.096	1.000	1.000	0.732	1.000
	Females 6 - 9 years	1.000	0.017	1.000	1.000	0.145	1.000
	Females 10 & 11 years	1.000	1.000	0.732	0.145	1.000	1.000
	Females 12 & 13 years	1.000	0.546	1.000	1.000	1.000	1.000
Glabella	Males 6 - 9 years	1.000	0.266	1.000	1.000	1.000	1.000
	Males 10 & 11 years	0.266	1.000	1.000	0.141	1.000	1.000
	Males 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 6 - 9 years	1.000	0.141	1.000	1.000	1.000	1.000
	Females 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
Nasion	Males 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
End nasal	Males 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
Midphiltrum	Males 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 12 & 13 years	1.000	1.000	1.000	0.607	1.000	1.000
	Females 6 - 9 years	1.000	1.000	0.607	1.000	1.000	1.000
	Females 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)

Table 4.24: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the labiale superius, labiale inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	Males			Females		
		6 - 9 years	10 & 11 years	12 & 13 years	6 - 9 years	10 & 11 years	12 & 13 years
Labiale superius	Males 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
Labiale inferius	Males 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
Labiomentale	Males 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 12 & 13 years	1.000	1.000	1.000	0.819	1.000	1.000
	Females 6 - 9 years	1.000	1.000	0.819	1.000	1.000	1.000
	Females 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000
Pogonion	Males 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Males 10 & 11 years	1.000	1.000	0.242	1.000	1.000	0.412
	Males 12 & 13 years	1.000	0.242	1.000	1.000	0.395	1.000
	Females 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000
	Females 10 & 11 years	1.000	1.000	0.395	1.000	1.000	0.675
	Females 12 & 13 years	1.000	0.412	1.000	1.000	0.675	1.000
Beneath chin	Males 6 - 9 years	1.000	1.000	1.000	1.000	0.147	0.062
	Males 10 & 11 years	1.000	1.000	1.000	0.559	0.628	0.325
	Males 12 & 13 years	1.000	1.000	1.000	0.280	1.000	1.000
	Females 6 - 9 years	1.000	0.559	0.280	1.000	1.000	1.000
	Females 10 & 11 years	0.147	0.628	1.000	1.000	1.000	1.000
	Females 12 & 13 years	0.062	0.325	1.000	1.000	1.000	1.000

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)

Table 4.25: Tissue thickness for Black children aged 6 to 9 years

Landmark	Male (n=13)				Female (n=16)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.76	1.05	4.126	5.395	4.97	0.87	4.508	5.430
Glabella	5.78	1.35	4.960	6.591	5.64	1.10	5.053	6.225
Nasion	4.86	0.45	4.593	5.136	4.79	1.28	4.108	5.477
End nasal	2.33	0.74	1.883	2.772	2.46	0.41	2.241	2.681
Midphiltrum	11.23	2.66	9.620	12.832	9.64	2.25	8.437	10.840
Labiale superius	12.38	2.45	10.901	13.860	12.78	1.39	12.037	13.519
Labiale inferius	12.45	2.55	10.909	13.990	11.88	2.26	10.678	13.084
Labiomentale	10.30	1.81	9.200	11.394	10.71	1.54	9.891	11.529
Pogonion	10.47	1.64	9.474	11.458	10.44	1.55	9.615	11.262
Beneath chin	4.98	1.46	4.096	5.855	5.61	1.20	4.973	6.251

Table 4.26: Tissue thickness for Black children aged 10 & 11 years

Landmark	Male (n=18)				Female (n=15)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.68	0.60	4.380	4.977	4.85	0.90	4.355	5.346
Glabella	5.32	0.70	4.972	5.667	5.96	1.07	5.367	6.557
Nasion	5.12	1.07	4.585	5.648	5.25	1.41	4.472	6.032
End nasal	2.63	0.51	2.378	2.888	2.77	1.05	2.192	3.354
Midphiltrum	10.69	2.23	9.585	11.803	9.24	2.40	7.910	10.570
Labiale superius	12.23	1.49	11.494	12.975	12.28	1.22	11.602	12.949
Labiale inferius	12.61	1.82	11.708	13.516	12.84	1.45	12.035	13.637
Labiomentale	10.45	1.83	9.536	11.357	10.81	1.00	10.255	11.358
Pogonion	10.19	1.56	9.418	10.969	12.27	2.50	10.884	13.649
Beneath chin	5.40	0.93	4.930	5.860	6.14	1.84	5.124	7.164

Table 4.27: Tissue thickness for Black children aged 12 & 13 years

Landmark	Male (n=12)				Female (n=16)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.62	1.07	3.939	5.305	5.33	1.20	4.692	5.971
Glabella	5.66	1.05	4.994	6.326	6.13	1.05	5.575	6.690
Nasion	4.58	0.89	4.014	5.149	5.05	1.48	4.260	5.837
End nasal	2.58	0.37	2.346	2.814	2.46	0.51	2.193	2.736
Midphiltrum	12.41	2.87	10.582	14.233	11.02	1.80	10.062	11.984
Labiale superius	11.57	3.08	9.614	13.522	13.35	1.98	12.299	14.410
Labiale inferius	13.10	2.14	11.737	14.458	14.13	1.94	13.101	15.167
Labiomentale	11.27	1.51	10.311	12.234	11.52	2.04	10.437	12.607
Pogonion	10.14	2.55	8.522	11.766	11.88	1.90	10.867	12.888
Beneath chin	5.17	0.98	4.551	5.794	5.92	0.97	5.406	6.436

Table 4.28: Tissue thickness for Coloured children aged 6 to 9 years

Landmark	Male (n=34)				Female (n=35)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.84	1.54	4.306	5.380	5.36	1.74	4.757	5.955
Glabella	6.46	1.75	5.848	7.069	6.63	2.04	5.927	7.331
Nasion	5.38	1.49	4.862	5.900	5.69	1.38	5.213	6.162
End nasal	2.21	0.83	1.918	2.496	2.32	0.92	2.003	2.632
Midphiltrum	12.35	3.17	11.245	13.458	12.69	2.09	11.975	13.412
Labiale superius	12.65	2.15	11.896	13.395	12.30	2.66	11.386	13.214
Labiale inferius	13.36	2.85	12.368	14.359	13.26	2.19	12.508	14.015
Labiomentale	12.03	2.41	11.187	12.869	11.89	2.11	11.168	12.615
Pogonion	10.58	2.52	9.699	11.461	10.30	2.68	9.385	11.224
Beneath chin	5.73	1.93	5.052	6.399	5.71	1.32	5.261	6.165

Table 4.29: Tissue thickness for Coloured children aged 10 and 11 years

Landmark	Male (n=31)				Female (n=63)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.35	1.00	3.979	4.712	4.65	1.16	4.357	4.942
Glabella	5.78	1.01	5.415	6.153	5.89	1.14	5.602	6.178
Nasion	4.95	1.58	4.371	5.527	5.24	1.40	4.888	5.595
End nasal	2.03	0.55	1.824	2.227	2.27	0.67	2.104	2.439
Midphiltrum	12.96	2.73	11.963	13.963	12.97	3.13	12.181	13.758
Labiale superius	11.95	2.39	11.068	12.824	12.27	2.31	11.688	12.851
Labiale inferius	13.19	2.77	12.174	14.203	13.24	2.43	12.632	13.855
Labiomentale	11.53	1.80	10.875	12.193	11.42	2.36	10.827	12.015
Pogonion	10.21	2.58	9.268	11.158	11.07	2.79	10.366	11.773
Beneath chin	5.86	1.62	5.265	6.451	6.31	1.62	5.900	6.718

Table 4.30: Tissue thickness for Coloured children aged 12 and 13 years

Landmark	Male (n=45)				Female (n=90)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	5.21	1.04	4.902	5.528	4.81	1.00	4.602	5.022
Glabella	6.19	0.99	5.891	6.488	5.92	1.44	5.616	6.218
Nasion	5.63	1.48	5.186	6.077	5.35	1.46	5.044	5.657
End nasal	2.21	0.66	2.012	2.405	2.18	0.64	2.048	2.317
Midphiltrum	13.14	3.94	11.956	14.324	12.48	3.29	11.794	13.174
Labiale superius	13.10	2.16	12.448	13.747	12.22	2.17	11.767	12.675
Labiale inferius	13.81	1.78	13.275	14.342	13.39	1.97	12.980	13.807
Labiomentale	12.32	2.17	11.667	12.970	11.99	1.84	11.602	12.373
Pogonion	10.69	2.31	9.990	11.380	11.13	2.72	10.563	11.701
Beneath chin	6.19	1.56	5.725	6.665	6.39	1.75	6.023	6.756

Table 4.31: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), sex and ancestry for yhe supraglabella

Supraglabella												
Group	Black Males			Black Females			Coloured Males			Coloured Females		
	Young	Middle	Older	Young	Middle	Older	Young	Middle	Older	Young	Middle	Older
BM 6 - 9 years	x	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BM 10 & 11 years	1.000	x	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BM 12 & 13 years	1.000	1.000	x	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BF 6 - 9 years	1.000	1.000	1.000	x	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BF 10 & 11 years	1.000	1.000	1.000	1.000	x	1.000	1.000	0.040	1.000	1.000	1.000	1.000
BF12 & 13 years	1.000	1.000	1.000	1.000	1.000	x	1.000	0.406	1.000	1.000	1.000	1.000
CM 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000	x	1.000	1.000	1.000	1.000	1.000
CM 10 & 11 years	1.000	1.000	1.000	1.000	0.040	0.406	1.000	x	0.098	0.032	1.000	1.000
CM 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.098	x	1.000	0.874	1.000
CF 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.032	1.000	x	0.279	1.000
CF 10 & 11 years	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.874	0.279	x	1.000
CF 12 & 13 years	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	x

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
Young: Ages 6 – 9; Middle: Ages 10 & 11; Older: Ages 12 & 13
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.32: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age, sex and ancestry for the end nasal landmark

End nasal												
Group	Black Males			Black Females			Coloured Males			Coloured Females		
	Young	Middle	Older	Young	Middle	Older	Young	Middle	Older	Young	Middle	Older
BM 6 - 9 years	x	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BM 10 & 11 years	1.000	x	1.000	1.000	1.000	1.000	1.000	0.201	1.000	1.000	1.000	0.759
BM 12 & 13 years	1.000	1.000	x	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BF 6 - 9 years	1.000	1.000	1.000	x	0.542	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BF 10 & 11 years	1.000	1.000	1.000	0.542	x	1.000	0.542	0.040	0.405	1.000	0.753	0.145
BF12 & 13 years	1.000	1.000	1.000	1.000	1.000	x	1.000	1.000	1.000	1.000	1.000	1.000
CM 6 - 9 years	1.000	1.000	1.000	1.000	0.542	1.000	x	1.000	1.000	1.000	1.000	1.000
CM 10 & 11 years	1.000	0.201	1.000	1.000	0.040	1.000	1.000	x	1.000	1.000	1.000	1.000
CM 12 & 13 years	1.000	1.000	1.000	1.000	0.405	1.000	1.000	1.000	x	1.000	1.000	1.000
CF 6 - 9 years	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	x	1.000	1.000
CF 10 & 11 years	1.000	1.000	1.000	1.000	0.753	1.000	1.000	1.000	1.000	1.000	x	1.000
CF 12 & 13 years	1.000	0.759	1.000	1.000	0.145	1.000	1.000	1.000	1.000	1.000	1.000	x

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
Young: Ages 6 – 9; Middle: Ages 10 & 11; Older: Ages 12 & 13
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.33: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), sex and ancestry for the midphiltrum

Midphiltrum												
Group	**Black Males**			**Black Females**			**Coloured Males**			**Coloured Females**		
	Young	**Middle**	**Older**	**Young**	**Middle**	**Older**	**Young**	**Middle**	**Older**	**Young**	**Middle**	**Older**
BM 6 - 9 years	x	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BM 10 & 11 years	1.000	x	1.000	1.000	1.000	1.000	1.000	0.767	0.257	1.000	0.333	1.000
BM 12 & 13 years	1.000	1.000	x	1.000	0.466	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BF 6 - 9 years	1.000	1.000	1.000	x	1.000	1.000	0.213	0.026	0.005	0.058	0.006	0.038
BF 10 & 11 years	1.000	1.000	0.466	1.000	x	1.000	0.064	0.007	0.001	0.016	0.001	0.009
BF12 & 13 years	1.000	1.000	1.000	1.000	1.000	x	1.000	1.000	1.000	1.000	1.000	1.000
CM 6 - 9 years	1.000	1.000	1.000	0.213	0.064	1.000	x	1.000	1.000	1.000	1.000	1.000
CM 10 & 11 years	1.000	0.767	1.000	0.026	0.007	1.000	1.000	x	1.000	1.000	1.000	1.000
CM 12 & 13 years	1.000	0.257	1.000	0.005	0.001	1.000	1.000	1.000	x	1.000	1.000	1.000
CF 6 - 9 years	1.000	1.000	1.000	0.058	0.016	1.000	0.213	1.000	1.000	x	1.000	1.000
CF 10 & 11 years	1.000	0.333	1.000	1.000	0.001	1.000	1.000	1.000	1.000	1.000	x	1.000
CF 12 & 13 years	1.000	1.000	1.000	0.038	0.009	1.000	1.000	1.000	1.000	1.000	1.000	x

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
Young: Ages 6 – 9; Middle: Ages 10 & 11; Older: Ages 12 & 13
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.34: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 8 years, 9 - 13 years) and ancestry for the supraglabella, glabella, nasion, end nasal and midphiltrum landmarks

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per ancestry minus younger group per ancestry)
Supraglabella	Black 6 - 8y	19	5.01	0.89	4.576	5.435	0.959	-0.16
	Black 9 - 13y	71	4.85	0.98	4.615	5.076		
	Coloured 6 - 8y	24	4.84	1.09	4.375	5.298		0.02
	Coloured 9 - 13y	274	4.86	1.26	4.710	5.009		
	Total	388	4.86	1.18	4.745	4.980		-0.14
Glabella	Black 6 - 8y	19	5.94	1.17	5.379	6.510	0.139	-0.26
	Black 9 - 13y	71	5.68	1.03	5.441	5.927		
	Coloured 6 - 8y	24	6.27	1.75	5.528	7.009		-0.20
	Coloured 9 - 13y	274	6.07	1.40	5.902	6.234		
	Total	388	6.00	1.36	5.869	6.140		-0.46
Nasion	Black 6 - 8y	19	4.93	1.04	4.426	5.426	0.084	0.05
	Black 9 - 13y	71	4.97	1.20	4.687	5.255		
	Coloured 6 - 8y	24	5.13	1.24	4.609	5.654		0.26
	Coloured 9 - 13y	274	5.39	1.48	5.216	5.568		
	Total	388	5.28	1.41	5.136	5.417		0.31
End nasal	Black 6 - 8y	19	2.45	0.60	2.159	2.737	0.001	0.12
	Black 9 - 13y	71	2.57	0.65	2.417	2.724		
	Coloured 6 - 8y	24	2.21	0.85	1.850	2.567		0.00
	Coloured 9 - 13y	274	2.21	0.69	2.126	2.289		
	Total	388	2.29	0.70	2.216	2.355		0.12
Midphiltrum	Black 6 - 8y	19	10.48	2.72	9.168	11.789	0.000	0.19
	Black 9 - 13y	71	10.67	2.46	10.087	11.249		
	Coloured 6 - 8y	24	12.85	2.86	11.643	14.061		-0.12
	Coloured 9 - 13y	274	12.74	3.20	12.355	13.116		
	Total	388	12.25	3.15	11.939	12.569		0.07

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
y - years

Table 4.35: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 8 years, 9 - 13 years) and ancestry for the labiale superius, labiale inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per ancestry minus younger group per ancestry)
Labiale superius	Black 6 - 8y	19	12.92	1.52	12.188	13.657	0.775	-0.57
	Black 9 - 13y	71	12.35	2.07	11.857	12.839		
	Coloured 6 - 8y	24	12.32	2.58	11.232	13.408		0.08
	Coloured 9 - 13y	274	12.40	2.27	12.130	12.668		
	Total	388	12.41	2.22	12.189	12.632		-0.49
Labiale inferius	Black 6 - 8y	19	12.19	2.65	10.915	13.473	0.102	0.81
	Black 9 - 13y	71	13.00	1.91	12.550	13.454		
	Coloured 6 - 8y	24	13.43	2.66	12.312	14.555		-0.05
	Coloured 9 - 13y	274	13.38	2.23	13.114	13.646		
	Total	388	13.26	2.24	13.033	13.479		0.75
Labiomentale	Black 6 - 8y	19	10.61	1.73	9.781	11.448	0.000	0.28
	Black 9 - 13y	71	10.89	1.67	10.497	11.286		
	Coloured 6 - 8y	24	10.87	1.64	10.180	11.564		1.08
	Coloured 9 - 13y	274	11.95	2.13	11.698	12.203		
	Total	388	11.62	2.06	11.419	11.830		1.36
Pogonion	Black 6 - 8y	19	10.17	1.20	9.596	10.752	0.304	0.94
	Black 9 - 13y	71	11.11	2.23	10.585	11.641		
	Coloured 6 - 8y	24	10.21	1.97	9.378	11.045		0.64
	Coloured 9 - 13y	274	10.85	2.68	10.527	11.166		
	Total	388	10.82	2.52	10.572	11.074		1.57
Beneath chin	Black 6 - 8y	19	5.30	1.42	4.622	5.986	0.009	0.33
	Black 9 - 13y	71	5.63	1.25	5.334	5.927		
	Coloured 6 - 8y	24	5.68	1.68	4.974	6.390		0.49
	Coloured 9 - 13y	274	6.17	1.66	5.974	6.370		
	Total	388	6.00	1.60	5.840	6.160		0.82

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
y - years

Table 4.36: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 8 years, 9 - 13 years) and sex for the supraglabella, glabella, nasion, end nasal and midphiltrum

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per sex minus younger group per sex)
Supraglabella	Male 6 - 8y	22	4.77	1.05	4.302	5.234	0.799	0.05
	Male 9 - 13y	131	4.81	1.18	4.611	5.018		
	Female 6 - 8y	21	5.06	0.95	4.630	5.493		-0.18
	Female 9 - 13y	214	4.88	1.22	4.718	5.047		
	Total	388	4.86	1.18	4.745	4.980		-0.13
Glabella	Male 6 - 8y	22	6.16	1.83	5.351	6.977	0.914	-0.20
	Male 9 - 13y	131	5.96	1.13	5.763	6.154		
	Female 6 - 8y	21	6.08	1.14	5.566	6.604		-0.08
	Female 9 - 13y	214	6.01	1.45	5.812	6.203		
	Total	388	6.00	1.36	5.869	6.140		-0.28
Nasion	Male 6 - 8y	22	4.81	0.95	4.386	5.227	0.458	0.49
	Male 9 - 13y	131	5.30	1.44	5.052	5.549		
	Female 6 - 8y	21	5.29	1.30	4.696	5.876		0.02
	Female 9 - 13y	214	5.31	1.44	5.115	5.502		
	Total	388	5.28	1.41	5.136	5.417		0.52
End nasal	Male 6 - 8y	22	2.21	0.65	1.919	2.499	0.760	0.06
	Male 9 - 13y	131	2.27	0.68	2.152	2.386		
	Female 6 - 8y	21	2.42	0.84	2.041	2.808		-0.13
	Female 9 - 13y	214	2.29	0.70	2.195	2.385		
	Total	388	2.29	0.70	2.216	2.355		-0.07
Midphiltrum	Male 6 - 8y	22	12.41	3.10	11.038	13.783	0.404	0.01
	Male 9 - 13y	131	12.42	3.28	11.855	12.991		
	Female 6 - 8y	21	11.17	2.86	9.865	12.470		1.07
	Female 9 - 13y	214	12.24	3.11	11.823	12.659		
	Total	388	12.25	3.15	11.939	12.569		1.09

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
y - years

Table 4.37: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 8 years, 9 - 13 years) and sex for the labiale superius, labial inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per sex minus younger group per sex)
Labiale superius	Male 6 - 8y	22	12.50	2.34	11.457	13.533	0.867	-0.02
	Male 9 - 13y	131	12.48	2.26	12.088	12.870		
	Female 6 - 8y	21	12.68	2.03	11.755	13.608		-0.35
	Female 9 - 13y	214	12.33	2.20	12.036	12.630		
	Total	388	12.41	2.22	12.189	12.632		-0.36
Labiale inferius	Male 6 - 8y	22	13.24	3.10	11.860	14.613	0.485	0.04
	Male 9 - 13y	131	13.28	2.24	12.891	13.664		
	Female 6 - 8y	21	12.52	2.21	11.514	13.523		0.80
	Female 9 - 13y	214	13.32	2.14	13.029	13.605		
	Total	388	13.26	2.24	13.033	13.479		0.84
Labiomentale	Male 6 - 8y	22	10.76	1.85	9.938	11.580	0.034	1.01
	Male 9 - 13y	131	11.77	2.15	11.393	12.138		
	Female 6 - 8y	21	10.76	1.49	10.080	11.436		0.96
	Female 9 - 13y	214	11.71	2.04	11.438	11.988		
	Total	388	11.62	2.06	11.419	11.830		1.96
Pogonion	Male 6 - 8y	22	10.29	1.96	9.422	11.156	0.027	0.18
	Male 9 - 13y	131	10.47	2.35	10.068	10.879		
	Female 6 - 8y	21	10.10	1.32	9.496	10.697		1.07
	Female 9 - 13y	214	11.16	2.71	10.798	11.528		
	Total	388	10.82	2.52	10.572	11.074		1.25
Beneath chin	Male 6 - 8y	22	5.40	1.87	4.569	6.224	0.017	0.41
	Male 9 - 13y	131	5.80	1.54	5.537	6.068		
	Female 6 - 8y	21	5.64	1.19	5.097	6.182		0.58
	Female 9 - 13y	214	6.22	1.62	6.000	6.437		
	Total	388	6.00	1.60	5.840	6.160		0.99

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
y - years

Table 4.38: Tissue thickness for Black children aged 6 to 8 years

Landmark	Male (n=9)				Female (n=10)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.96	1.13	4.091	5.822	5.05	0.68	4.566	5.532
Glabella	6.06	1.43	4.969	7.160	5.84	0.96	5.150	6.523
Nasion	4.90	0.49	4.525	5.276	4.95	1.39	3.953	5.945
End nasal	2.43	0.72	1.869	2.984	2.47	0.50	2.108	2.826
Midphiltrum	11.35	2.98	9.056	13.637	9.70	2.34	8.024	11.370
Upper lip border	12.88	2.14	11.235	14.532	12.96	0.75	12.424	13.490
Lower lip border	12.82	2.79	10.678	14.960	11.63	2.54	9.816	13.449
Labiomental groove	10.45	1.75	9.105	11.799	10.76	1.79	9.481	12.041
Pogonion	10.21	1.28	9.224	11.190	10.15	1.19	9.293	10.997
Beneath chin	5.07	1.56	3.873	6.267	5.52	1.32	4.569	6.461

Table 4.39: Tissue thickness for Black children aged 9 to 13 years

Landmark	Male (n=34)				Female (n=37)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.62	0.80	4.336	4.896	5.06	1.08	4.696	5.416
Glabella	5.42	0.87	5.114	5.719	5.93	1.11	5.560	6.300
Nasion	4.89	0.97	4.552	5.226	5.05	1.39	4.584	5.510
End nasal	2.55	0.52	2.371	2.733	2.59	0.75	2.336	2.839
Midphiltrum	11.33	2.53	10.448	12.211	10.06	2.25	9.308	10.812
Upper lip border	11.88	2.30	11.081	12.686	12.78	1.77	12.186	13.364
Lower lip border	12.67	1.95	11.987	13.346	13.31	1.85	12.694	13.926
Labiomental groove	10.68	1.77	10.061	11.298	11.09	1.56	10.565	11.608
Pogonion	10.28	2.01	9.576	10.977	11.88	2.17	11.157	12.605
Beneath chin	5.24	0.99	4.896	5.589	5.99	1.37	5.530	6.445

Table 4.40: Tissue thickness for Coloured children aged 6 to 8 years

Landmark	Male (n=13)				Female (n=11)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.64	1.02	4.021	5.253	5.07	1.18	4.282	5.863
Glabella	6.23	2.13	4.948	7.517	6.31	1.29	5.447	7.175
Nasion	4.74	1.19	4.025	5.458	5.59	1.18	4.797	6.387
End nasal	2.06	0.58	1.707	2.410	2.39	1.09	1.653	3.118
Midphiltrum	13.15	3.07	11.293	15.001	12.50	2.71	10.685	14.322
Upper lip border	12.23	2.52	10.706	13.747	12.43	2.76	10.575	14.287
Lower lip border	13.53	3.39	11.479	15.572	13.32	1.56	12.277	14.372
Labiomental groove	10.97	1.96	9.788	12.155	10.75	1.25	9.917	11.592
Pogonion	10.35	2.37	8.917	11.776	10.05	1.48	9.056	11.047
Beneath chin	5.62	2.08	4.363	6.882	5.75	1.11	5.006	6.500

Table 4.41: Tissue thickness for Coloured children aged 9 to 13 years

Landmark	Male (n=79)				Female (n=177)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.88	1.28	4.627	5.142	4.85	1.25	4.661	5.031
Glabella	6.15	1.15	5.916	6.381	6.02	1.52	5.799	6.249
Nasion	5.44	1.55	5.133	5.757	5.36	1.45	5.149	5.578
End nasal	2.17	0.70	2.028	2.311	2.23	0.68	2.127	2.329
Midphiltrum	12.81	3.44	12.113	13.500	12.70	3.07	12.242	13.152
Upper lip border	12.69	2.23	12.239	13.136	12.24	2.28	11.903	12.579
Lower lip border	13.49	2.30	13.029	13.956	13.32	2.20	12.992	13.645
Labiomental groove	12.15	2.15	11.712	12.580	11.84	2.11	11.531	12.156
Pogonion	10.54	2.46	10.047	11.039	11.01	2.79	10.599	11.427
Beneath chin	6.00	1.65	5.668	6.331	6.27	1.67	6.019	6.515

Table 4.42: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 8 years, 9 - 13 years) sex and ancestry for the end nasal landmark

End nasal								
Group	**Black Males**		**Black Females**		**Coloured Males**		**Coloured Females**	
	6 - 8 years	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**
BM 6 - 8 years	x	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BM 9 - 13 years	1.000	x	1.000	1.000	0.798	0.156	1.000	0.345
BF 6 - 8 years	1.000	1.000	x	1.000	1.000	1.000	1.000	1.000
BF 9 - 13 years	1.000	1.000	1.000	x	0.044	0.049	1.000	0.114
CM 6 - 8 years	1.000	0.798	1.000	0.044	x	1.000	1.000	1.000
CM 9 - 13 years	1.000	0.156	1.000	0.049	1.000	x	1.000	1.000
CF 6 - 8 years	1.000	1.000	1.000	1.000	1.000	1.000	x	1.000
CF 9 - 13 years	1.000	0.345	1.000	0.114	1.000	1.000	1.000	X

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.43: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 8 years, 9 - 13 years), sex and ancestry for the midphiltrum

Midphiltrum								
Group	**Black Males**		**Black Females**		**Coloured Males**		**Coloured Females**	
	6 - 8 years	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**
BM 6 - 8 years	x	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BM 9 - 13 years	1.000	x	1.000	1.000	1.000	0.420	1.000	0.462
BF 6 - 8 years	1.000	1.000	x	1.000	0.200	0.061	0.975	0.070
BF 9 - 13 years	1.000	1.000	1.000	x	0.048	0.000	0.545	0.000
CM 6 - 8 years	1.000	1.000	0.200	0.048	x	1.000	1.000	1.000
CM 9 - 13 years	1.000	0.420	0.061	0.000	1.000	x	1.000	1.000
CF 6 - 8 years	1.000	1.000	0.975	0.545	1.000	1.000	x	1.000
CF 9 - 13 years	1.000	0.462	0.070	0.000	1.000	1.000	1.000	X

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.44: Table P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 8 years, 9 - 13 years), sex and ancestry for the labiomentale

Labiomentale								
Group	**Black Males**		**Black Females**		**Coloured Males**		**Coloured Females**	
	6 - 8 years	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**
BM 6 - 8 years	x	1.000	1.000	1.000	1.000	0.448	1.000	1.000
BM 9 - 13 years	1.000	x	1.000	1.000	1.000	0.008	1.000	0.059
BF 6 - 8 years	1.000	1.000	x	1.000	1.000	1.000	1.000	1.000
BF 9 - 13 years	1.000	1.000	1.000	x	1.000	0.186	1.000	1.000
CM 6 - 8 years	1.000	1.000	1.000	1.000	x	1.000	1.000	1.000
CM 9 - 13 years	0.448	0.008	1.000	0.186	1.000	x	1.000	1.000
CF 6 - 8 years	1.000	1.000	1.000	1.000	1.000	1.000	x	1.000
CF 9 - 13 years	1.000	0.059	1.000	1.000	1.000	1.000	1.000	X

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.45: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age, sex and ancestry for the beneath chin landmark

Beneath chin								
Group	**Black Males**		**Black Females**		**Coloured Males**		**Coloured Females**	
	6 - 8 years	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**	**6 - 8 years**	**9 - 13 years**
BM 6 - 8 years	x	1.000	1.000	1.000	1.000	1.000	1.000	0.770
BM 9 - 13 years	1.000	x	1.000	1.000	1.000	0.472	1.000	0.017
BF 6 - 8 years	1.000	1.000	x	1.000	1.000	1.000	1.000	1.000
BF 9 - 13 years	1.000	1.000	1.000	x	1.000	1.000	1.000	1.000
CM 6 - 8 years	1.000	1.000	1.000	1.000	x	1.000	1.000	1.000
CM 9 - 13 years	1.000	0.472	1.000	1.000	1.000	x	1.000	1.000
CF 6 - 8 years	1.000	1.000	1.000	1.000	1.000	1.000	x	1.000
CF 9 - 13 years	0.770	0.017	1.000	1.000	1.000	1.000	1.000	X

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.46: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 11 years, 12 & 13 years)

Landmark	Group	N	Mean	SD	95% Confidence Interval		T-test, p-value	Difference in mm (older group minus younger group)
Supraglabella	6 - 11y	225	4.86	1.26	4.626	4.957	0.447	0.10
	12 & 13y	163	4.96	1.05	4.797	5.123		
	Total	388	4.91	1.16	4.712	5.04		
Glabella	6 - 11y	225	6.04	1.53	5.824	6.198	0.747	-0.05
	12 & 13y	163	5.99	1.27	5.799	6.191		
	Total	388	6.02	1.4	5.811	6.194		
Nasion	6 - 11y	225	5.31	1.33	5.048	5.409	0.819	0.03
	12 & 13y	163	5.34	1.45	5.117	5.566		
	Total	388	5.32	1.39	5.083	5.488		
End nasal	6 - 11y	225	2.35	0.79	2.216	2.412	0.189	-0.10
	12 & 13y	163	2.25	0.63	2.149	2.343		
	Total	388	2.3	0.71	2.183	2.378		
Midphiltrum	6 - 11y	225	11.55	2.92	11.673	12.456	0.006	0.97
	12 & 13y	163	12.52	3.37	11.994	13.038		
	Total	388	12.03	3.15	11.833	12.747		
Labiale superius	6 - 11y	225	12.28	2.21	12.04	12.613	0.303	0.25
	12 & 13y	163	12.53	2.27	12.176	12.877		
	Total	388	12.4	2.24	12.108	12.745		
Labiale inferius	6 - 11y	225	12.86	2.42	12.719	13.354	0.009	0.7
	12 & 13y	163	13.56	1.93	13.26	13.858		
	Total	388	13.21	2.18	12.99	13.606		
Labiomentale	6 - 11y	225	11.25	2.05	11.09	11.644	0.002	0.73
	12 & 13y	163	11.98	1.94	11.68	12.281		
	Total	388	11.62	2	11.385	11.963		
Pogonion	6 - 11y	225	10.41	2.19	10.36	11.017	0.051	0.68
	12 & 13y	163	11.09	2.04	10.616	11.402		
	Total	388	10.75	2.12	10.488	11.209		
Beneath chin	6 - 11y	225	10.48	2.39	5.647	6.064	0.05	0.53
	12 & 13y	163	11.01	2.54	5.951	6.45		
	Total	388	10.75	2.47	5.799	6.257		

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
y - years

Table 4.47: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 11 years, 12 & 13 years) and ancestry for the supraglabella, glabella, nasion, end nasal and midphiltrum

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per ancestry minus younger group per ancestry)
	Black 6 - 11y	62	4.81	0.84	4.600	5.024		0.22
	Black 12 & 13y	28	5.03	1.18	4.569	5.486		
Supraglabella	Coloured 6 - 11y	163	4.78	1.39	4.569	4.999	0.561	0.16
	Coloured 12 & 13y	135	4.95	1.03	4.771	5.122		
	Total	388	4.86	1.18	4.745	4.980		0.38
	Black 6 - 11y	62	5.65	1.06	5.385	5.921		0.28
	Black 12 & 13y	28	5.93	1.05	5.521	6.339		
Glabella	Coloured 6 - 11y	163	6.15	1.52	5.912	6.382	0.109	-0.14
	Coloured 12 & 13y	135	6.01	1.31	5.785	6.231		
	Total	388	6.00	1.36	5.869	6.140		0.14
	Black 6 - 11y	62	5.01	1.12	4.729	5.297		-0.16
	Black 12 & 13y	28	4.85	1.26	4.358	5.338		
Nasion	Coloured 6 - 11y	163	5.31	1.46	5.085	5.536	0.079	0.13
	Coloured 12 & 13y	135	5.44	1.47	5.194	5.695		
	Total	388	5.28	1.41	5.136	5.417		-0.03
	Black 6 - 11y	62	2.56 [a]	0.71	2.379	2.738		-0.04
	Black 12 & 13y	28	2.51	0.45	2.339	2.689		
End nasal	Coloured 6 - 11y	163	2.22 [a]	0.74	2.106	2.336	0.001	-0.03
	Coloured 12 & 13y	135	2.19 [a]	0.64	2.081	2.301		
	Total	388	2.29	0.70	2.216	2.355		-0.07
	Black 6 - 11y	62	10.18 [b]	2.44	9.562	10.801		1.43
	Black 12 & 13y	28	11.62 [c]	2.38	10.694	12.539		
Midphiltrum	Coloured 6 - 11y	163	12.78 [b]	2.86	12.338	13.222	0.000	-0.08
	Coloured 12 & 13y	135	12.70 [c]	3.52	12.103	13.302		
	Total	388	12.25	3.15	11.939	12.569		1.36

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
[a - c] Significant differences between specific groups (ANOVA, $p \leq 0.05$)
y -years

Table 4.48: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 11 years, 12 & 13 years) and ancestry for the labiale superius, labiale inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per ancestry minus younger group per ancestry)
Labiale superius	Black 6 - 11y	62	12.42	1.63	12.001	12.830	0.820	0.17
	Black 12 & 13y	28	12.59	2.62	11.575	13.603		
	Coloured 6 - 11y	163	12.29	2.36	11.928	12.658		0.22
	Coloured 12 & 13y	135	12.51	2.20	12.139	12.887		
	Total	388	12.41	2.22	12.189	12.632		0.39
Labiale inferius	Black 6 - 11y	62	12.44 [a, b]	2.02	11.932	12.955	0.010	1.25
	Black 12 & 13y	28	13.69 [a]	2.06	12.893	14.487		
	Coloured 6 - 11y	163	13.26	2.52	12.872	13.651		0.27
	Coloured 12 & 13y	135	13.53 [b]	1.91	13.206	13.858		
	Total	388	13.26	2.24	13.033	13.479		1.52
Labiomentale	Black 6 - 11y	62	10.57 [c, d]	1.56	10.175	10.966	0.000	0.84
	Black 12 & 13y	28	11.42	1.80	10.716	12.114		
	Coloured 6 - 11y	163	11.67 [d]	2.21	11.328	12.013		0.43
	Coloured 12 & 13y	135	12.10 [c]	1.96	11.765	12.431		
	Total	388	11.62	2.06	11.419	11.830		1.27
Pogonion	Black 6 - 11y	62	10.82	1.98	10.313	11.318	0.609	0.32
	Black 12 & 13y	28	11.13	2.33	10.232	12.037		
	Coloured 6 - 11y	163	10.64	2.67	10.227	11.054		0.34
	Coloured 12 & 13y	135	10.98	2.59	10.542	11.424		
	Total	388	10.82	2.52	10.572	11.074		0.66
Beneath chin	Black 6 - 11y	62	5.54 [e]	1.40	5.189	5.899	0.006	0.06
	Black 12 & 13y	28	5.60	1.03	5.203	5.998		
	Coloured 6 - 11y	163	5.97	1.64	5.720	6.227		0.35
	Coloured 12 & 13y	135	6.32 [e]	1.69	6.038	6.612		
	Total	388	6.00	1.60	5.840	6.160		0.41

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
[a – e] Significant differences between specific groups (ANOVA, $p \leq 0.05$)
y - years

Table 4.49: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 11 years, 12 & 13 years) and sex for the supraglabella, glabella, nasion, end nasal and midphiltrum

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per sex minus younger group per sex)
Supraglabella	Male 6 - 11y	96	4.64	1.18	4.402	4.879	0.125	0.45
	Male 12 & 13y	57	5.09	1.07	4.807	5.373		
	Female 6 - 11y	129	4.90	1.31	4.675	5.133		-0.01
	Female 12 & 13y	106	4.89	1.05	4.689	5.092		
	Total	388	4.86	1.18	4.745	4.980		0.44
Glabella	Male 6 - 11y	96	5.93	1.37	5.657	6.213	0.833	0.14
	Male 12 & 13y	57	6.08	1.02	5.808	6.349		
	Female 6 - 11y	129	6.07	1.46	5.813	6.322		-0.12
	Female 12 & 13y	106	5.95	1.38	5.683	6.216		
	Total	388	6.00	1.36	5.869	6.140		0.03
Nasion	Male 6 - 11y	96	5.12	1.35	4.848	5.396	0.620	0.29
	Male 12 & 13y	57	5.41	1.44	5.029	5.793		
	Female 6 - 11y	129	5.31	1.40	5.065	5.551		0.00
	Female 12 & 13y	106	5.30	1.46	5.023	5.587		
	Total	388	5.28	1.41	5.136	5.417		0.29
End nasal	Male 6 - 11y	96	2.24	0.70	2.102	2.387	0.419	0.04
	Male 12 & 13y	57	2.29	0.62	2.122	2.452		
	Female 6 - 11y	129	2.37	0.78	2.230	2.501		-0.14
	Female 12 & 13y	106	2.22	0.63	2.103	2.346		
	Total	388	2.29	0.70	2.216	2.355		-0.10
Midphiltrum	Male 6 - 11y	96	12.09	2.89	11.500	12.672	0.274	0.90
	Male 12 & 13y	57	12.99	3.73	11.996	13.976		
	Female 6 - 11y	129	12.05	3.05	11.516	12.580		0.22
	Female 12 & 13y	106	12.26	3.15	11.656	12.870		
	Total	388	12.25	3.15	11.939	12.569		1.12

No significant differences between groups were detected (ANOVA, $p \leq 0.05$)
y - years

Table 4.50: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 11 years, 12 & 13 years) and sex for the labiale superius, labiale inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per sex minus younger group per sex)
Labiale superius	Male 6 - 11y	96	12.31	2.16	11.870	12.744	0.598	0.47
	Male 12 & 13y	57	12.78	2.43	12.130	13.421		
	Female 6 - 11y	129	12.34	2.21	11.957	12.726		0.05
	Female 12 & 13y	106	12.39	2.17	11.974	12.810		
	Total	388	12.41	2.22	12.189	12.632		0.52
Labiale inferius	Male 6 - 11y	96	13.04	2.60	12.515	13.570	0.149	0.62
	Male 12 & 13y	57	13.66	1.86	13.165	14.153		
	Female 6 - 11y	129	13.03	2.27	12.636	13.428		0.47
	Female 12 & 13y	106	13.51	1.98	13.125	13.886		
	Total	388	13.26	2.24	13.033	13.479		1.09
Labiomentale	Male 6 - 11y	96	11.34 [a]	2.13	10.906	11.769	0.033	0.76
	Male 12 & 13y	57	12.10 [a]	2.08	11.546	12.651		
	Female 6 - 11y	129	11.39	2.10	11.023	11.756		0.53
	Female 12 & 13y	106	11.92	1.87	11.557	12.277		
	Total	388	11.62	2.06	11.419	11.830		1.29
Pogonion	Male 6 - 11y	96	10.37	2.26	9.915	10.832	0.078	0.20
	Male 12 & 13y	57	10.57	2.35	9.947	11.195		
	Female 6 - 11y	129	10.92	2.65	10.462	11.384		0.32
	Female 12 & 13y	106	11.24	2.62	10.740	11.748		
	Total	388	10.82	2.52	10.572	11.074		0.52
Beneath chin	Male 6 - 11y	96	5.60 [b]	1.62	5.276	5.934	0.017	0.37
	Male 12 & 13y	57	5.98	1.51	5.579	6.381		
	Female 6 - 11y	129	6.04	1.54	5.774	6.310		0.28
	Female 12 & 13y	106	6.32 [b]	1.66	5.999	6.639		
	Total	388	6.00	1.60	5.840	6.160		0.65

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
[a ,b] Significant differences between specific groups (ANOVA, $p \leq 0.05$)
y - years

Table 4.51: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age groups 6 – 10 years and 11 to 13 years

Landmark	Group	N	Mean	SD	95% Confidence Interval		T-test, p-value	Difference in mm (older group minus younger group)
Supraglabella	6 - 10y	151	4.83	1.30	4.619	5.037	0.671	0.06
	11 - 13y	237	4.88	1.10	4.744	5.026		
	Total	388	4.86	1.20	4.681	5.031		
Glabella	6 - 10y	151	6.06	1.57	5.804	6.309	0.245	-0.09
	11 - 13y	237	5.97	1.21	5.817	6.125		
	Total	388	6.01	1.39	5.810	6.217		
Nasion	6 - 10y	151	5.32	1.31	5.108	5.530	0.159	-0.07
	11 - 13y	237	5.25	1.47	5.061	5.437		
	Total	388	5.28	1.39	5.084	5.483		
End nasal	6 - 10y	151	2.28	0.74	2.162	2.398	0.569	0.01
	11 - 13y	237	2.29	0.68	2.203	2.376		
	Total	388	2.28	0.71	2.182	2.387		
Midphiltrum	6 - 10y	151	11.72	2.93	11.248	12.189	0.008	0.88
	11 - 13y	237	12.59	3.25	12.179	13.011		
	Total	388	12.16	3.09	11.713	12.600		
Labiale superius	6 - 10y	151	12.30	2.29	11.935	12.670	0.488	0.18
	11 - 13y	237	12.48	2.17	12.201	12.757		
	Total	388	12.39	2.23	12.068	12.714		
Labiale inferius	6 - 10y	151	12.79	2.48	12.395	13.192	0.002	0.76
	11 - 13y	237	13.55	2.02	13.292	13.809		
	Total	388	13.17	2.25	12.843	13.501		
Labiomentale	6 - 10y	151	11.28	2.10	10.946	11.620	0.060	0.56
	11 - 13y	237	11.84	2.01	11.585	12.100		
	Total	388	11.56	2.05	11.266	11.860		
Pogonion	6 - 10y	151	10.37	2.33	9.998	10.747	0.004	0.74
	11 - 13y	237	11.11	2.59	10.778	11.442		
	Total	388	10.74	2.46	10.388	11.095		
Beneath chin	6 - 10y	151	5.58	1.44	5.347	5.811	0.000	0.69
	11 - 13y	237	6.27	1.65	6.058	6.480		
	Total	388	5.92	1.54	5.702	6.145		

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
y- years

Table 4.52: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 10 years and 11 to 13 years) and ancestry for the supraglabella, glabella, nasion, end nasal and midphiltrum

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group minus younger group)
Supraglabella	Black 6 - 10y	46	4.74	0.86	4.483	4.994	0.714	0.29
	Black 11 - 13y	44	5.03	1.04	4.712	5.341		
	Coloured 6 - 10y	105	4.87	1.45	4.586	5.148		-0.01
	Coloured 10 - 13y	193	4.85	1.12	4.694	5.011		
	Total	388	4.86	1.18	4.745	4.980		0.27
Glabella	Black 6 - 10y	46	5.55 [a]	1.07	5.229	5.862	0.020	0.40
	Black 11 - 13y	44	5.94	1.02	5.631	6.252		
	Coloured 6 - 10y	105	6.28 [a]	1.70	5.951	6.610		-0.30
	Coloured 10 - 13y	193	5.98	1.25	5.801	6.154		
	Total	388	6.00	1.36	5.869	6.140		0.09
Nasion	Black 6 - 10y	46	4.99	1.00	4.696	5.288	0.087	-0.06
	Black 11 - 13y	44	4.93	1.32	4.528	5.332		
	Coloured 6 - 10y	105	5.46	1.41	5.189	5.735		-0.14
	Coloured 10 - 13y	193	5.32	1.49	5.110	5.534		
	Total	388	5.28	1.41	5.136	5.417		-0.20
End nasal	Black 6 - 10y	46	2.44	0.53	2.283	2.595	0.000	0.22
	Black 11 - 13y	44	2.66 [b]	0.73	2.435	2.876		
	Coloured 6 - 10y	105	2.21 [b]	0.80	2.055	2.366		0.00
	Coloured 10 - 13y	193	2.21 [b]	0.64	2.115	2.296		
	Total	388	2.29	0.70	2.216	2.355		0.21
Midphiltrum	Black 6 - 10y	46	10.28 [c]	2.58	9.516	11.049	0.000	0.71
	Black 11 - 13y	44	10.99 [c]	2.38	10.264	11.714		
	Coloured 6 - 10y	105	12.35 [c]	2.86	11.795	12.901		0.61
	Coloured 10 - 13y	193	12.96 [c]	3.32	12.490	13.432		
	Total	388	12.25	3.15	11.939	12.569		1.32

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
[a – c] Significant differences between specific groups (ANOVA, $p \leq 0.05$)
y - years

Table 4.53: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age groups (6 – 10 years and 11 – 13 years) and ancestry for the labiale superius, labiale inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per ancestry minus younger group per ancestry)
Labiale superius	Black 6 - 10y	46	12.46	1.81	11.921	12.996	0.824	0.02
	Black 11 - 13y	44	12.48	2.16	11.825	13.137		
	Coloured 6 - 10y	105	12.23	2.47	11.756	12.713		0.24
	Coloured 10 - 13y	193	12.48	2.18	12.169	12.789		
	Total	388	12.41	2.22	12.189	12.632		0.27
Labiale inferius	Black 6 - 10y	46	12.14 [a]	2.12	11.515	12.775	0.001	1.40
	Black 11 - 13y	44	13.55 [a]	1.84	12.991	14.107		
	Coloured 6 - 10y	105	13.08	2.58	12.579	13.577		0.47
	Coloured 10 - 13y	193	13.55 [a]	2.06	13.258	13.844		
	Total	388	13.26	2.24	13.033	13.479		1.88
Labiomentale	Black 6 - 10y	46	10.37 [b]	1.60	9.895	10.844	0.000	0.95
	Black 11 - 13y	44	11.32	1.63	10.822	11.814		
	Coloured 6 - 10y	105	11.68 [b]	2.17	11.264	12.103		0.28
	Coloured 10 - 13y	193	11.96 [b]	2.07	11.667	12.256		
	Total	388	11.62	2.06	11.419	11.830		1.23
Pogonion	Black 6 - 10y	46	10.47 [c, d]	1.51	10.021	10.917	0.034	0.91
	Black 11 - 13y	44	11.38 [c]	2.49	10.624	12.137		
	Coloured 6 - 10y	105	10.33	2.62	9.824	10.836		0.72
	Coloured 10 - 13y	193	11.05 [d]	2.62	10.677	11.421		
	Total	388	10.82	2.52	10.572	11.074		1.63
Beneath chin	Black 6 - 10y	46	5.29 [e]	1.22	4.931	5.654	0.000	0.55
	Black 11 - 13y	44	5.84	1.31	5.444	6.242		
	Coloured 6 - 10y	105	5.70	1.52	5.411	5.998		0.66
	Coloured 10 - 13y	193	6.37 [e]	1.70	6.124	6.608		
	Total	388	6.00	1.60	5.840	6.160		1.21

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
[a – e] Significant differences between specific groups (ANOVA, $p \leq 0.05$)
y - years

Table 4.54: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 10 years and 11 – 13 years) and sex for the supraglabella, glabella, nasion, end nasal and midphiltrum

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group per sex minus younger group per sex)
Supraglabella	Male 6 - 10y	68	4.71	1.24	4.409	5.007	0.686	0.18
	Male 11 - 13y	85	4.89	1.09	4.653	5.123		
	Female 6 - 10y	83	4.93	1.35	4.632	5.220		-0.04
	Female 11 - 13y	152	4.88	1.11	4.705	5.061		
	Total	388	4.86	1.18	4.745	4.980		0.14
Glabella	Male 6 - 10y	68	6.04	1.52	5.678	6.412	0.934	-0.10
	Male 11 - 13y	85	5.94	1.00	5.728	6.158		
	Female 6 - 10y	83	6.07	1.62	5.712	6.420		-0.08
	Female 11 - 13y	152	5.99	1.31	5.776	6.196		
	Total	388	6.00	1.36	5.869	6.140		-0.18
Nasion	Male 6 - 10y	68	5.19	1.33	4.866	5.512	0.734	0.07
	Male 11 - 13y	85	5.26	1.44	4.953	5.572		
	Female 6 - 10y	83	5.42	1.29	5.142	5.707		-0.18
	Female 11 - 13y	152	5.24	1.49	5.003	5.481		
	Total	388	5.28	1.41	5.136	5.417		-0.11
End nasal	Male 6 - 10y	68	2.24	0.73	2.059	2.413	0.913	0.04
	Male 11 - 13y	85	2.28	0.62	2.145	2.414		
	Female 6 - 10y	83	2.32	0.74	2.154	2.478		-0.02
	Female 11 - 13y	152	2.29	0.71	2.181	2.408		
	Total	388	2.29	0.70	2.216	2.355		0.02
Midphiltrum	Male 6 - 10y	68	11.83 [a]	2.91	11.129	12.539	0.037	1.06
	Male 11 - 13y	85	12.89 [a]	3.44	12.149	13.633		
	Female 6 - 10y	83	11.62	2.95	10.979	12.269		0.81
	Female 11 - 13y	152	12.43	3.14	11.926	12.933		
	Total	388	12.25	3.15	11.939	12.569		1.86

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
[a] Significant differences between specific groups (ANOVA, $p \leq 0.05$)
y - years

Table 4.55: Descriptive statistics and p-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 10 years and 11 – 13 years) and sex for the labiale superius, labiale inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm (Older group minus younger group)
Labiale superius	Male 6 - 10y	68	12.39	2.21	11.858	12.928	0.818	0.16
	Male 11 - 13y	85	12.55	2.32	12.051	13.053		
	Female 6 - 10y	83	12.23	2.36	11.714	12.743		0.21
	Female 11 - 13y	152	12.44	2.09	12.103	12.774		
	Total	388	12.41	2.22	12.189	12.632		0.37
Labiale inferius	Male 6 - 10y	68	12.84 [a]	2.60	12.211	13.469	0.013	0.78
	Male 11 - 13y	85	13.62 [a]	2.12	13.160	14.074		
	Female 6 - 10y	83	12.75 [b]	2.39	12.233	13.277		0.76
	Female 11 - 13y	152	13.51 [b]	1.97	13.198	13.829		
	Total	388	13.26	2.24	13.033	13.479		1.54
Labiomentale	Male 6 - 10y	68	11.37 [c]	2.30	10.811	11.925	0.071	0.46
	Male 11 - 13y	85	11.82 [c]	1.99	11.395	12.252		
	Female 6 - 10y	83	11.21 [c]	1.92	10.794	11.634		0.64
	Female 11 - 13y	152	11.85 [c]	2.03	11.527	12.179		
	Total	388	11.62	2.06	11.419	11.830		1.09
Pogonion	Male 6 - 10y	68	10.37 [d]	2.16	9.850	10.894	0.001	0.14
	Male 11 - 13y	85	10.51 [d]	2.40	9.989	11.026		
	Female 6 - 10y	83	10.37 [d]	2.48	9.832	10.914		1.07
	Female 11 - 13y	152	11.4d	2.64	11.024	11.871		
	Total	388	10.82	2.52	10.572	11.074		1.21
Beneath chin	Male 6 - 10y	68	5.47 [e]	1.61	5.079	5.857	0.000	0.50
	Male 11 - 13y	85	5.97 [e]	1.55	5.632	6.299		
	Female 6 - 10y	83	5.67 [e]	1.29	5.387	5.952		0.77
	Female 11 - 13y	152	6.44 [e]	1.68	6.168	6.708		
	Total	388	6.00	1.60	5.840	6.160		1.27

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
[a – e] Significant differences between specific groups (ANOVA, $p \leq 0.05$)
y - years

Table 4.56: Tissue thickness for Black children aged 6 to 10 years

Landmark	Male (n=24)				Female (n=44)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.64	0.87	4.267	5.004	4.75	1.40	4.321	5.174
Glabella	5.48	1.10	5.020	5.948	6.03	1.00	5.785	6.277
Nasion	5.01	0.69	4.724	5.302	5.29	1.58	4.805	5.765
End nasal	2.42	0.62	2.154	2.681	2.14	0.77	1.902	2.372
Midphiltrum	10.99	2.66	9.872	12.116	12.29	2.97	11.388	13.195
Upper lip border	12.34	2.12	11.445	13.238	12.42	2.28	11.727	13.115
Lower lip border	12.39	2.22	11.451	13.323	13.09	2.78	12.243	13.932
Labiomentale	10.13	1.78	9.379	10.882	12.04	2.29	11.347	12.739
Pogonion	10.25	1.39	9.660	10.835	10.44	2.49	9.684	11.197
Beneath chin	5.04	1.18	4.541	5.534	5.70	1.77	5.165	6.240

Table 4.57: Tissue thickness for Black children aged 11 to 13 years

Landmark	Male (n=19)				Female (n=66)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.75	0.90	4.320	5.187	4.93	1.14	4.647	5.207
Glabella	5.64	0.94	5.184	6.093	6.03	1.00	5.785	6.277
Nasion	4.74	1.08	4.216	5.259	5.41	1.49	5.046	5.780
End nasal	2.66	0.45	2.446	2.879	2.17	0.63	2.015	2.323
Midphiltrum	11.76	2.50	10.555	12.968	13.22	3.61	12.328	14.105
Upper lip border	11.78	2.49	10.579	12.978	12.77	2.24	12.224	13.326
Lower lip border	13.09	1.96	12.147	14.036	13.77	2.15	13.239	14.298
Labiomentale	11.27	1.53	10.527	12.003	11.98	2.08	11.472	12.496
Pogonion	10.28	2.38	9.136	11.426	10.57	2.42	9.977	11.168
Beneath chin	5.42	1.02	4.927	5.912	6.12	1.64	5.720	6.526

Table 4.58: Tissue thickness for Coloured children aged 6 to 10 years

Landmark	Male (n=22)				Female (n=61)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	4.85	0.85	4.473	5.229	4.95	1.49	4.571	5.335
Glabella	5.61	1.05	5.146	6.079	6.23	1.76	5.778	6.681
Nasion	4.97	1.27	4.407	5.532	5.59	1.27	5.263	5.915
End nasal	2.46	0.41	2.282	2.642	2.26	0.83	2.052	2.475
Midphiltrum	9.51	2.31	8.481	10.530	12.39	2.80	11.672	13.105
Upper lip border	12.59	1.44	11.949	13.223	12.10	2.61	11.432	12.768
Lower lip border	11.88	2.03	10.980	12.782	13.07	2.45	12.443	13.697
Labiomentale	10.63	1.37	10.024	11.236	11.42	2.06	10.898	11.952
Pogonion	10.71	1.62	9.992	11.432	10.25	2.72	9.554	10.947
Beneath chin	5.57	1.23	5.026	6.115	5.71	1.32	5.366	6.044

Table 4.59: Tissue thickness for Coloured children aged 11 to 13 years

Landmark	Male (n=25)				Female (n=127)			
	Mean (mm)	SD	95% Confidence Interval		Mean (mm)	SD	95% Confidence Interval	
Supraglabella	5.23	1.10	4.780	5.688	4.81	1.11	4.620	5.008
Glabella	6.17	1.04	5.744	6.600	5.95	1.36	5.711	6.188
Nasion	5.08	1.49	4.463	5.690	5.27	1.49	5.012	5.537
End nasal	2.65	0.89	2.283	3.017	12.83	3.16	12.274	13.382
Midphiltrum	10.40	2.16	9.512	11.294	12.83	3.16	12.274	13.382
Upper lip border	13.01	1.73	12.299	13.730	12.33	2.14	11.949	12.702
Lower lip border	13.90	1.69	13.197	14.596	13.44	2.02	13.084	13.792
Labiomentale	11.36	1.74	10.642	12.075	11.95	2.08	11.585	12.315
Pogonion	12.22	2.28	11.276	13.155	11.30	2.69	10.823	11.769
Beneath chin	6.16	1.44	5.572	6.757	6.49	1.73	6.188	6.796

Table 4.60: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 10 years and 11 – 13 years), sex and ancestry for the midphiltrum

Midphiltrum								
Group	**BM 6 - 10 years**	**BM 11 - 13 years**	**BF 6 - 10 years**	**BF 11 - 13 years**	**CM 6 - 10 years**	**CM 11 - 13 years**	**CF 6 - 10 years**	**CF 11 - 13 years**
BM 6 - 10 years	x	1.000	1.000	1.000	1.000	0.060	1.000	0.183
BM 11 - 13 years	1.000	x	0.486	1.000	1.000	1.000	1.000	1.000
BF 6 - 10 years	1.000	0.486	x	1.000	0.013	1.000	0.004	1.000
BF 11 - 13 years	1.000	1.000	1.000	x	0.357	0.002	1.000	0.008
CM 6 - 10 years	1.000	1.000	0.013	0.357	x	1.000	1.000	1.000
CM 11 - 13 years	0.060	1.000	1.000	0.002	1.000	x	1.000	1.000
CF 6 - 10 years	1.000	1.000	0.004	1.000	1.000	1.000	x	1.000
CF 11 - 13 years	0.183	1.000	1.000	0.008	1.000	1.000	1.000	x

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.61: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 10 years and 11 – 13 years), sex and ancestry for labiale inferius

Labiale inferius								
Group	**BM 6 - 10 years**	**BM 11 - 13 years**	**BF 6 - 10 years**	**BF 11 - 13 years**	**CM 6 - 10 years**	**CM 11 - 13 years**	**CF 6 - 10 years**	**CF 11 - 13 years**
BM 6 - 10 years	x	1.000	1.000	0.473	1.000	0.247	1.000	0.911
BM 11 - 13 years	1.000	x	1.000	1.000	1.000	1.000	1.000	1.000
BF 6 - 10 years	1.000	1.000	x	0.052	1.000	0.016	0.853	0.066
BF 11 - 13 years	0.473	1.000	0.052	x	1.000	1.000	1.000	1.000
CM 6 - 10 years	1.000	1.000	1.000	1.000	x	1.000	1.000	1.000
CM 11 - 13 years	0.247	1.000	0.016	1.000	1.000	x	1.000	1.000
CF 6 - 10 years	1.000	1.000	0.853	1.000	1.000	1.000	x	1.000
CF 11 - 13 years	0.911	1.000	0.066	1.000	1.000	1.000	1.000	x

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.62: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 10 years and 11 – 13 years), sex and ancestry for the labiomentale

Labiomentale								
Group	**BM 6 - 10 years**	**BM 11 - 13 years**	**BF 6 - 10 years**	**BF 11 - 13 years**	**CM 6 - 10 years**	**CM 11 - 13 years**	**CF 6 - 10 years**	**CF 11 - 13 years**
BM 6 - 10 years	x	1.000	1.000	0.923	0.006	0.004	0.218	0.002
BM 11 - 13 years	1.000	x	1.000	1.000	1.000	1.000	1.000	1.000
BF 6 - 10 years	1.000	1.000	x	1.000	0.206	0.180	1.000	0.130
BF 11 - 13 years	0.923	1.000	1.000	x	1.000	1.000	1.000	1.000
CM 6 - 10 years	0.006	1.000	0.206	1.000	x	1.000	1.000	1.000
CM 11 - 13 years	0.004	1.000	0.180	1.000	1.000	x	1.000	1.000
CF 6 - 10 years	0.218	1.000	1.000	1.000	1.000	1.000	x	1.000
CF 11 - 13 years	0.002	1.000	0.130	1.000	1.000	1.000	1.000	x

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.63: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 10 years and 11 – 13 years), sex and ancestry for the pogonion

	Pogonion							
Group	**BM 6 - 10 years**	**BM 11 - 13 years**	**BF 6 - 10 years**	**BF 11 - 13 years**	**CM 6 - 10 years**	**CM 11 - 13 years**	**CF 6 - 10 years**	**CF 11 - 13 years**
BM 6 - 10 years	x	1.000	1.000	0.160	1.000	1.000	1.000	1.000
BM 11 - 13 years	1.000	x	1.000	0.299	1.000	1.000	1.000	1.000
BF 6 - 10 years	1.000	1.000	x	1.000	1.000	0.140	1.000	1.000
BF 11 - 13 years	0.160	0.299	1.000	x	0.125	1.000	0.026	1.000
CM 6 - 10 years	1.000	1.000	1.000	0.125	x	1.000	1.000	1.000
CM 11 - 13 years	1.000	1.000	0.140	1.000	1.000	x	1.000	1.000
CF 6 - 10 years	1.000	1.000	1.000	0.026	1.000	1.000	x	0.197
CF 11 - 13 years	1.000	1.000	1.000	1.000	1.000	1.000	0.197	x

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.64: P-values of ANOVA comparisons with Bonferroni correction of tissue thickness for children in terms of age (6 – 10 years and 11 – 13 years), sex and ancestry for the beneath chin landmark

	Beneath chin							
Group	**BM 6 - 10 years**	**BM 11 - 13 years**	**BF 6 - 10 years**	**BF 11 - 13 years**	**CM 6 - 10 years**	**CM 11 - 13 years**	**CF 6 - 10 years**	**CF 11 - 13 years**
BM 6 - 10 years	x	1.000	1.000	0.328	1.000	0.103	1.000	0.001
BM 11 - 13 years	1.000	x	1.000	1.000	1.000	1.000	1.000	0.151
BF 6 - 10 years	1.000	1.000	x	1.000	1.000	1.000	1.000	0.304
BF 11 - 13 years	0.328	1.000	1.000	x	1.000	1.000	1.000	1.000
CM 6 - 10 years	1.000	1.000	1.000	1.000	x	1.000	1.000	0.112
CM 11 - 13 years	0.103	1.000	1.000	1.000	1.000	x	1.000	1.000
CF 6 - 10 years	1.000	1.000	1.000	1.000	1.000	1.000	x	0.036
CF 11 - 13 years	0.001	0.151	0.304	1.000	0.112	1.000	0.036	x

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females

Table 4.65: Comparison of tissue thickness values from Williamson *et al.* (2002) to results of Black children 6 to 9 years from the current study

	6 - 9 years					
	Current study	Williamson	T-test	Current study	Williamson	T-test
Landmark	BM (n=13)	Male (n=30)	p-value	BF (n=16)	Female (n=23)	p-value
Supraglabella	4.76	5.31	0.0837	4.97	5.08	0.6146
Glabella	5.78	6.25	0.2290	5.64	5.86	0.4335
Nasion	4.86	6.50	0.0000	4.79	5.99	0.0020
End nasal	2.33	2.99	0.0070	2.46	2.97	0.0002
Midphiltrum	11.23	13.44	0.0110	9.64	12.51	0.0001
Labiomentale	10.30	13.60	0.000	10.71	12.50	0.0003
Pogonion	10.47	10.08	0.4130	10.44	10.44	0.9962
Beneath chin	4.98	9.21	0.0000	5.61	8.41	0.0000

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: BM – Black males; BF – Black females; WM – White males; WF – White females

Table 4.66: Comparison of tissue thickness values from Williamson *et al.* (2002) to results of Black children 10 to 12 years from the current study

	10 -12 years					
	Current study	Williamson	T-test	Current study	Williamson	T-test
Landmark	BM (n=23)	Male (n=32)	p-value	BF (n=26)	Female (n=42)	p-value
Supraglabella	4.69	5.18	0.0032	5.033	5.51	0.0416
Glabella	5.33	6.25	0.0000	6.00	6.36	0.1175
Nasion	5.07	6.41	0.0000	5.28	6.22	0.0011
End nasal	2.63	2.95	0.0064	2.68	3.31	0.0011
Midphiltrum	11.18	13.89	0.0000	9.90	13.98	0.0000
Labiomentale	10.32	13.98	0.0000	10.83	13.49	0.0000
Pogonion	10.32	11.55	0.0010	12.00	11.36	0.1279
Beneath chin	5.49	9.21	0.0000	6.15	9.67	0.0000

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: BM – Black males; BF – Black females; WM – White males; WF – White females

Table 4.67: Comparison of tissue thickness values from Williamson *et al.* (2002) to results of Black children 13 years and older from the current study

	≥ 13 years					
	Current study	Williamson	T-test	Current study	Williamson	T-test
Landmark	BM (n=7)	Male (n=15)	p-value	BF (n=5)	Female (n=18)	p-value
Supraglabella	4.54	6.01	0.0137	5.44	5.22	0.5186
Glabella	5.86	6.78	0.0808	6.30	6.11	0.3681
Nasion	4.36	6.92	0.0004	4.44	6.07	0.1408
End nasal	2.54	3.45	0.0001	2.28	2.88	0.0032
Midphiltrum	12.04	15.98	0.0153	11.48	14.58	0.0053
Labiomentale	12.27	14.69	0.0008	12.99	14.07	0.4160
Pogonion	9.68	13.07	0.0279	12.40	12.16	0.8634
Beneath chin	4.69	10.15	0.0000	5.38	9.99	0.0002

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: BM – Black males; BF – Black females; WM – White males; WF – White females

Table 4.68: Comparison of tissue thickness values from Williamson *et al.* (2002) to results of Coloured children 6 to 9 years from the current study

	6 - 9 years					
	Current study	Williamson	T-test	Current study	Williamson	T-test
Landmark	CM (n=34)	Male (n=30)	p-value	CF (n=35)	Female (n=23)	p-value
Supraglabella	4.84	5.31	0.0858	5.36	5.08	0.3562
Glabella	6.46	6.25	0.4919	6.62	5.86	0.0328
Nasion	5.38	6.50	0.0001	5.69	5.99	0.2040
End nasal	2.21	2.99	0.0000	2.32	2.97	0.0002
Midphiltrum	12.35	13.44	0.0537	12.69	12.51	0.6073
Labiomentale	12.03	13.60	0.0006	11.89	12.50	0.0966
Pogonion	10.58	10.08	0.2563	10.30	10.44	0.7666
Beneath chin	5.73	9.21	0.0000	5.71	8.41	0.0000

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: CM – Coloured males; CF –Coloured females

Table 4.69: Comparison of tissue thickness values from Williamson *et al.* (2002) to results of Coloured children 10 to 12 years from the current study

	10 -12 years					
	Current study	Williamson	T-test	Current study	Williamson	T-test
Landmark	CM (n=53)	Male (n=32)	p-value	CF (n=115)	Female (n=42)	p-value
Supraglabella	4.70	5.18	0.0024	4.75	5.51	0.0000
Glabella	5.87	6.25	0.0070	5.84	6.36	0.0001
Nasion	5.22	6.41	0.0000	5.24	6.22	0.0000
End nasal	2.13	2.95	0.0000	2.21	3.31	0.0000
Midphiltrum	13.12	13.89	0.0599	12.76	13.98	0.0001
Labiomentale	11.87	13.98	0.0000	11.61	13.49	0.0000
Pogonion	10.61	11.55	0.0112	11.14	11.36	0.4022
Beneath chin	5.90	9.21	0.0000	6.32	9.67	0.0000

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: CM – Coloured males; CF –Coloured females

Table 4.70: Comparison of tissue thickness values from Williamson *et al.* (2002) to results of Coloured children 13 years and older from the current study

	≥ 13 years					
	Current study	Williamson	T-test	Current study	Williamson	T-test
Landmark	CM (n=23)	Male (n=15)	p-value	CF (n=38)	Female (n=18)	p-value
Supraglabella	5.23	6.01	0.0018	4.72	5.22	0.0024
Glabella	6.39	6.78	0.0677	6.11	6.11	0.9862
Nasion	5.66	6.92	0.0001	5.51	6.07	0.0130
End nasal	2.14	3.45	0.0000	2.24	2.88	0.0000
Midphiltrum	12.95	15.98	0.0045	12.44	14.58	0.0002
Labiomentale	12.29	14.69	0.0000	12.20	14.07	0.0000
Pogonion	10.23	13.07	0.0000	11.01	12.16	0.0068
Beneath chin	6.42	10.15	0.0000	6.46	9.99	0.0000

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: CM – Coloured males; CF – Coloured females

Table 4.71: Comparison of tissue thickness values from Wilkinson (2002) to results of Black children 6 to 8 years from the current study

Landmark	6 - 8 years					
	Current study	Wilkinson	T-test	Current study	Wilkinson	T-test
	BM (n=9)	WM (n=36)	p-value	BF (n=10)	WF (n=43)	p-value
Glabella	6.07	4.00	0.0025	5.84	3.90	0.0001
Nasion	4.90	5.70	0.0012	4.95	5.00	0.9103
End nasal	2.43	1.80	0.0320	2.47	1.70	0.0009
Midphiltrum	11.35	9.00	0.0458	9.70	8.30	0.0915
Labiomentale	10.45	8.10	0.0038	10.76	7.60	0.0003
Pogonion	10.21	8.30	0.0021	10.14	7.40	0.0000
Beneath chin	5.07	4.60	0.3916	5.52	4.20	0.0118

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: BM – Black males; BF – Black females; WM – White males; WF – White females

Table 4.72: Comparison of tissue thickness values from Wilkinson (2002) to results of Coloured children 6 to 8 years from the current study

Landmark	6 - 8 years					
	Current study	Wilkinson	T-test	Current study	Wilkinson	T-test
	CM (n=13)	WM (n=36)	p-value	CF (n=11)	WF (n=43)	p-value
Glabella	6.23	4.00	0.0026	6.31	3.90	0.0001
Nasion	4.74	5.70	0.0130	5.59	5.00	0.1283
End nasal	2.06	1.80	0.1356	2.39	1.70	0.0637
Midphiltrum	13.15	9.00	0.0004	12.50	8.30	0.0004
Labiomentale	10.97	8.10	0.0002	10.76	7.60	0.0000
Pogonion	10.35	8.30	0.0089	10.05	7.40	0.0001
Beneath chin	5.62	4.60	0.1024	5.75	4.20	0.0009

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: CM – Coloured males; CF –Coloured females; WM – White males; WF – White females

Table 4.73: Comparison of tissue thickness values from Wilkinson (2002) to results of Black children 9 to 13 years from the current study

	9 -13 years					
	Current study	Wilkinson	T-test	Current study	Wilkinson	T-test
Landmark	BM (n=23)	WM (n=45)	p-value	BF (n=26)	WF (n=51)	p-value
Glabella	5.42	4.60	0.0000	5.93	4.40	0.0000
Nasion	4.89	4.70	0.2623	5.05	5.50	0.0550
End nasal	2.55	1.60	0.0000	2.59	1.50	0.0000
Midphiltrum	11.33	9.70	0.0007	10.06	9.40	0.0834
Labiomentale	10.68	9.60	0.0012	11.09	9.00	0.0000
Pogonion	10.28	8.70	0.0001	11.88	8.80	0.0000
Beneath chin	5.24	5.50	0.1394	5.99	5.50	0.0375

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: BM – Black males; BF – Black females; WM – White males; WF – White females

Table 4.74: Comparison of tissue thickness values from Wilkinson (2002) to results of Coloured children 9 to 13 years from the current study

	9 -13 years					
	Current study	Wilkinson	T-test	Current study	Wilkinson	T-test
Landmark	CM (n=53)	WM (n=45)	p-value	CF (n=115)	WF (n=51)	p-value
Glabella	6.15	4.60	0.0000	6.02	4.40	0.0000*
Nasion	5.44	4.70	0.0000	5.36	5.50	0.2098
End nasal	2.17	1.60	0.0000	2.23	1.50	0.0000
Midphiltrum	12.81	9.70	0.000	12.70		
Labiomentale	12.15	9.60	0.0000	11.84	9.00	0.0000
Pogonion	10.54	8.70	0.0000	11.01	8.80	0.0000
Beneath chin	6.00	5.50	0.0036	6.27	5.50	0.0000

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: CM – Coloured males; CF –Coloured females; WM – White males; WF – White females

Table 4.75: Comparison of tissue thickness values from Manhein *et al.* (2000) to results of Black children 6 to 8 years from the current study

	6 - 8 years					
	Current study	Manhein	T-test	Current study	Manhein	T-test
Landmark	BM (n=9)	BM (n=37)	p-value	BF (n=10)	BF (n=52)	p-value
Glabella	6.07	4.10	0.0033	5.84	4.00	0.0002
Nasion	4.90	5.40	0.0153	4.95	4.90	0.9138
End nasal	2.43	1.80	0.0320	2.47	1.70	0.0009
Midphiltrum	11.35	9.00	0.0458	9.70	8.90	0.3093
Labiomentale	10.45	8.60	0.0132	10.76	8.20	0.0014
Pogonion	10.21	8.30	0.0021	10.14	8.30	0.0009
Beneath chin	5.07	4.50	0.3041	5.52	4.80	0.1213

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: BM – Black males; BF – Black females

Table 4.76: Comparison of tissue thickness values from Manhein *et al*. (2000) to results of Coloured children 6 to 8 years from the current study

	6 - 8 years					
	Current study	Manhein	T-test	Current study	Manhein	T-test
Landmark	CM (n=13)	BM (n=37)	p-value	CF (n=11)	BF (n=52)	p-value
Glabella	6.23	4.10	0.0035	6.31	4.00	0.0001
Nasion	4.74	5.40	0.0684	5.59	4.90	0.0813
End nasal	2.06	1.80	0.1356	2.39	1.70	0.0637
Midphiltrum	13.15	9.00	0.0004	12.50	8.90	0.0013
Labiomentale	10.97	8.60	0.0009	10.76	8.20	0.0000
Pogonion	10.35	8.30	0.0089	10.05	8.30	0.0029
Beneath chin	5.62	4.50	0.0760	5.75	4.80	0.0175

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: BM – Black males; BF – Black females; CM – Coloured males; CF –Coloured females

Table 4.77: Comparison of tissue thickness values from Manhein *et al.* (2000) to results of Black children 9 to 13 years from the current study

Landmark	9 -13 years					
	Current study	Manhein	T-test	Current study	Manhein	T-test
	BM (n=34)	BM (n=61)	p-value	BF (n=37)	BF (n=57)	p-value
Glabella	5.42	4.50	0.0000	5.93	4.30	0.0000
Nasion	4.89	5.40	0.0041	5.05	5.40	0.1309
End nasal	2.55	1.90	0.0000	2.59	1.70	0.0000
Midphiltrum	11.33	10.00	0.0043	10.06	9.60	0.2226
Labiomentale	10.68	9.80	0.0067	11.09	10.30	0.0042
Pogonion	10.28	9.90	0.2818	11.88	10.00	0.0000
Beneath chin	5.24	5.50	0.1394	5.99	5.80	0.4118

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: BM – Black males; BF – Black females

Table 4.78: Comparison of tissue thickness values from Manhein *et al*. (2000) to results of Coloured children 9 to 13 years from the current study

Landmark	9 -13 years					
	Current study	Manhein	T-test	Current study	Manhein	T-test
	CM (n=97)	BM (n=61)	p-value	CF (n=177)	BF (n=57)	p-value
Glabella	6.15	4.50	0.000	6.02	4.30	0.0000
Nasion	5.44	5.40	0.7756	5.36	5.40	0.7354
End nasal	2.17	1.90	0.0003	2.23	1.70	0.0000
Midphiltrum	12.81	10.00	0.0000	12.70	9.60	0.0000
Labiomentale	12.15	9.80	0.0000	11.84	10.30	0.0000
Pogonion	10.54	9.90	0.0116	11.01	10.00	0.0000
Beneath chin	6.00	5.50	0.0036	6.27	5.80	0.0003

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key: BM – Black males; BF – Black females; CM – Coloured males; CF –Coloured females

Table 4.79: Comparison of results from Stephan and Simpson (2008b) to results of current study

Landmark	Current study	Stephan & Simpson (2008b)	Difference (mm)	Current study	Stephan & Simpson (2008b)	Difference (mm)
	6 - 11 years	0 - 11 years		12 - 13 years	12 - 17 years	
Glabella	5.9	5.0	-0.9	5.9	5.5	-0.4
Nasion	5.0	8.0	3.0	5.1	8.0	2.9
End nasal	2.2	2.5	0.3	2.2	2.5	0.3
Midphiltrum	11.7	11.5	-0.2	12.0	15.0	3.0
Upper lip border	12.1	13.5	1.4	12.3	14.5	2.2
Lower lip border	12.8	14.5	1.7	13.4	15.5	2.1
Labiomentale	11.2	10.0	-1.2	11.8	11.0	-0.8
Pogonion	10.4	10.5	0.1	10.7	11.5	0.8
Beneath chin	5.7	6.5	0.8	6.0	7.5	1.5

Table 4.80: Comparison of tissue thickness in Class I, Class II and Class III facial profile (skeletal type) of South African children with age, ancestry and sex combined

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value
Supraglabella	Class I	84	4.94	1.12	4.701	5.187	0.065
	Class II	247	4.91	1.21	4.760	5.064	
	Class III	57	4.53	1.09	4.238	4.815	
	Total	388	4.86	1.18	4.745	4.980	
Glabella	Class I	84	6.22	1.67	5.854	6.577	0.053
	Class II	247	6.01	1.29	5.851	6.176	
	Class III	57	5.65	1.03	5.379	5.928	
	Total	388	6.00	1.36	5.869	6.140	
Nasion	Class I	84	5.59	1.45	5.273	5.904	0.000
	Class II	247	5.35	1.38	5.175	5.521	
	Class III	57	4.51	1.20	4.188	4.823	
	Total	388	5.28	1.41	5.136	5.417	
End nasal	Class I	84	2.30	0.75	2.142	2.468	0.194
	Class II	247	2.31	0.71	2.226	2.404	
	Class III	57	2.13	0.54	1.987	2.276	
	Total	388	2.29	0.70	2.216	2.355	
Midphiltrum	Class I	84	13.56	3.33	12.838	14.281	0.000
	Class II	247	11.75	2.95	11.384	12.124	
	Class III	57	12.50	3.23	11.639	13.353	
	Total	388	12.25	3.15	11.939	12.569	
Labiale superius	Class I	84	12.85	2.13	12.384	13.308	0.017
	Class II	247	12.17	2.16	11.897	12.438	
	Class III	57	12.82	2.46	12.169	13.474	
	Total	388	12.41	2.22	12.189	12.632	
Labiale inferius	Class I	84	13.33	2.02	12.893	13.768	0.182
	Class II	247	13.35	2.28	13.062	13.633	
	Class III	57	12.75	2.35	12.129	13.374	
	Total	388	13.26	2.24	13.033	13.479	
Labiomentale	Class I	84	11.66	1.78	11.279	12.049	0.414
	Class II	247	11.69	2.14	11.420	11.957	
	Class III	57	11.29	2.09	10.736	11.845	
	Total	388	11.62	2.06	11.419	11.830	
Pogonion	Class I	84	10.71	2.42	10.188	11.239	0.736
	Class II	247	10.90	2.58	10.575	11.221	
	Class III	57	10.66	2.41	10.019	11.301	
	Total	388	10.82	2.52	10.572	11.074	
Beneath chin	Class I	84	5.18	1.23	4.634	5.723	0.272
	Class II	247	5.67	1.40	5.283	6.053	
	Class III	57	5.75	0.86	5.275	6.223	
	Total	388	5.56	1.29	5.292	5.832	

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)

Table 4.81: Comparison of the differences in mm of tissue thickness between Class I, Class II and Class III facial profile (skeletal type) of South African children with age, ancestry and sex combined

Landmark	Difference between Class I & Class II (mm)	Difference between Class I & Class III (mm)	Difference between Class II & Class III (mm)	Mean difference (mm)
Supraglabella	0.03	0.42	0.39	0.28
Glabella	0.20	0.56	0.36	0.37
Nasion	0.24	1.08	0.84	0.72
End nasal	-0.01	0.17	0.18	0.12
Midphiltrum	1.81	1.06	-0.74	0.71
Labiale superius	0.68	0.02	-0.65	0.02
Labiale inferius	-0.02	0.58	0.60	0.39
Labiomentale	-0.02	0.37	0.40	0.25
Pogonion	-0.18	0.05	0.24	0.04
Beneath chin	-0.49	-0.57	-0.08	-0.38

Differences > 1 mm are highlighted in light grey

Table 4.82: Comparison of tissue thickness in Class I, Class II and Class III facial profile (skeletal type) of South African children per age (6 – 10 years and 11 – 13 years) with ancestry and sex combined for the supraglabella, glabella, nasion, end nasal and midphiltrum

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm
	Class I 6 - 10 y	33	5.09	1.29	4.636	5.548		0.24
	Class I 11 - 13 y	51	4.85	1.00	4.568	5.130		
	Class II 6 - 10 y	97	4.82	1.34	4.550	5.091		-0.15
Supraglabella	Class II 11 - 13 y	150	4.97	1.12	4.791	5.153	0.190	
	Class III 6 - 10 y	21	4.45	1.05	3.972	4.924		-0.12
	Class III 11 - 13 y	36	4.57	1.12	4.192	4.952		
	Total	388	4.86	1.18	4.745	4.980		-0.01
	Class I 6 - 10 y	33	6.44	2.24	5.647	7.232		0.37
	Class I 11 - 13 y	51	6.07	1.16	5.743	6.397		
	Class II 6 - 10 y	97	6.02	1.37	5.741	6.293		0.01
Glabella	Class II 11 - 13 y	150	6.01	1.25	5.809	6.212	0.196	
	Class III 6 - 10 y	21	5.64	1.02	5.170	6.102		-0.03
	Class III 11 - 13 y	36	5.66	1.05	5.307	6.020		
	Total	388	6.00	1.36	5.869	6.140		0.12
	Class I 6 - 10 y	33	5.51	1.45	4.993	6.024		-0.13
	Class I 11 - 13 y	51	5.64	1.47	5.228	6.052		
	Class II 6 - 10 y	97	5.46	1.26	5.203	5.712		0.18
Nasion	Class II 11 - 13 y	150	5.28	1.45	5.043	5.511	0.000	
	Class III 6 - 10 y	21	4.38	0.92	3.962	4.795		-0.20
	Class III 11 - 13 y	36	4.58	1.34	4.126	5.033		
	Total	388	5.28	1.41	5.136	5.417		-0.05
	Class I 6 - 10 y	33	2.36	0.86	2.061	2.668		0.10
	Class I 11 - 13 y	51	2.27	0.68	2.074	2.458		
	Class II 6 - 10 y	97	2.27	0.72	2.125	2.414		-0.07
End nasal	Class II 11 - 13 y	150	2.34	0.70	2.230	2.458	0.463	
	Class III 6 - 10 y	21	2.20	0.62	1.915	2.478		0.10
	Class III 11 - 13 y	36	2.09	0.50	1.924	2.263		
	Total	388	2.29	0.70	2.216	2.355		0.04
	Class I 6 - 10 y	33	12.69	3.33	11.508	13.872		-1.43
	Class I 11 - 13 y	51	14.12	3.23	13.214	15.030		
	Class II 6 - 10 y	97	11.29	2.69	10.744	11.829		-0.77
Midphiltrum	Class II 11 - 13 y	150	12.06	3.08	11.560	12.552	0.000	
	Class III 6 - 10 y	21	12.19	3.00	10.821	13.553		-0.49
	Class III 11 - 13 y	36	12.68	3.38	11.532	13.822		
	Total	388	12.25	3.15	11.939	12.569		-0.90

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
Differences > 1 mm are highlighted in light grey
y - years

Table 4.83: Comparison of tissue thickness in Class I, Class II and Class III facial profile (skeletal type) of South African children per age (6 – 10 years and 11 – 13 years) with ancestry and sex combined for the labiale superius, labiale inferius, labiomentale, pogonion and beneath the chin landmark

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm
Labiale superius	Class I 6 - 10 y	33	12.56	2.41	11.704	13.416	0.094	-0.47
	Class I 11 - 13 y	51	13.03	1.93	12.489	13.573		
	Class II 6 - 10 y	97	12.15	2.28	11.687	12.607		-0.03
	Class II 11 - 13 y	150	12.18	2.08	11.845	12.517		
	Class III 6 - 10 y	21	12.62	2.14	11.643	13.591		-0.32
	Class III 11 - 13 y	36	12.94	2.65	12.044	13.837		
	Total	388	12.41	2.22	12.189	12.632		-0.28
Labiale inferius	Class I 6 - 10 y	33	12.93	2.22	12.140	13.713	0.007	-0.66
	Class I 11 - 13 y	51	13.59	1.85	13.071	14.112		
	Class II 6 - 10 y	97	12.77	2.56	12.254	13.285		-0.95
	Class II 11 - 13 y	150	13.72	1.99	13.399	14.043		
	Class III 6 - 10 y	21	12.69	2.60	11.511	13.878		-0.09
	Class III 11 - 13 y	36	12.78	2.22	12.032	13.536		
	Total	388	13.26	2.24	13.033	13.479		-0.57
Labiomentale	Class I 6 - 10 y	33	10.97	1.58	10.407	11.526	0.036	-1.15
	Class I 11 - 13 y	51	12.12	1.76	11.619	12.611		
	Class II 6 - 10 y	97	11.37	2.21	10.926	11.818		-0.52
	Class II 11 - 13 y	150	11.89	2.08	11.558	12.229		
	Class III 6 - 10 y	21	11.37	2.28	10.332	12.410		0.13
	Class III 11 - 13 y	36	11.24	2.00	10.566	11.920		
	Total	388	11.62	2.06	11.419	11.830		-0.51
Pogonion	Class I 6 - 10 y	33	10.16	2.48	9.286	11.043	0.088	-0.90
	Class I 11 - 13 y	51	11.07	2.34	10.410	11.728		
	Class II 6 - 10 y	97	10.40	2.32	9.930	10.864		-0.83
	Class II 11 - 13 y	150	11.22	2.69	10.788	11.657		
	Class III 6 - 10 y	21	10.59	2.25	9.564	11.609		-0.12
	Class III 11 - 13 y	36	10.70	2.54	9.844	11.562		
	Total	388	10.82	2.52	10.572	11.074		-0.62
Beneath chin	Class I 6 - 10 y	33	5.16	1.41	4.661	5.664	0.000	-1.31
	Class I 11 - 13 y	51	6.47	1.61	6.021	6.929		
	Class II 6 - 10 y	97	5.59	1.38	5.312	5.870		-0.66
	Class II 11 - 13 y	150	6.25	1.73	5.969	6.527		
	Class III 6 - 10 y	21	6.18	1.59	5.450	6.901		0.11
	Class III 11 - 13 y	36	6.06	1.32	5.617	6.508		
	Total	388	6.00	1.60	5.840	6.160		-0.62

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
Differences > 1 mm are highlighted in light grey
y - years

Table 4.84: Comparison of tissue thickness in Class I, Class II and Class III facial profile (skeletal type) of South African children per ancestry with age and sex combined for the supraglabella, glabella, nasion, end nasal and midphiltrum

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm
Supraglabella	Class I Black	22	4.97	1.07	4.495	5.447	0.353	0.04
	Class I Coloured	62	4.93	1.14	4.644	5.226		
	Class II Black	53	4.92	0.93	4.664	5.179		0.01
	Class II Coloured	194	4.91	1.28	4.728	5.091		
	Class III Black	15	4.59	0.85	4.121	5.067		0.09
	Class III Coloured	42	4.50	1.17	4.138	4.866		
	Total	388	4.86	1.18	4.745	4.980		0.05
Glabella	Class I Black	22	5.93	0.99	5.486	6.368	0.066	-0.39
	Class I Coloured	62	6.32	1.84	5.850	6.785		
	Class II Black	53	5.76	1.13	5.446	6.067		-0.33
	Class II Coloured	194	6.08	1.33	5.895	6.272		
	Class III Black	15	5.40	0.86	4.926	5.878		-0.34
	Class III Coloured	42	5.74	1.08	5.405	6.081		
	Total	388	6.00	1.36	5.869	6.140		-0.35
Nasion	Class I Black	22	5.39	1.30	4.812	5.962	0.000	-0.27
	Class I Coloured	62	5.66	1.51	5.277	6.043		
	Class II Black	53	4.86	1.08	4.567	5.159		-0.62
	Class II Coloured	194	5.48	1.43	5.279	5.682		
	Class III Black	15	4.69	1.16	4.042	5.331		0.25
	Class III Coloured	42	4.44	1.21	4.063	4.819		
	Total	388	5.28	1.41	5.136	5.417		-0.21
End nasal	Class I Black	22	2.56	0.51	2.331	2.781	0.001	0.34
	Class I Coloured	62	2.22	0.81	2.011	2.420		
	Class II Black	53	2.58	0.75	2.369	2.782		0.33
	Class II Coloured	194	2.24	0.68	2.147	2.341		
	Class III Black	15	2.42	0.30	2.253	2.587		0.39
	Class III Coloured	42	2.03	0.58	1.848	2.207		
	Total	388	2.29	0.70	2.216	2.355		0.35
Midphiltrum	Class I Black	22	10.35	3.18	8.945	11.762	0.000	-4.34
	Class I Coloured	62	14.70	2.56	14.047	15.347		
	Class II Black	53	10.82	2.40	10.156	11.476		-1.19
	Class II Coloured	194	12.01	3.04	11.580	12.440		
	Class III Black	15	10.37	1.71	9.422	11.310		-2.89
	Class III Coloured	42	13.26	3.32	12.223	14.291		
	Total	388	12.25	3.15	11.939	12.569		-2.81

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
Differences > 1 mm are highlighted in light grey

Table 4.85: Comparison of tissue thickness in Class I, Class II and Class III facial profile (skeletal type) of South African children per ancestry with age and sex combined for the labiale superius, labiale inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm
Labiale superius	Class I Black	22	12.65	1.42	12.024	13.285	0.123	-0.26
	Class I Coloured	62	12.91	2.34	12.321	13.507		
	Class II Black	53	12.23	2.22	11.615	12.841		0.08
	Class II Coloured	194	12.15	2.15	11.847	12.455		
	Class III Black	15	13.05	1.68	12.121	13.980		0.31
	Class III Coloured	42	12.74	2.70	11.899	13.580		
	Total	388	12.41	2.22	12.189	12.632		0.04
Labiale inferius	Class I Black	22	12.96	2.34	11.925	13.996	0.172	-0.50
	Class I Coloured	62	13.46	1.89	12.980	13.942		
	Class II Black	53	12.85	2.03	12.284	13.406		-0.64
	Class II Coloured	194	13.48	2.32	13.155	13.814		
	Class III Black	15	12.59	2.09	11.437	13.749		-0.21
	Class III Coloured	42	12.81	2.45	12.043	13.572		
	Total	388	13.26	2.24	13.033	13.479		-0.45
Labiomentale	Class I Black	22	11.11	1.58	10.410	11.811	0.000	-0.75
	Class I Coloured	62	11.86	1.81	11.400	12.320		
	Class II Black	53	10.55	1.48	10.148	10.961		-1.44
	Class II Coloured	194	12.00	2.19	11.688	12.309		
	Class III Black	15	11.41	2.29	10.144	12.677		0.16
	Class III Coloured	42	11.25	2.04	10.611	11.884		
	Total	388	11.62	2.06	11.419	11.830		-0.68
Pogonion	Class I Black	22	10.36	2.16	9.401	11.319	0.827	-0.48
	Class I Coloured	62	10.84	2.51	10.201	11.477		
	Class II Black	53	11.20	2.01	10.644	11.750		0.38
	Class II Coloured	194	10.82	2.71	10.432	11.201		
	Class III Black	15	10.73	2.21	9.509	11.952		0.10
	Class III Coloured	42	10.64	2.51	9.853	11.417		
	Total	388	10.82	2.52	10.572	11.074		0.00
Beneath chin	Class I Black	22	5.18	1.23	4.634	5.723	0.049	-1.06
	Class I Coloured	62	6.24	1.71	5.801	6.671		
	Class II Black	53	5.67	1.40	5.283	6.053		-0.41
	Class II Coloured	194	6.08	1.68	5.840	6.317		
	Class III Black	15	5.75	0.86	5.275	6.223		-0.48
	Class III Coloured	42	6.23	1.55	5.748	6.715		
	Total	388	6.00	1.60	5.840	6.160		-0.65

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
Differences > 1 mm are highlighted in light grey

Table 4.86: Comparison of tissue thickness in Class I, Class II and Class III facial profile (skeletal type) of South African children per sex with age and ancestry combined for the supraglabella, glabella, nasion, end nasal and midphiltrum

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm
	Class I Males	32	4.80	0.92	4.468	5.135		-0.23
	Class I Females	52	5.03	1.22	4.691	5.373		
	Class II Males	96	4.94	1.27	4.683	5.199		0.05
Supraglabella	Class II Females	151	4.89	1.18	4.705	5.083	0.278	
	Class III Males	24	4.53	1.14	4.050	5.012		0.01
	Class III Males	33	4.52	1.07	4.145	4.901		
	Total	388	4.86	1.18	4.745	4.980		-0.06
	Class I Males	32	6.15	1.51	5.599	6.691		-0.11
	Class I Females	52	6.26	1.76	5.767	6.750		
	Class II Males	96	6.07	1.23	5.824	6.323		0.10
Glabella	Class II Females	151	5.98	1.34	5.760	6.190	0.274	
	Class III Males	24	5.60	1.04	5.163	6.045		-0.08
	Class III Males	33	5.69	1.04	5.320	6.058		
	Total	388	6.00	1.36	5.869	6.140		-0.03
	Class I Males	32	5.59	1.32	5.109	6.063		0.00
	Class I Females	52	5.59	1.54	5.161	6.019		
	Class II Males	96	5.19	1.37	4.910	5.466		-0.26
Nasion	Class II Females	151	5.45	1.38	5.228	5.671	0.000	
	Class III Males	24	4.66	1.21	4.150	5.170		0.27
	Class III Males	33	4.39	1.19	3.971	4.816		
	Total	388	5.28	1.41	5.136	5.417		0.00
	Class I Males	32	2.49	0.66	2.255	2.730		0.30
	Class I Females	52	2.19	0.79	1.970	2.408		
	Class II Males	96	2.25	0.70	2.105	2.389		-0.11
End nasal	Class II Females	151	2.36	0.71	2.243	2.473	0.123	
	Class III Males	24	2.09	0.63	1.825	2.355		-0.07
	Class III Males	33	2.16	0.48	1.990	2.332		
	Total	388	2.29	0.70	2.216	2.355		0.04
	Class I Males	32	13.73	3.13	12.602	14.857		0.27
	Class I Females	52	13.46	3.47	12.489	14.421		
	Class II Males	96	12.07	3.09	11.447	12.699		0.52
Midphiltrum	Class II Females	151	11.55	2.85	11.093	12.009	0.000	
	Class III Males	24	11.88	3.66	10.334	13.427		-1.06
	Class III Males	33	12.94	2.85	11.933	13.955		
	Total	388	12.25	3.15	11.939	12.569		-0.09

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
Differences > 1 mm are highlighted in light grey

Table 4.87: Comparison of tissue thickness in Class I, Class II and Class III facial profile (skeletal type) of South African children per sex with age and ancestry combined labiale superius, labiale inferius, labiomentale, pogonion and beneath chin landmarks

Landmark	Group	N	Mean	SD	95% Confidence Interval		ANOVA, p-value	Difference in mm
Labiale superius	Class I Males	32	12.75	2.00	12.033	13.472	0.092	-0.15
	Class I Females	52	12.90	2.22	12.284	13.522		
	Class II Males	96	12.32	2.21	11.877	12.773		0.26
	Class II Females	151	12.07	2.13	11.726	12.410		
	Class III Males	24	12.60	2.64	11.489	13.718		-0.38
	Class III Males	33	12.98	2.35	12.147	13.812		
	Total	388	12.41	2.22	12.189	12.632		-0.09
Labiale inferius	Class I Males	32	13.73	1.67	13.129	14.332	0.173	0.65
	Class I Females	52	13.08	2.18	12.476	13.691		
	Class II Males	96	13.40	2.40	12.916	13.887		0.09
	Class II Females	151	13.31	2.20	12.958	13.667		
	Class III Males	24	12.20	2.69	11.060	13.332		-0.96
	Class III Males	33	13.15	2.01	12.443	13.867		
	Total	388	13.26	2.24	13.033	13.479		-0.07
Labiomentale	Class I Males	32	11.59	1.76	10.955	12.222	0.668	-0.12
	Class I Females	52	11.71	1.80	11.209	12.212		
	Class II Males	96	11.69	2.11	11.258	12.112		-0.01
	Class II Females	151	11.69	2.17	11.342	12.040		
	Class III Males	24	10.91	2.28	9.950	11.876		-0.65
	Class III Males	33	11.56	1.93	10.880	12.248		
	Total	388	11.62	2.06	11.419	11.830		-0.26
Pogonion	Class I Males	32	9.97	2.24	9.161	10.779	0.059	-1.20
	Class I Females	52	11.17	2.44	10.493	11.849		
	Class II Males	96	10.67	2.22	10.224	11.125		-0.37
	Class II Females	151	11.04	2.78	10.594	11.487		
	Class III Males	24	9.86	2.25	8.905	10.806		-1.39
	Class III Males	33	11.25	2.39	10.397	12.094		
	Total	388	10.82	2.52	10.572	11.074		-0.99
Beneath chin	Class I Males	32	5.80	1.82	5.147	6.461	0.557	-0.25
	Class I Females	52	6.05	1.56	5.619	6.490		
	Class II Males	96	5.80	1.55	5.483	6.109		-0.32
	Class II Females	151	6.11	1.68	5.844	6.384		
	Class III Males	24	5.87	1.60	5.193	6.548		-0.40
	Class III Males	33	6.27	1.25	5.831	6.717		
	Total	388	6.00	1.60	5.840	6.160		-0.32

Significant differences between groups are highlighted (ANOVA, $p \leq 0.05$)
Differences > 1 mm are highlighted in light grey

Table 4.88: Comparison of tissue thickness values of class I, class II and class II facial profile (skeletal type) from Utsuno et al. (2005) to results of Black children from the current study

	6 - 9 years								
Landmark	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**T-test**	**Current study**	**Utsuno *et al.* (2005)**	**p value**
	BF, class I (n=5)	**JF, class I (n=9)**		**BF, class II (n=8)**	**JF, class II (n=8)**	**p-value**	**BF, Class III (n=3)**	**JF, class III (n=15)**	
Glabella	5.80	4.75	0.2277	5.75	4.65	0.0080	5.08	5.20	0.8009
Nasion	5.58	5.81	0.7874	4.68	5.31	0.0800	3.78	5.90	0.0215
End nasal	2.37	2.59	0.2611	2.50	2.72	0.2155	2.53	2.90	0.2785
Midphiltrum	9.07	11.49	0.1177	9.70	10.31	0.4697	10.37	11.20	0.5866
Upper lip border	12.38	14.36	0.0663	13.00	13.25	0.6394	12.84	15.60	0.0221
Lower lip border	11.20	15.26	0.0237	12.21	16.44	0.0005	12.14	16.20	0.1561
Labiomentale	9.95	14.19	0.0001	10.99	13.73	0.0010	11.24	12.50	0.5136
Pogonion	9.89	11.22	0.1670	11.00	11.43	0.4142	9.86	11.40	0.2172
Beneath chin	5.05	5.83	0.3190	5.81	6.00	0.6526	6.03	6.80	0.0406

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key:BF – Black females; JF – Japanese females

Table 4.89: Comparison of tissue thickness values of class I, class II and class II facial profile (skeletal type) from Utsuno et al. (2005) to results of Black children from the current study

	10 & 11 years								
Landmark	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**p value**
	BF, class I (n=8)	**JF, class I (n=19)**		**BF, class II (n=5)**	**JF, class II (n=9)**		**BF, class III (n=2)**	**JF, class III (n=21)**	
Glabella	6.27	5.52	0.0496	5.95	5.18	0.2617	4.78	5.60	0.1695
Nasion	5.64	6.01	0.5600	4.71	5.94	0.0501	5.08	6.40	0.1844
End nasal	2.48	2.74	0.1181	3.49	2.77	0.3717	2.15	2.80	0.1162
Midphiltrum	8.83	12.33	0.0173	9.73	12.02	0.0137	9.66	11.70	0.1687
Upper lip border	12.60	14.43	0.0123	11.75	13.75	0.0015	12.27	15.10	0.1048
Lower lip border	12.33	14.60	0.0062	13.35	16.16	0.0059	13.57	14.30	0.0903
Labiomentale	10.48	13.01	0.0006	11.23	14.04	0.0002	10.99	12.80	0.2737
Pogonion	11.47	11.08	0.6266	13.56	10.96	0.1342	12.23	11.20	0.5181
Beneath chin	5.87	6.85	0.0374	7.04	5.16	0.2111	5.00	6.90	0.0000

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key:BF – Black females; JF – Japanese females

Table 4.90: Comparison of tissue thickness values of class I, class II and class II facial profile (skeletal type) from Utsuno et al. (2005) to results of Black children from the current study

	12 & 13 years								
Landmark	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**p value**
	BF, class I (n=5)	**JF, class I (n=17)**		**BF, class II (n=7)**	**JF, class II (n=4)**		**BF, class III (n=4)**	**JF, class III (n=8)**	
Glabella	6.66	5.50	0.0693	5.75	6.02	0.5486	6.15	5.60	0.2651
Nasion	4.86	5.86	0.1576	5.16	6.80	0.0289	5.08	6.10	0.3865
End nasal	2.62	2.75	0.7409	2.40	2.89	0.0096	2.39	2.50	0.4754
Midphiltrum	11.59	13.93	0.0093	10.93	12.73	0.0922	10.48	12.20	0.1089
Upper lip border	13.85	15.22	0.1288	12.39	14.80	0.0241	14.42	14.40	0.9811
Lower lip border	14.77	15.73	0.3727	13.86	16.27	0.0124	13.82	14.50	0.5920
Labiomentale	11.47	14.64	0.0059	10.39	14.59	0.0001	13.58	12.20	0.3557
Pogonion	11.66	11.81	0.8573	11.88	12.75	0.1721	12.16	11.20	0.5727
Beneath chin	5.48	5.96	0.0813	6.30	6.75	0.2850	5.80	6.30	0.4950

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key:BF – Black females; JF – Japanese females

Table 4.91: Comparison of tissue thickness values of class I, class II and class II facial profile (skeletal type) from Utsuno et al. (2005) to results of Coloured children from the current study

	6 - 9 years								
Landmark	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**T-test**	**Current study**	**Utsuno *et al.* (2005)**	**p-value**
	CF, class I (n=17)	**JF, class I (n=11)**		**CF, class II (n=17)**	**JF, class II (n=8)**	**p-value**	**CF, class III (n=1)**	**JF, class III (n=15)**	
Glabella	6.61	4.75	0.0062	6.73	4.65	0.0001	5.20	5.20	none
Nasion	6.05	5.81	0.5050	5.37	5.31	0.8451	4.87	5.90	none
End nasal	2.36	2.59	0.3855	2.28	2.72	0.0347	2.33	2.90	none
Midphiltrum	13.37	11.49	0.0017	11.91	10.31	0.0034	14.41	11.20	none
Upper lip border	12.33	14.36	0.0101	12.30	13.25	0.1521	11.80	15.60	none
Lower lip border	13.08	15.26	0.0003	13.46	16.44	0.0002	13.00	16.20	none
Labiomentale	11.72	14.19	0.0001	12.11	13.73	0.0122	11.10	12.50	none
Pogonion	10.59	11.22	0.3290	9.90	11.43	0.0400	12.40	11.40	none
Beneath chin	5.53	5.83	0.3092	5.82	6.00	0.6179	7.00	6.80	none

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key:BF – Black females; JF – Japanese females

Table 4.92: Comparison of tissue thickness values of class I, class II and class II facial profile (skeletal type) from Utsuno et al. (2005) to results of Coloured children from the current study

	10 & 11 years								
Landmark	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**p value**
	CF, class I (n=27)	**JF, class I (n=19)**		**CF, class II (n=45)**	**JF, class II (n=9)**		**CF, class III (n=6)**	**JF, class III (n=21)**	
Glabella	6.16	5.52	0.0039	5.67	5.18	0.0383	5.76	5.60	0.6935
Nasion	5.21	6.01	0.0031	5.56	5.94	0.1572	3.77	6.40	0.0012
End nasal	2.24	2.74	0.0017	2.33	2.77	0.0007	2.13	2.80	0.0122
Midphiltrum	13.89	12.33	0.0228	11.76	12.02	0.5704	14.87	11.70	0.0410
Upper lip border	12.57	14.43	0.0004	11.66	13.75	0.0000	13.96	15.10	0.4989
Lower lip border	13.29	14.60	0.0097	13.09	16.16	0.0000	13.77	14.30	0.6072
Labiomentale	10.97	13.01	0.0000	12.02	14.04	0.00002	10.49	12.80	0.0573
Pogonion	11.82	11.08	0.2044	10.48	10.96	0.2972	10.66	11.20	0.6928
Beneath chin	6.47	6.85	0.2950	6.07	5.16	0.0013	6.77	6.90	0.8588

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key:BF – Black females; JF – Japanese females

Table 4.93: Comparison of tissue thickness values of class I, class II and class II facial profile (skeletal type) from Utsuno et al. (2005) to results of Coloured children from the current study

	12 & 13 years								
Landmark	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**p value**	**Current study**	**Utsuno *et al.* (2005)**	**p value**
	CF (n=29)	**JF, class I (n=17)**		**CF (n=45)**	**JF, class II (n=4)**		**CF (n=16)**	**JF, class III (n=8)**	
Supraglabella									
Glabella	5.77	5.50	0.2432	6.07	6.02	0.8499	5.77	5.60	0.5930
Nasion	5.53	5.86	0.2374	5.54	6.80	0.0000	4.49	6.10	0.0001
End nasal	1.99	2.75	0.0000	2.35	2.89	0.0000	2.07	2.50	0.0084
Midphiltrum	13.52	13.93	0.4543	11.41	12.73	0.0135	13.62	12.20	0.0483
Upper lip border	12.53	15.22	0.0000	11.95	14.80	0.0000	12.41	14.40	0.0023
Lower lip border	13.41	15.73	0.0000	13.55	16.27	0.0000	12.91	14.50	0.0054
Labiomentale	12.33	14.64	0.0000	11.92	14.59	0.0000	11.55	12.20	0.0922
Pogonion	10.72	11.81	0.0430	11.33	12.75	0.0016	11.32	11.20	0.8368
Beneath chin	6.31	5.96	0.2870	6.47	6.75	0.3425	6.31	6.30	0.9826

Significant differences between groups are highlighted (*t*-test, $p \leq 0.05$)
Key:BF – Black females; JF – Japanese females

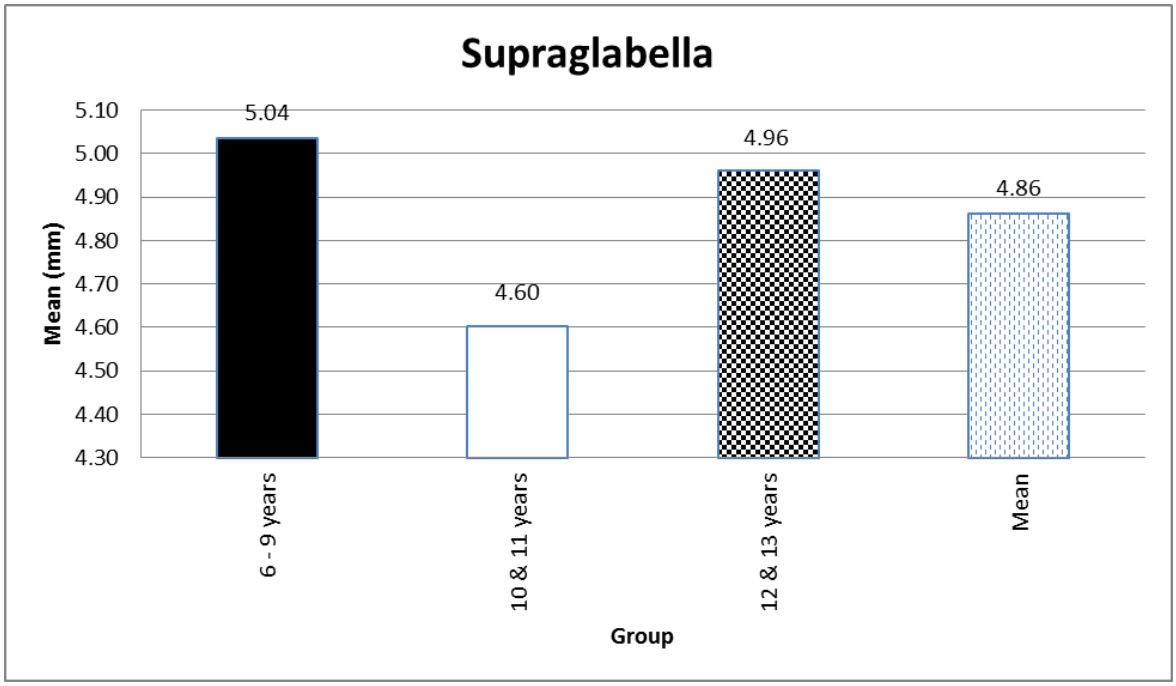

Figure 4.1: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the supraglabella

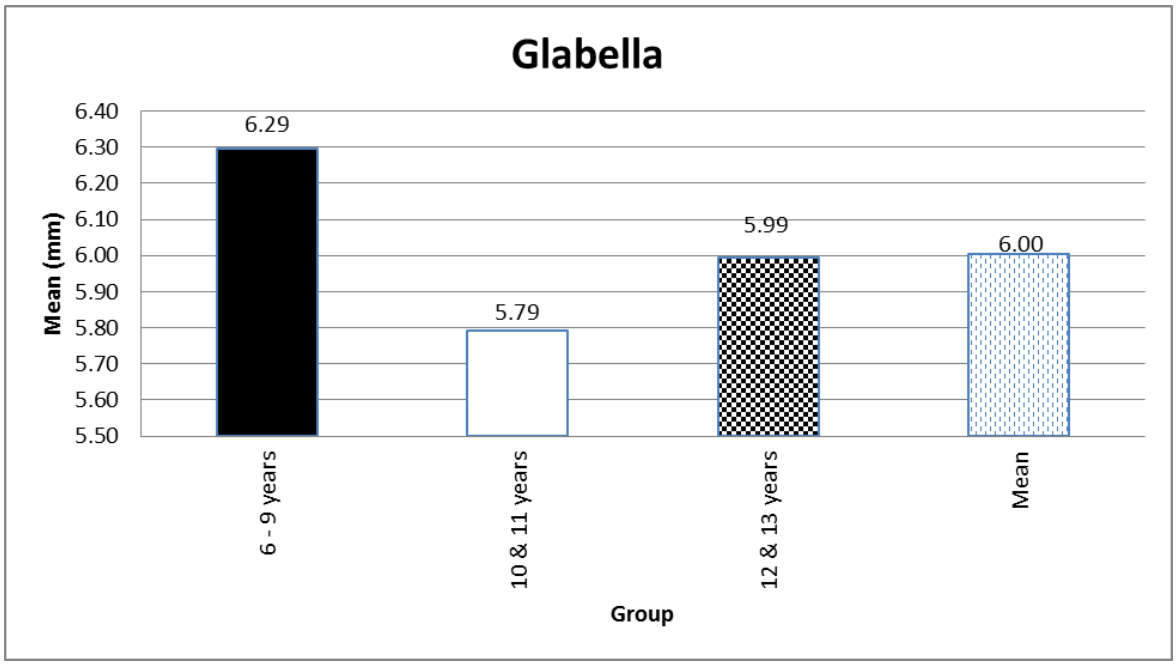

Figure 4.2: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the glabella

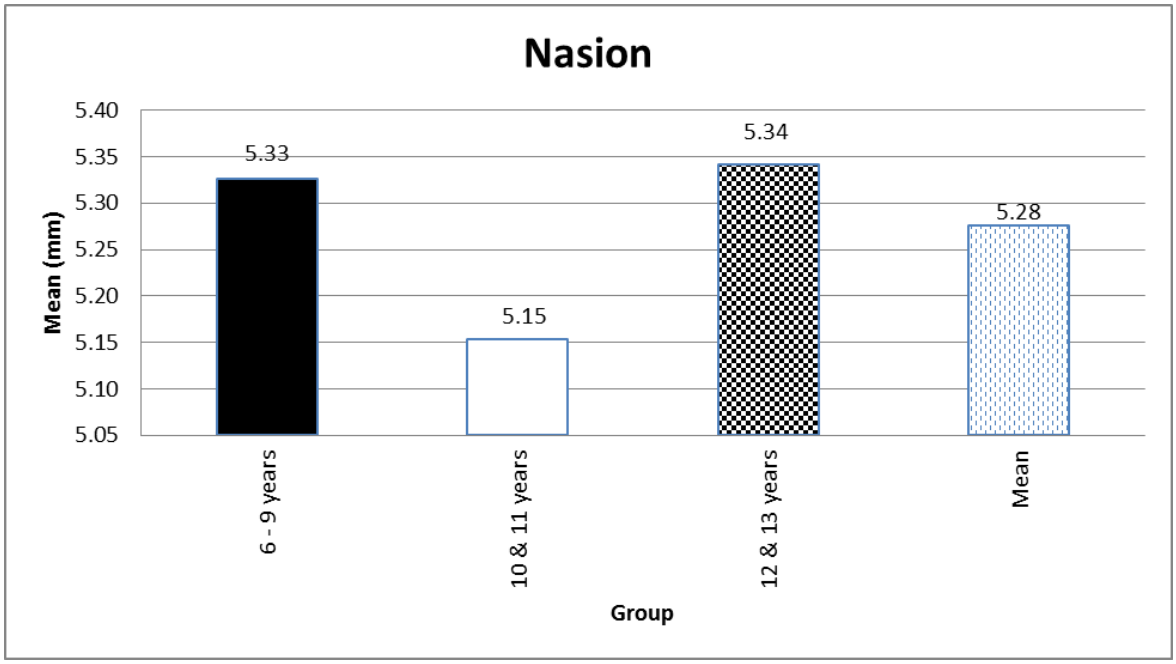

Figure 4.3: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the nasion

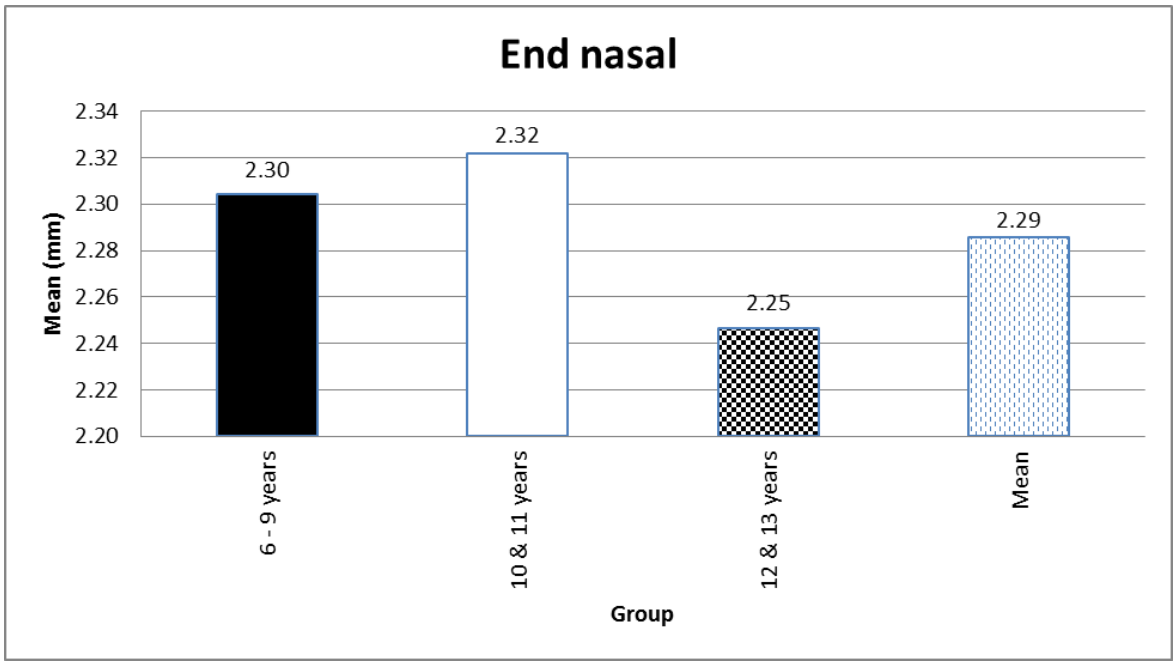

Figure 4.4: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the end nasal

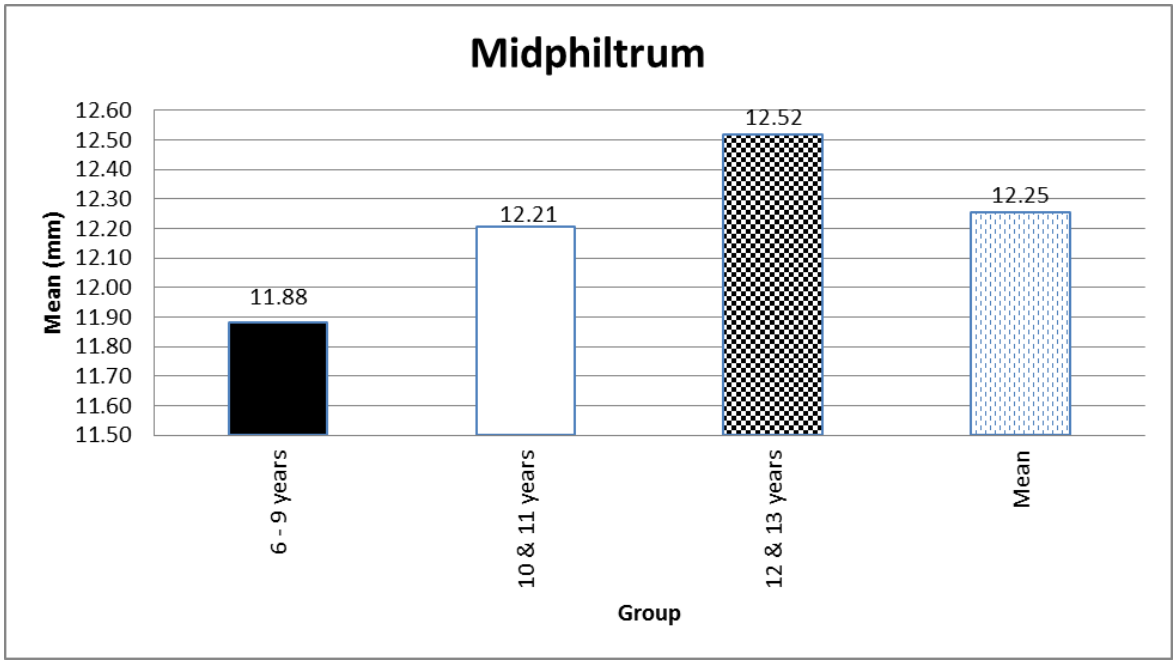

Figure 4.5: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the midphiltrum

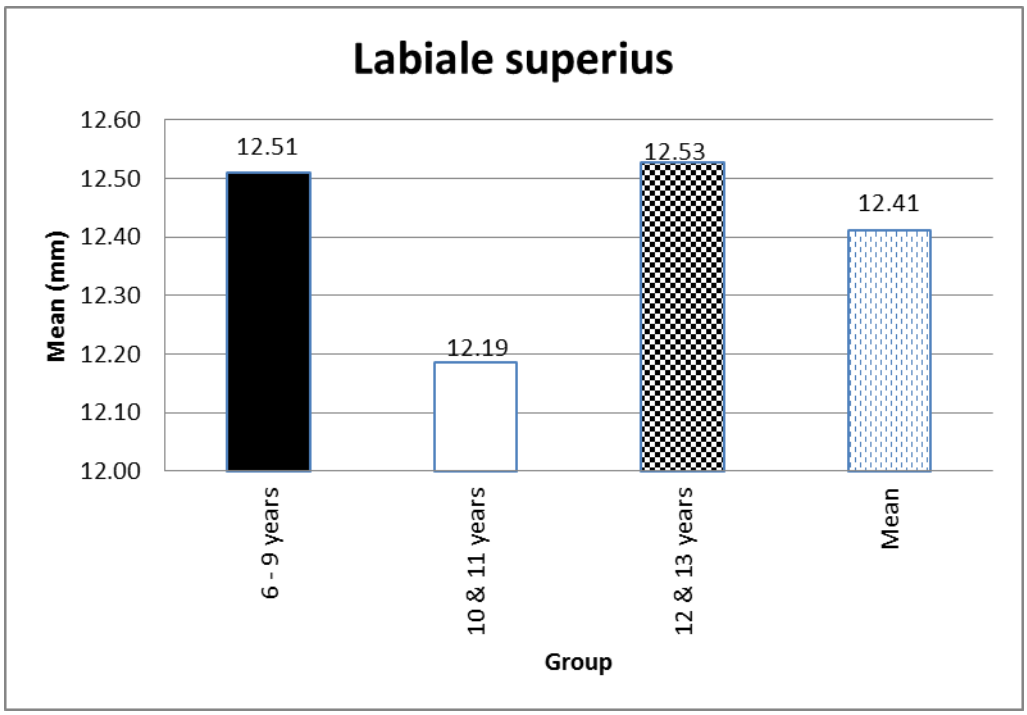

Figure 4.6: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the labiale superius

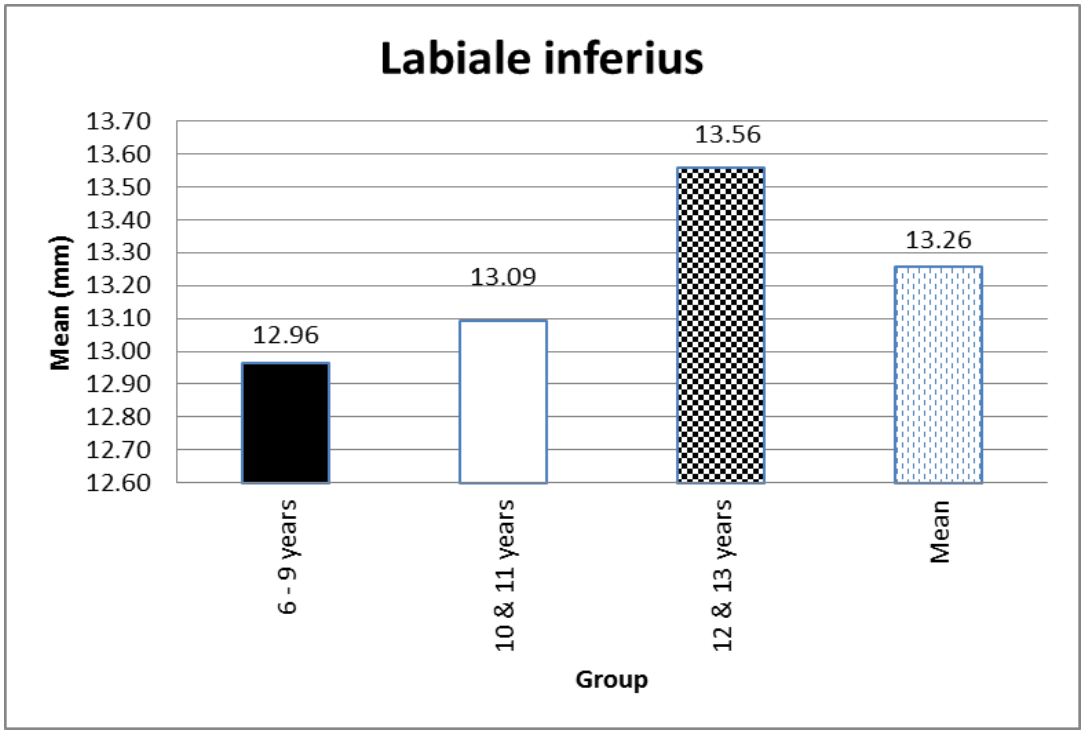

Figure 4.7: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the labiale inferius

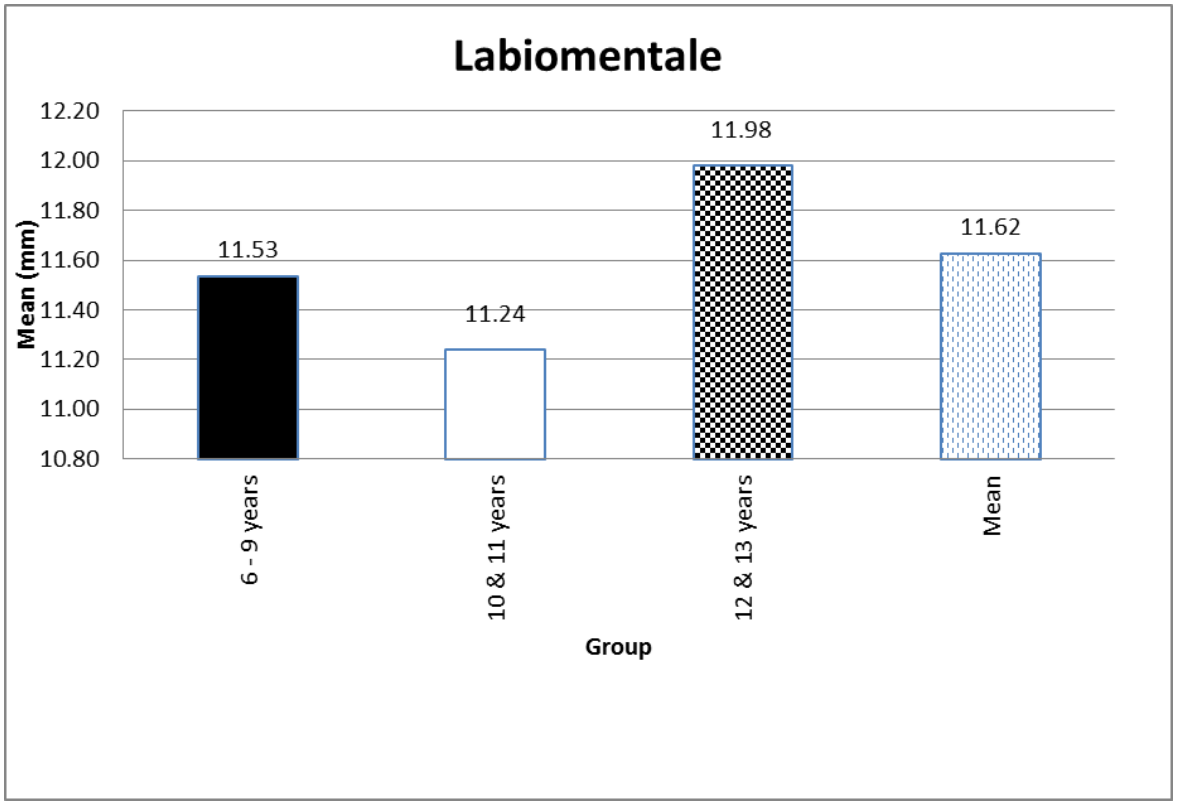

Figure 4.8: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the labiomentale

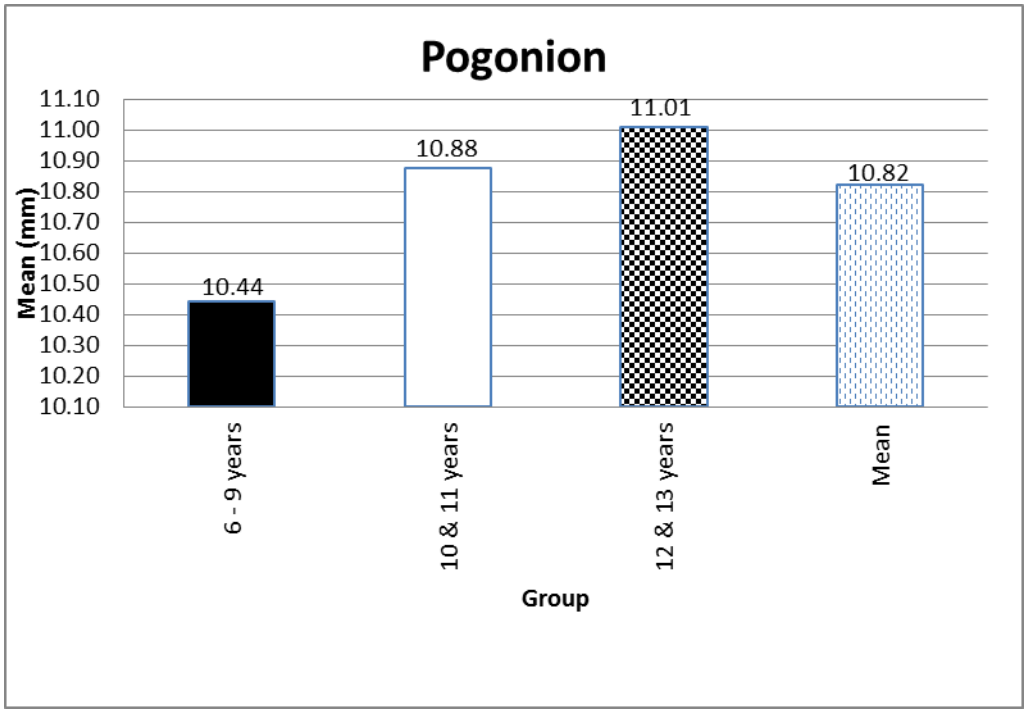

Figure 4.9: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the pogonion

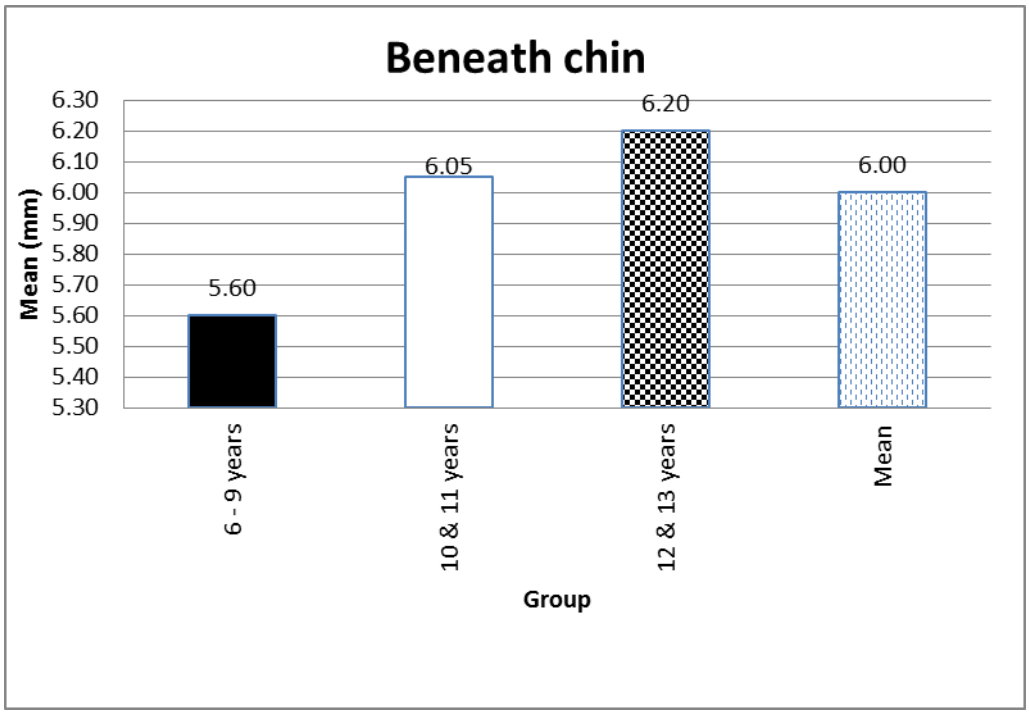

Figure 4.10: Comparison of the tissue thickness in terms of three age groups (6 – 9 years, 10 & 11 years and 12 & 13 years) for the beneath chin landmark

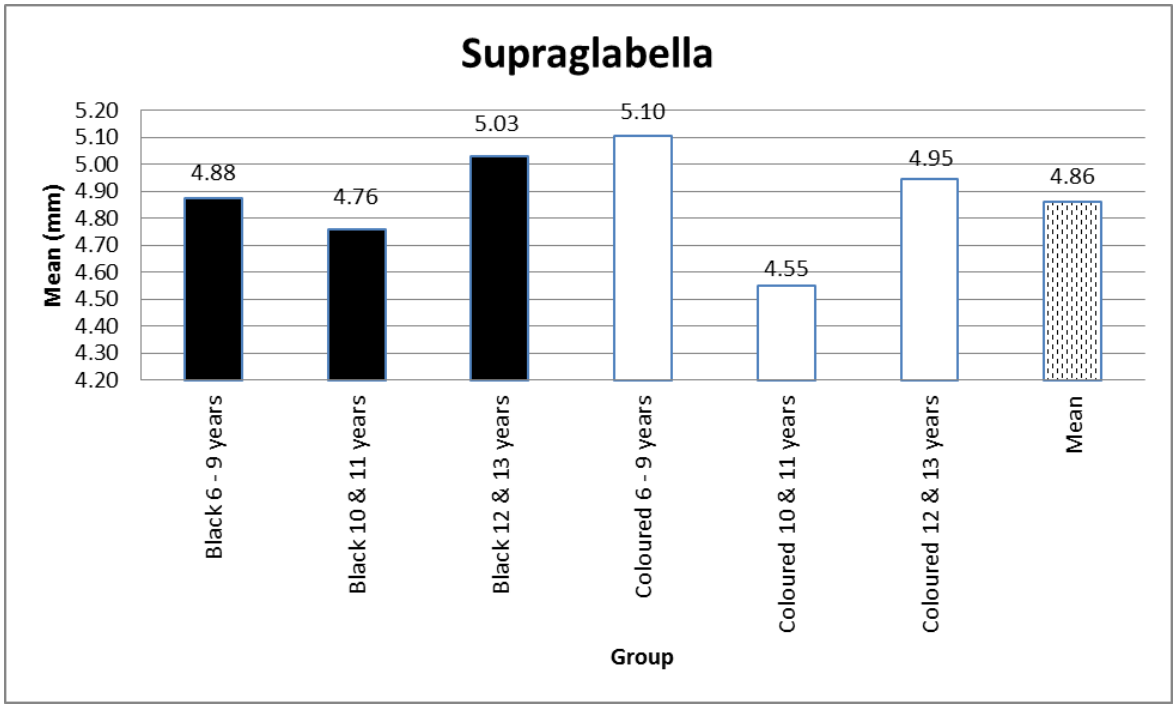

Figure 4.11: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the supraglabella

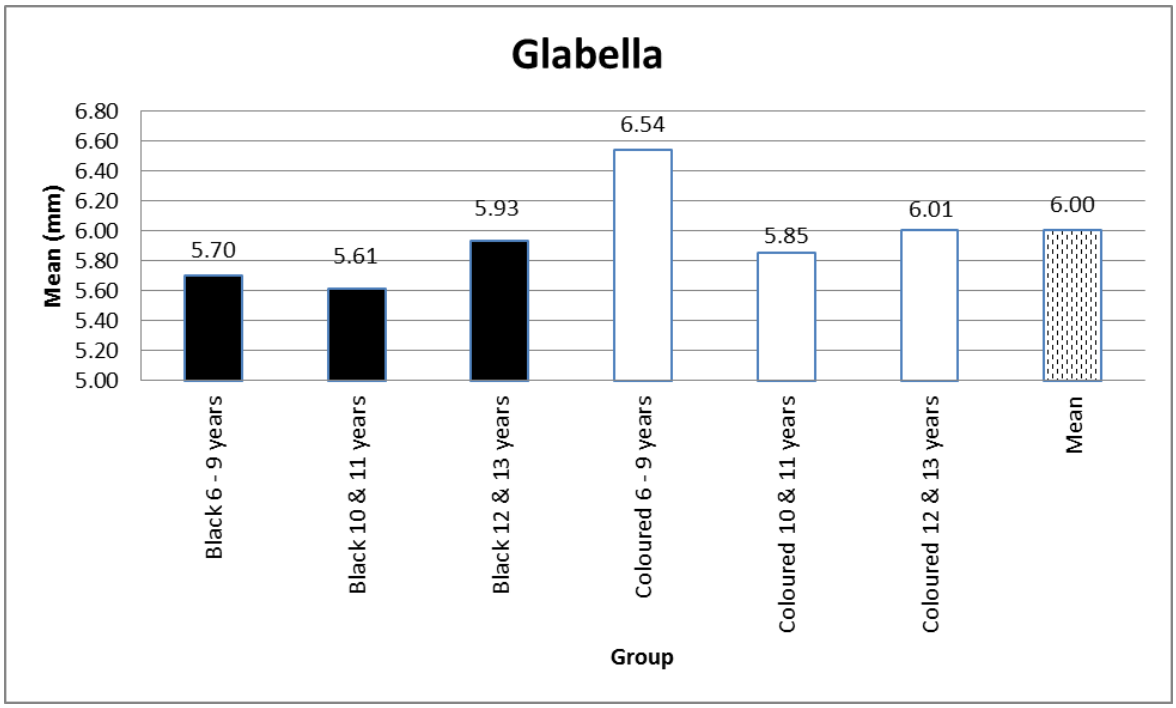

Figure 4.12: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the glabella

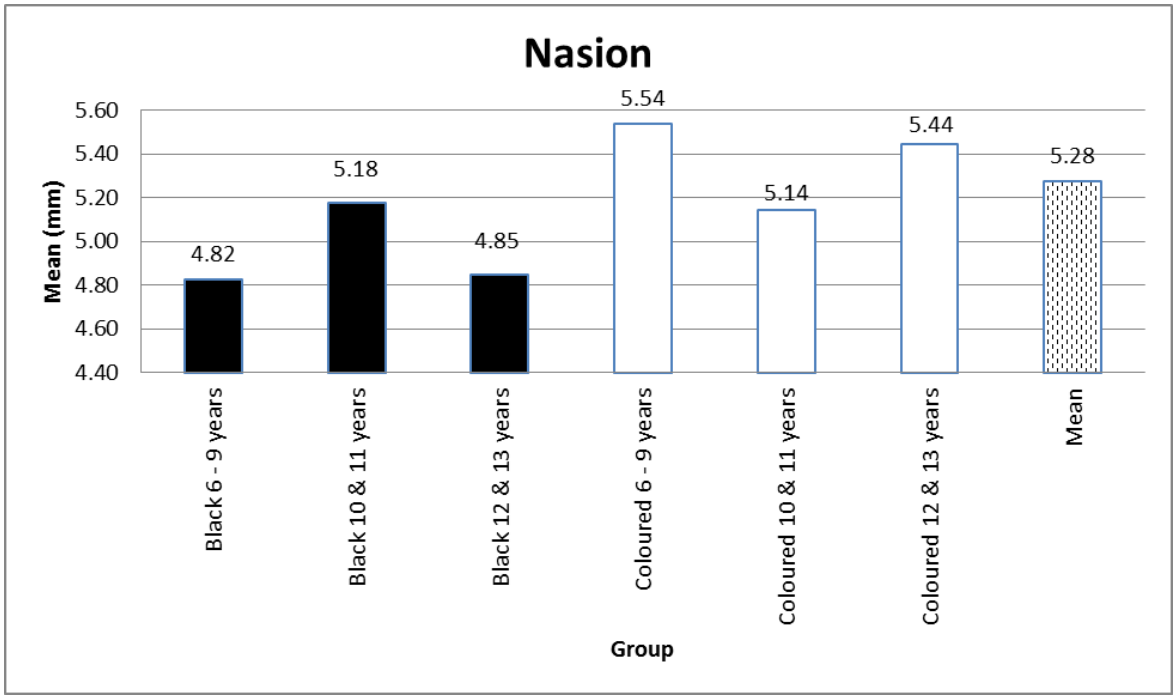

Figure 4.13: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the nasion

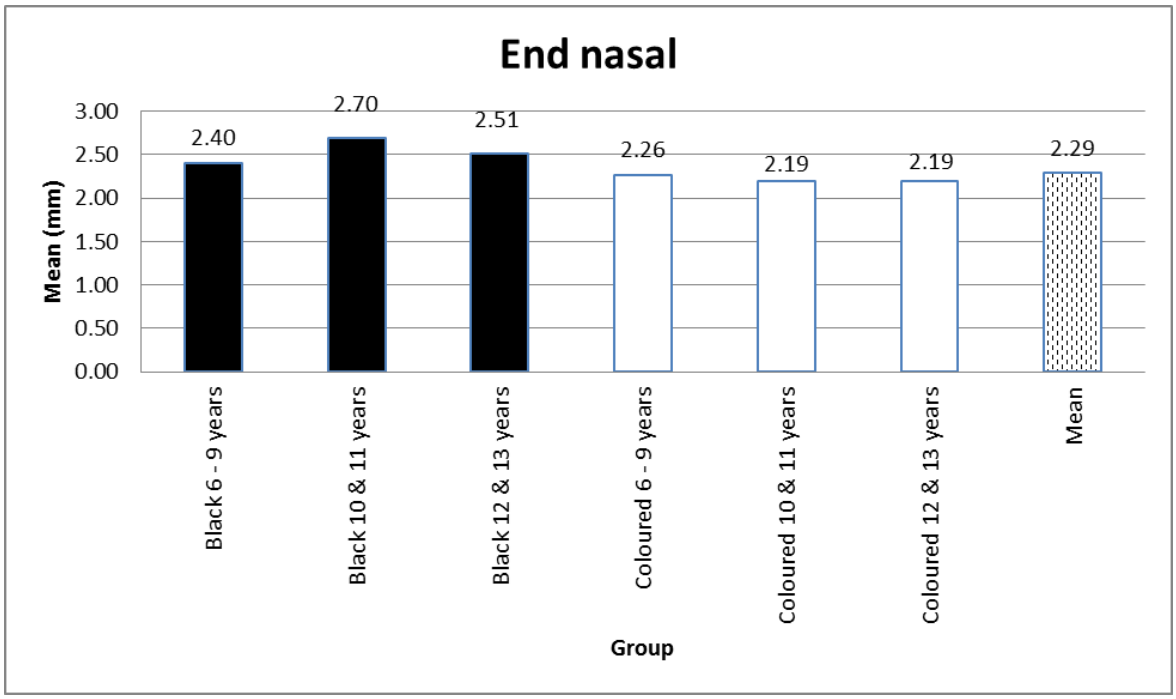

Figure 4.14: Co Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the end nasal

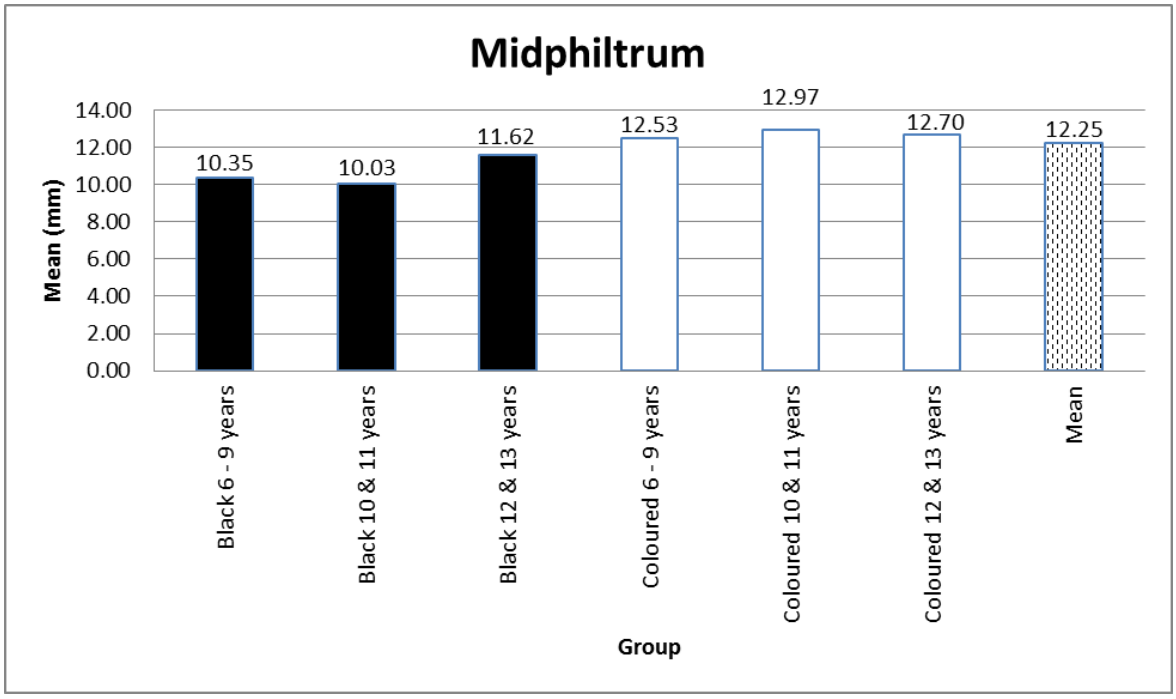

Figure 4.15: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the midphiltrum

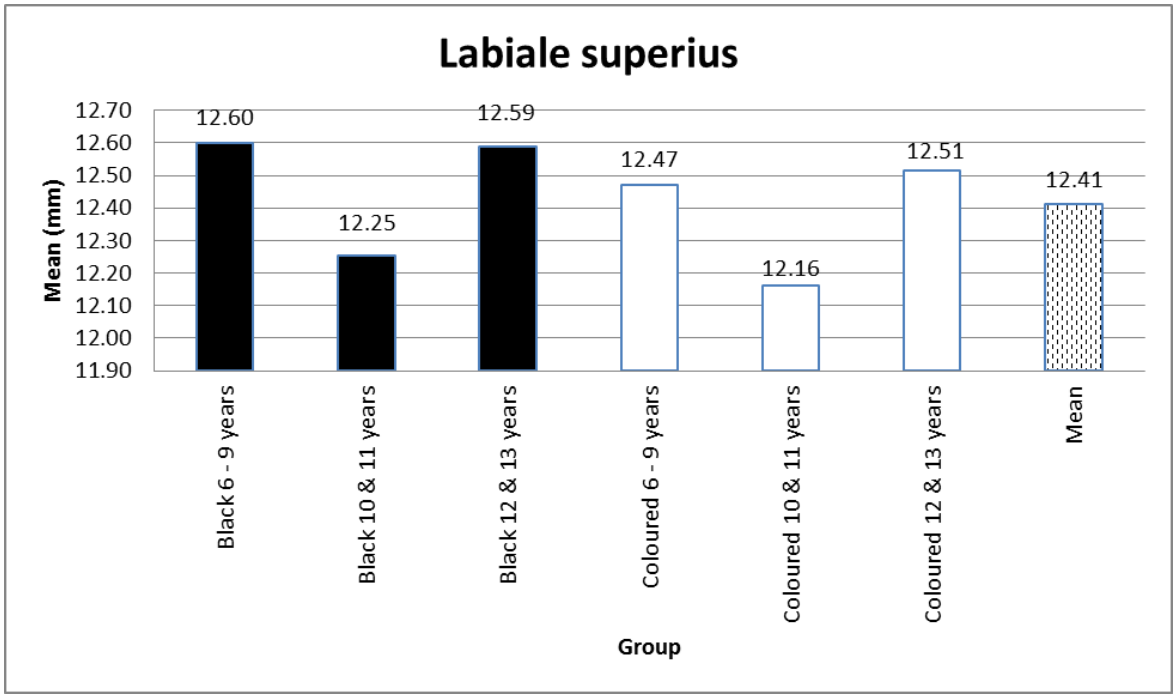

Figure 4.16: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the labiale superius

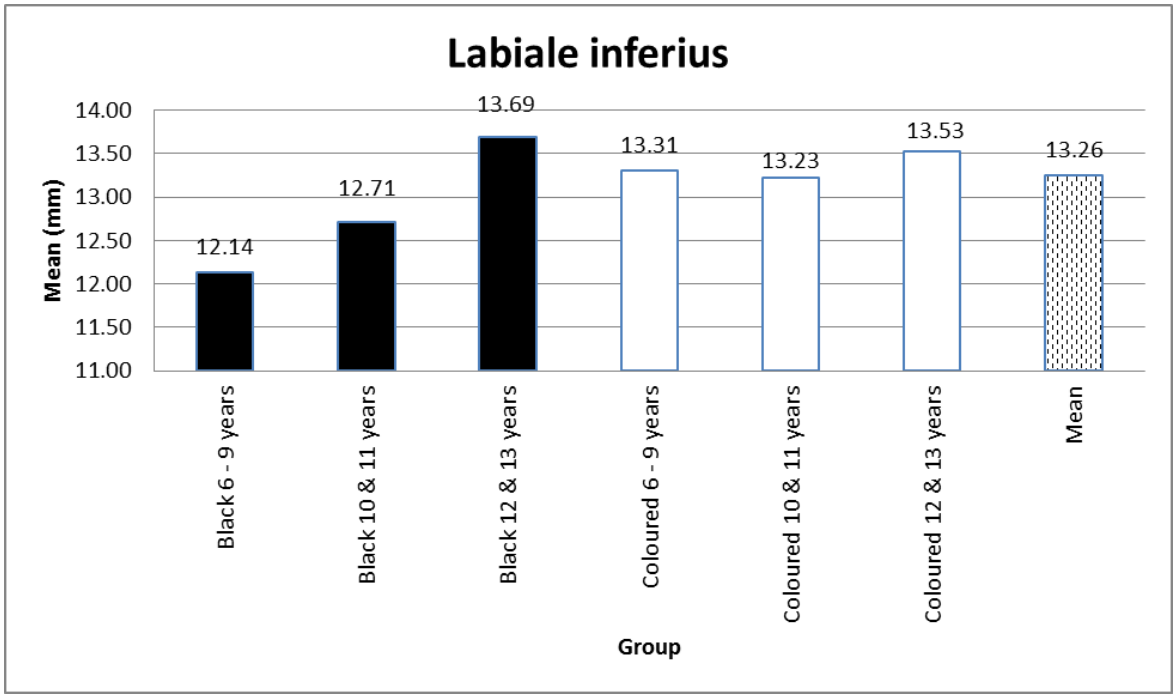

Figure 4.17: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the labiale inferius

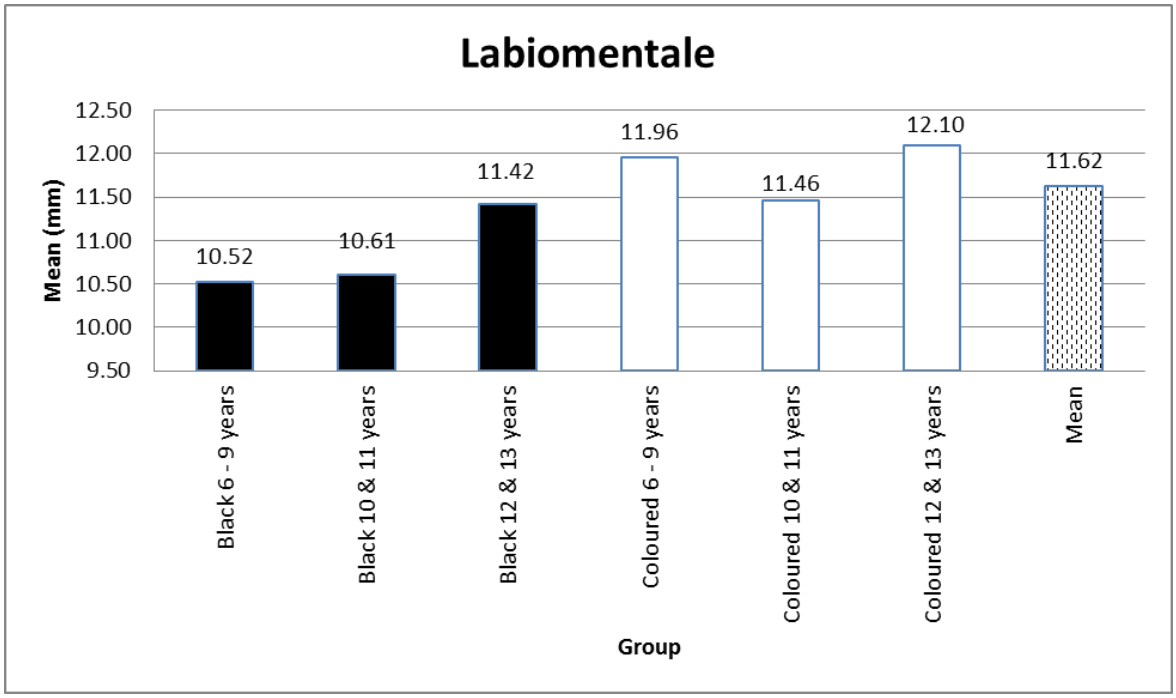

Figure 4.18: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the labiomentale

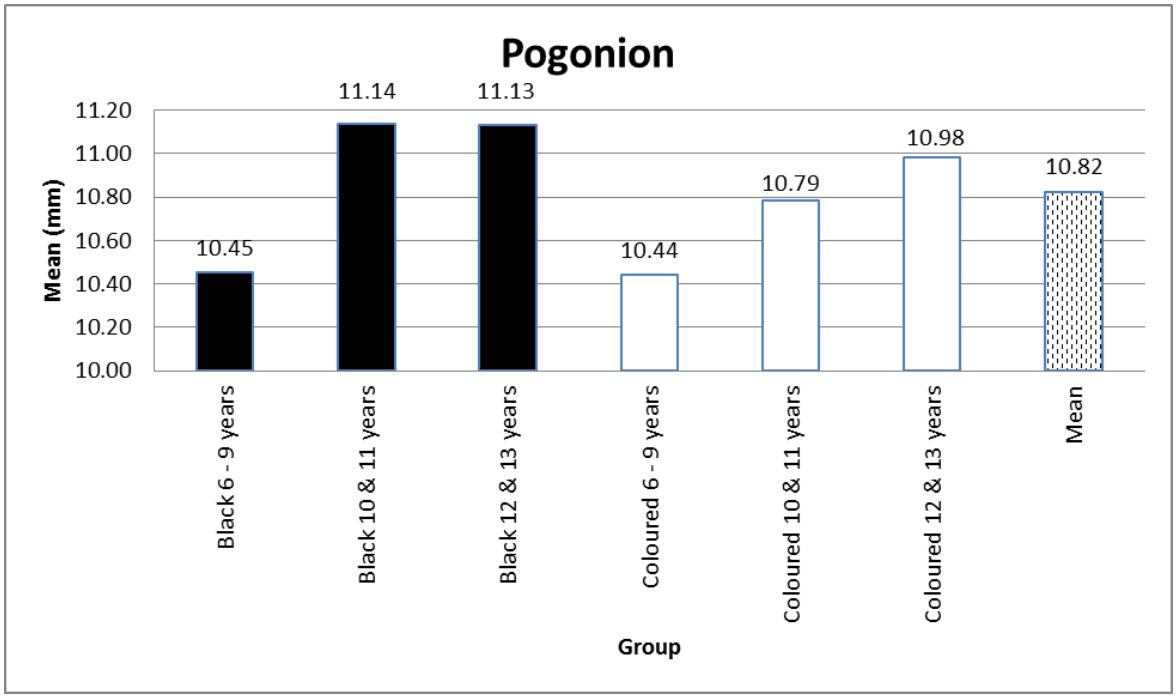

Figure 4.19: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for the pogonion

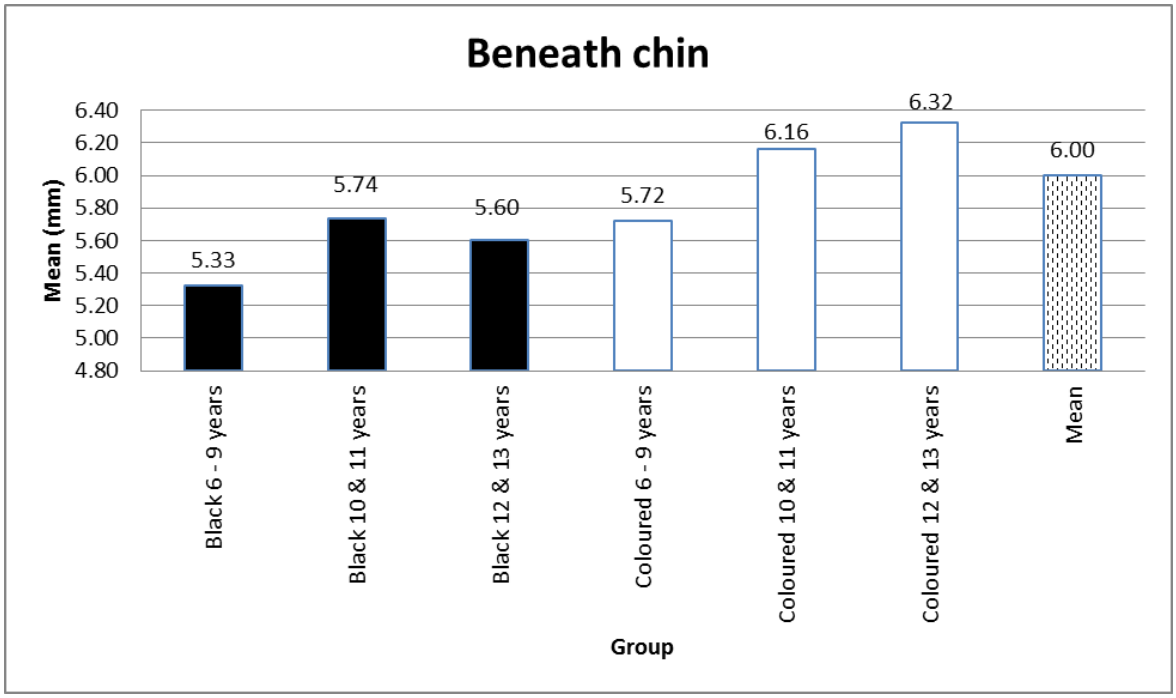

Figure 4.20: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and ancestry for beneath the chin

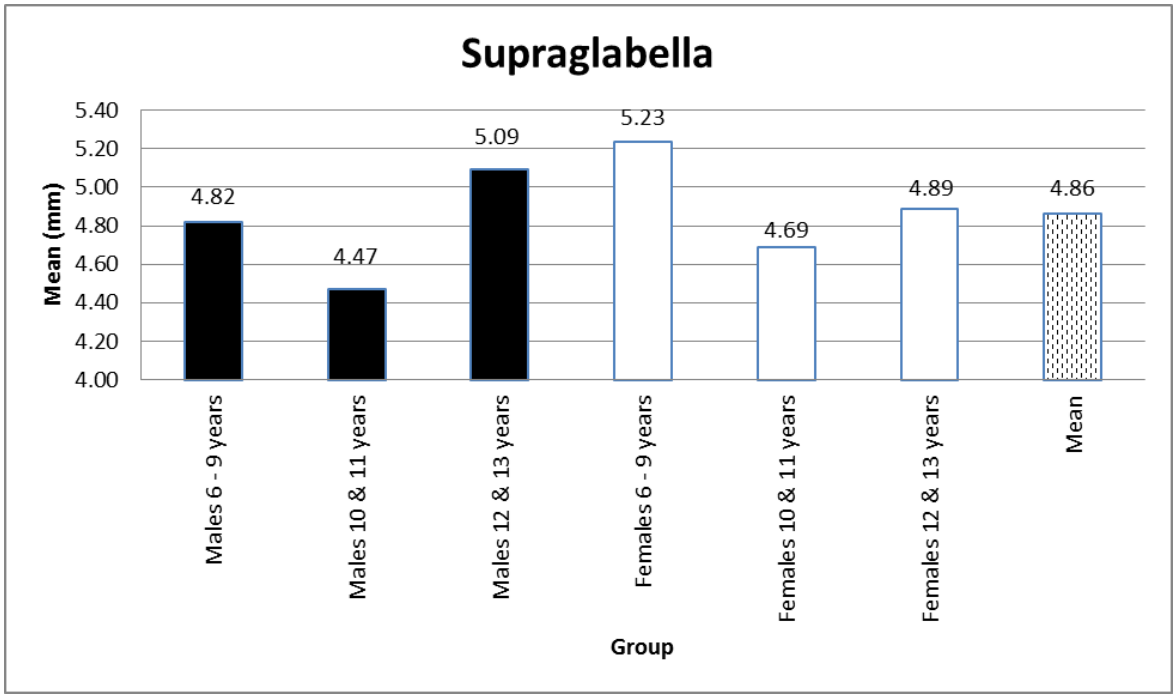

Figure 4.21: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the supraglabella

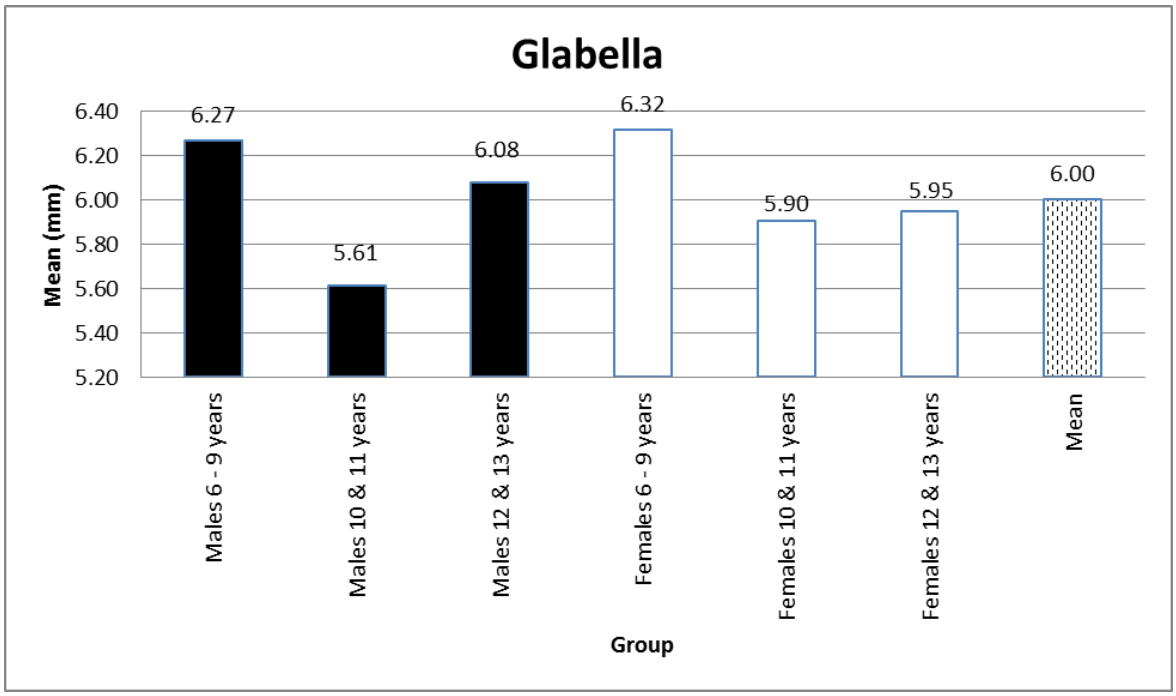

Figure 4.22: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the glabella

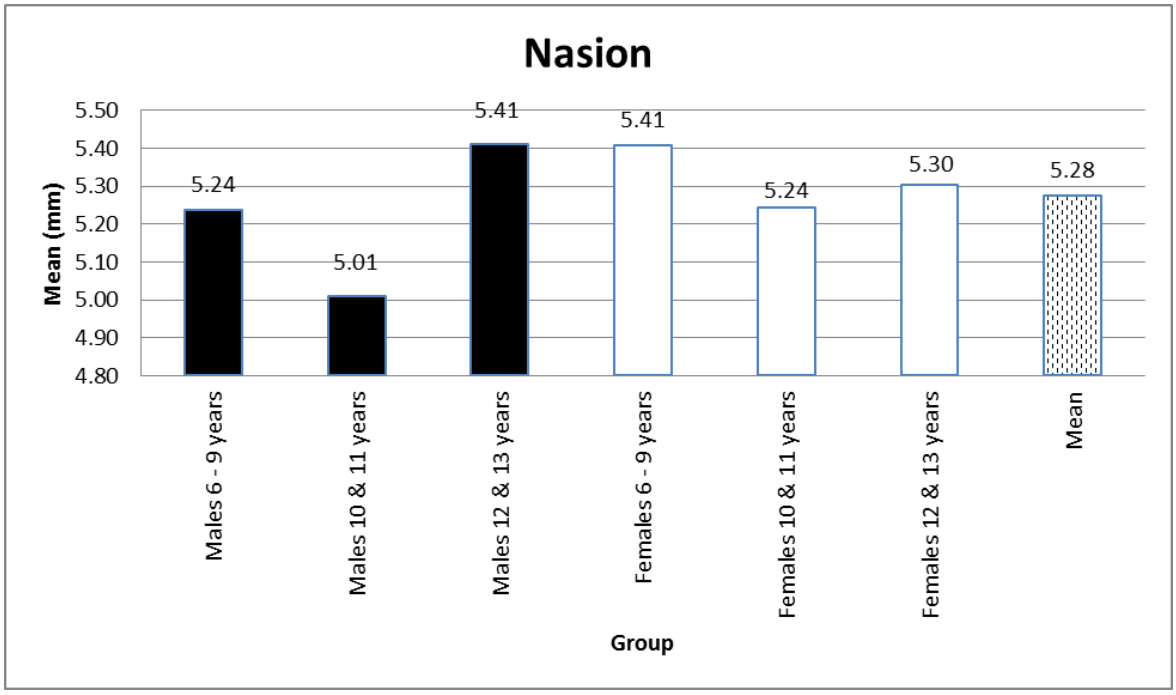

Figure 4.23: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the nasion

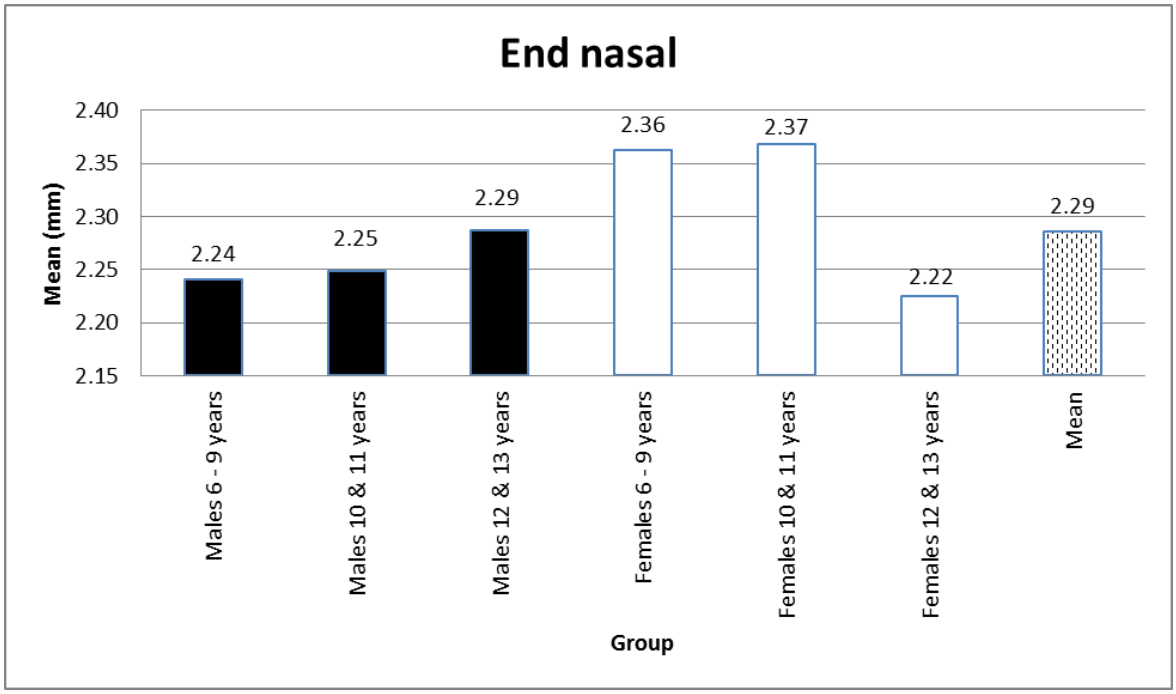

Figure 4.24: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the end nasal

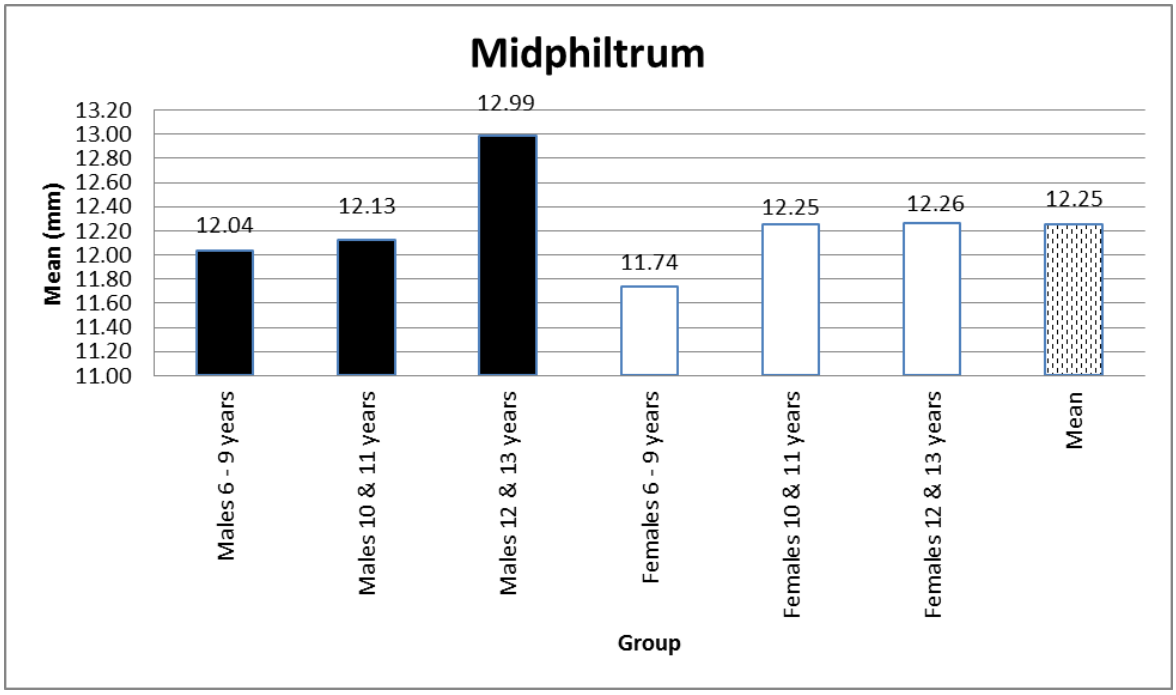

Figure 4.25: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the midphiltrum

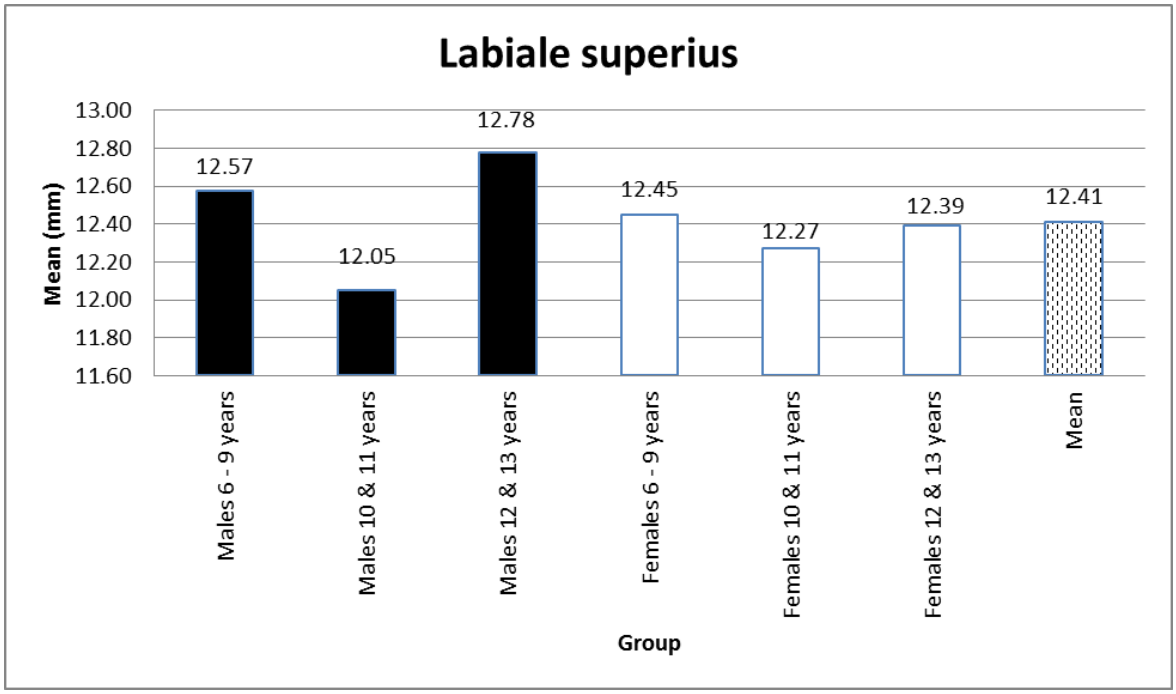

Figure 4.26: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the labiale superius

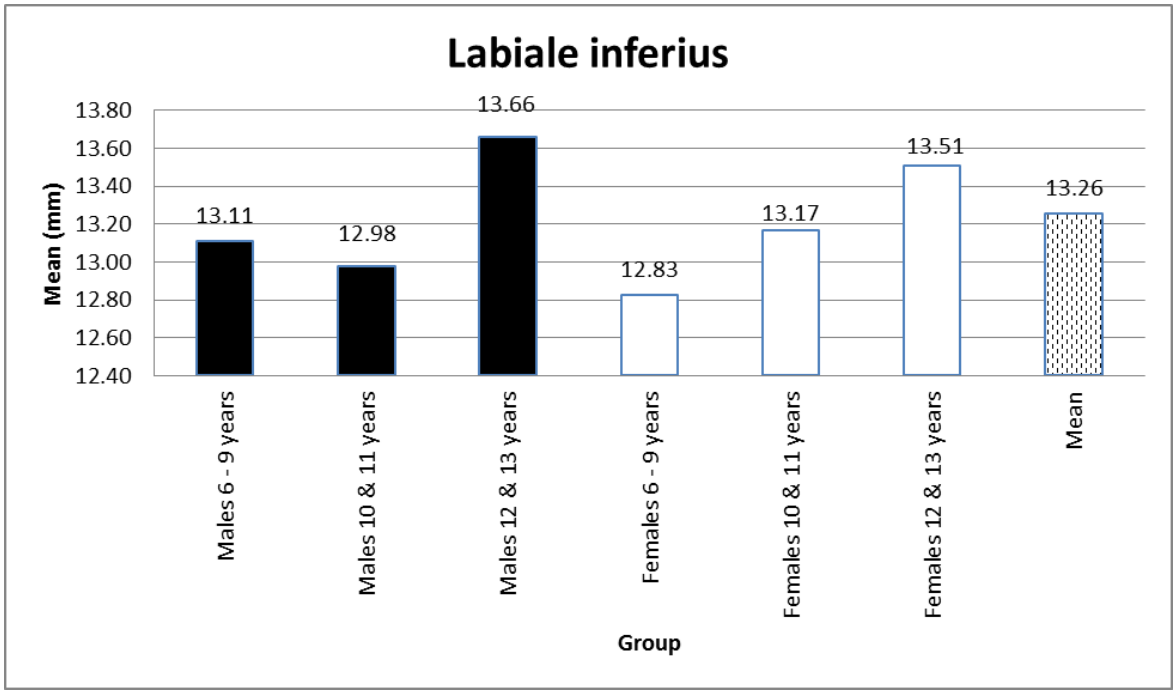

Figure 4.27: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the labiale inferius

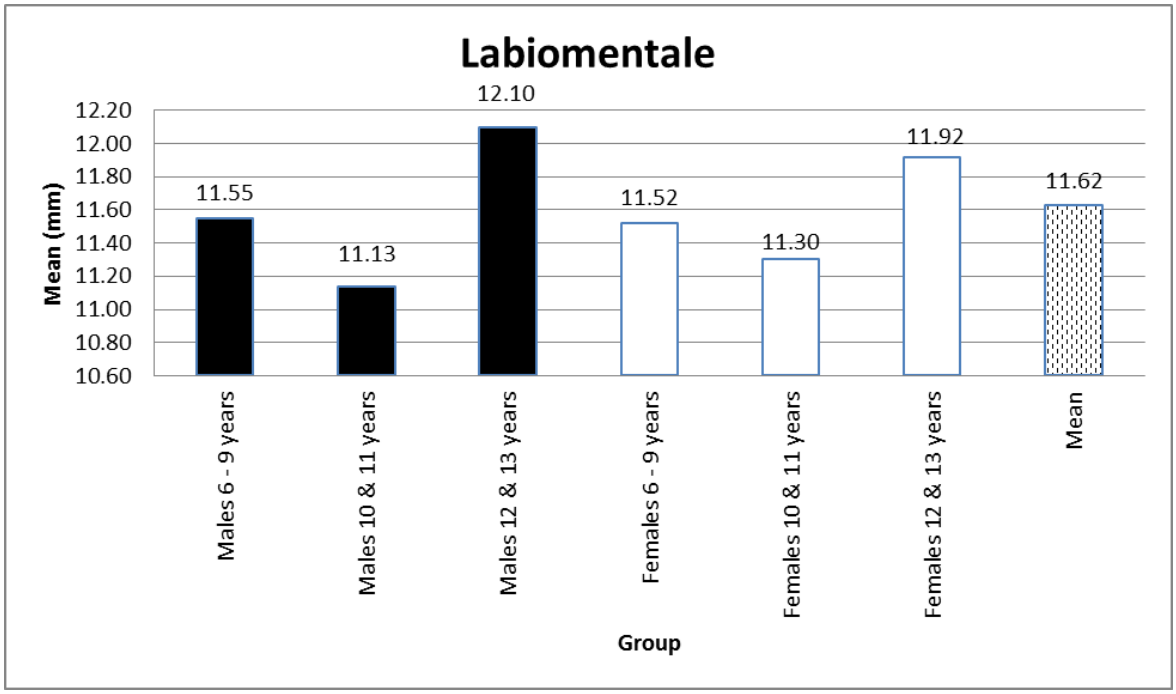

Figure 4.28: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the labiomentale

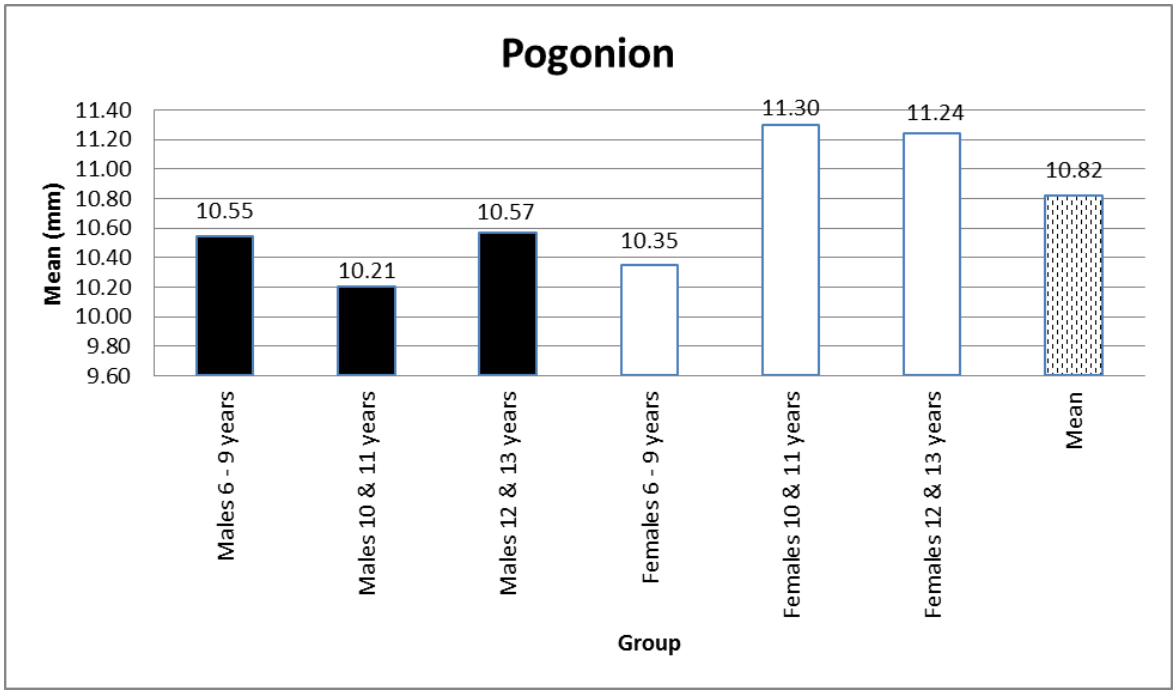

Figure 4.29: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the pogonion

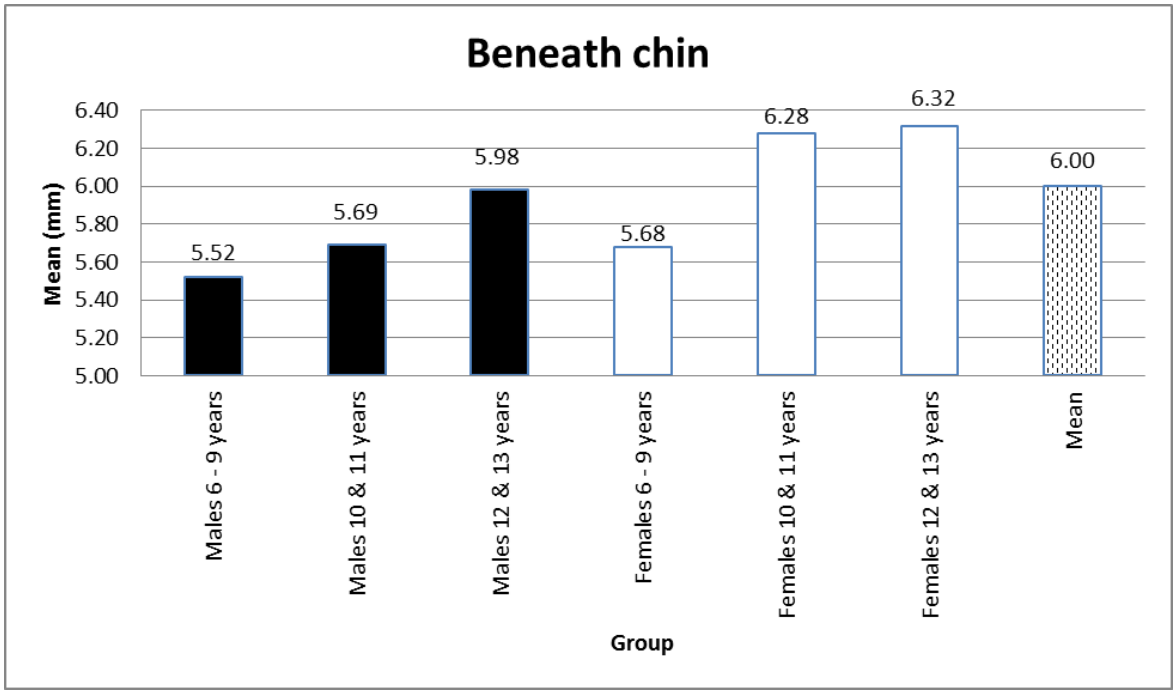

Figure 4.30: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years) and sex for the beneath chin

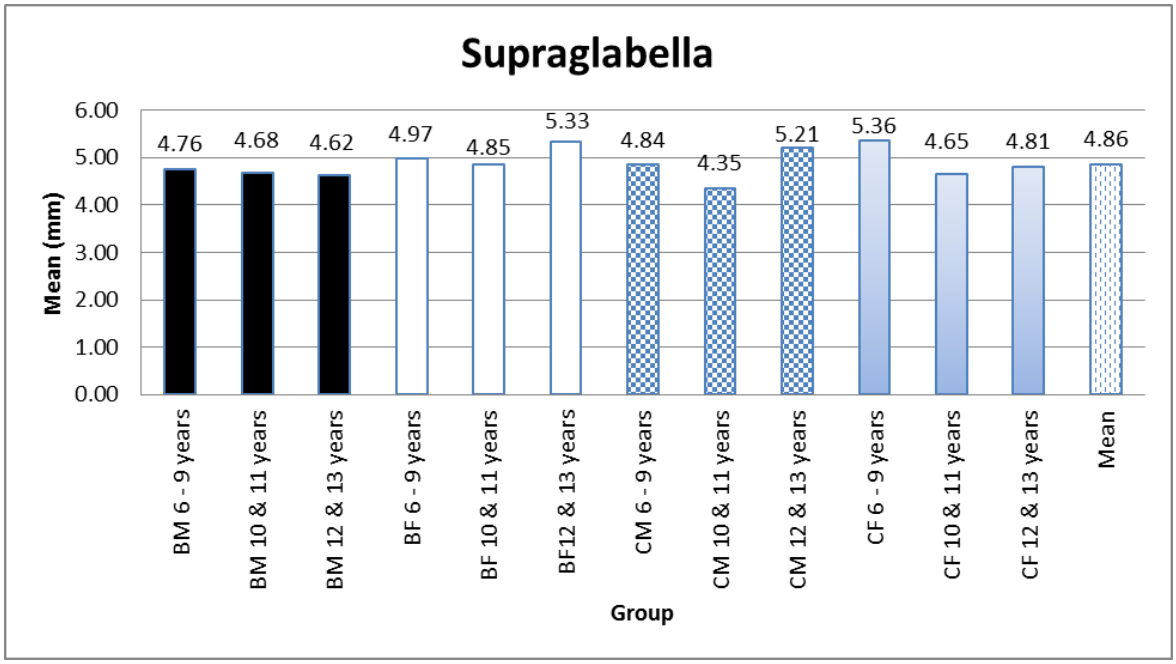

Figure 4.31: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex for the supraglabella

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

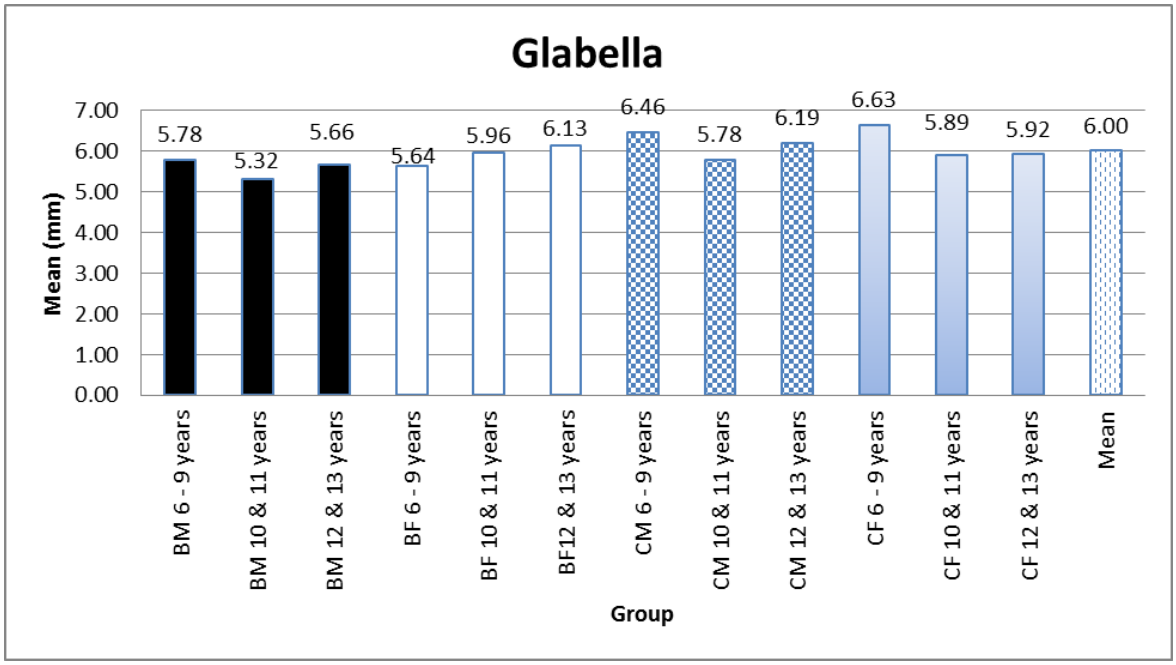

Figure 4.32: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex for the glabella

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

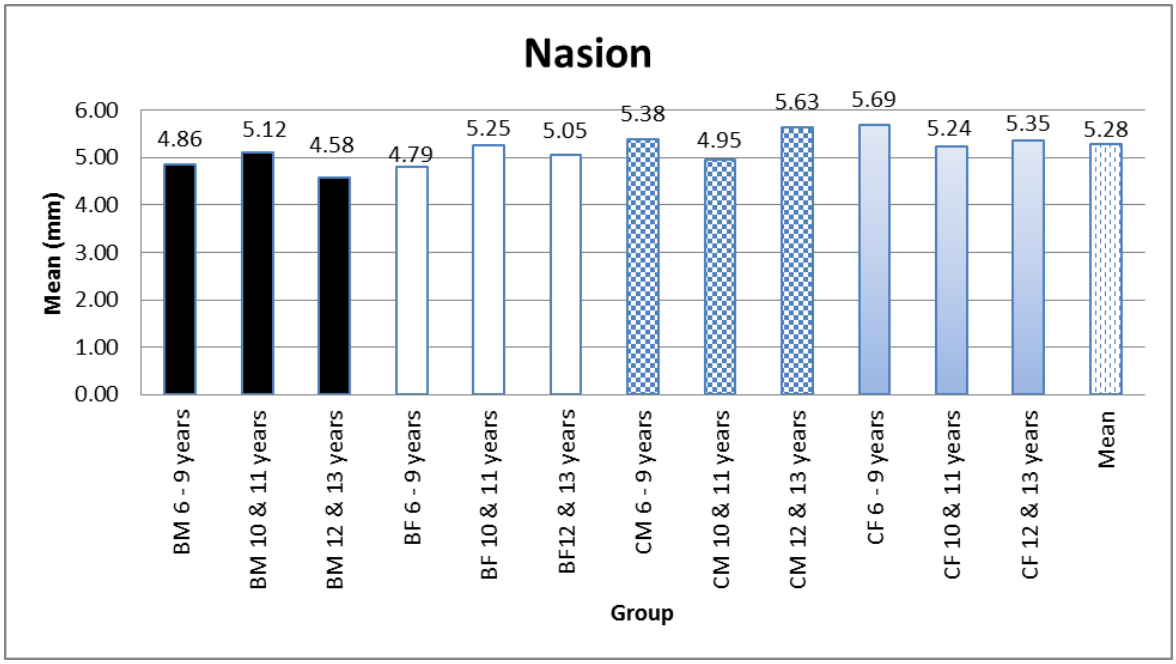

Figure 4.33: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex for the nasion

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

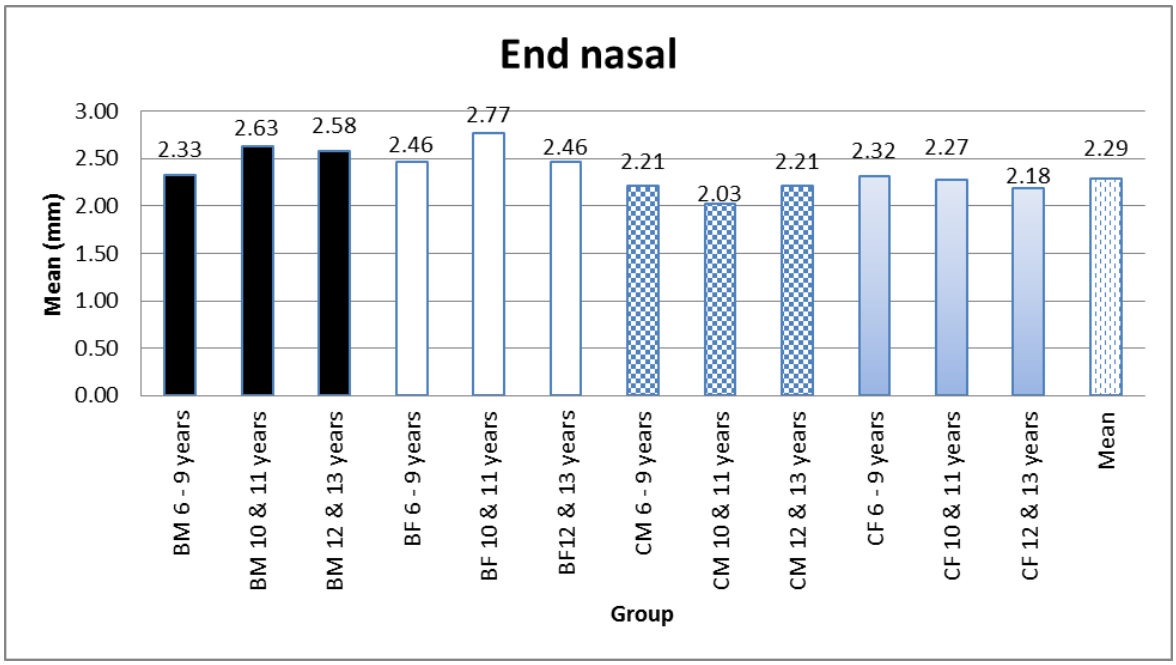

Figure 4.34: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex) for the end nasal landmark

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

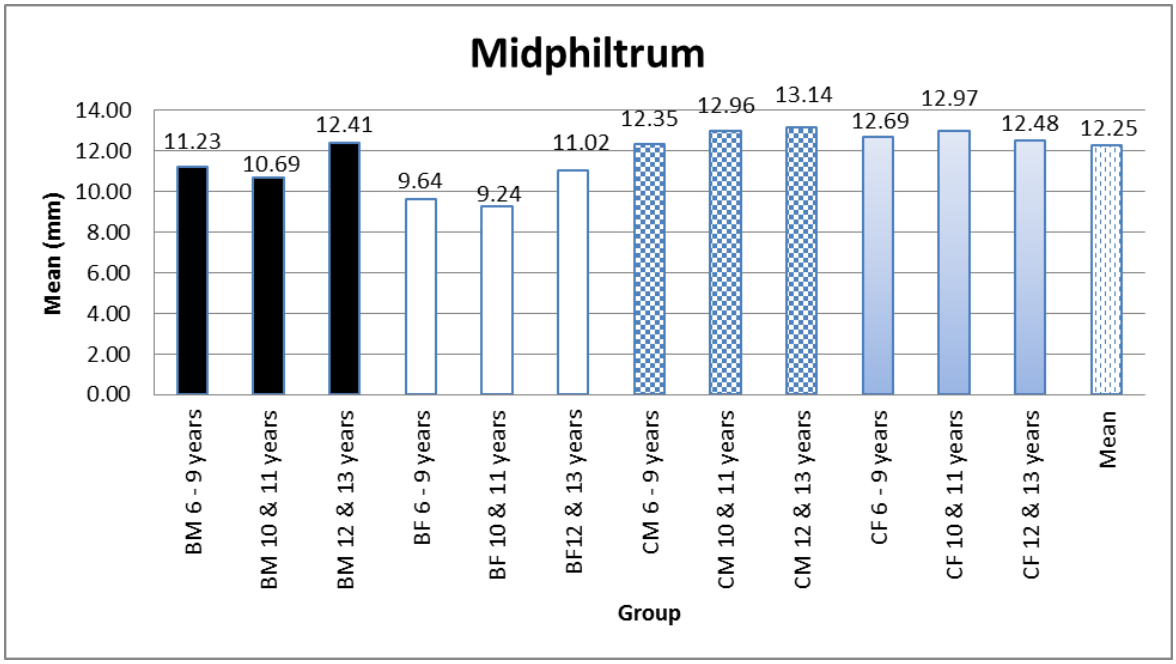

Figure 4.35: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex for the midphiltrum

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

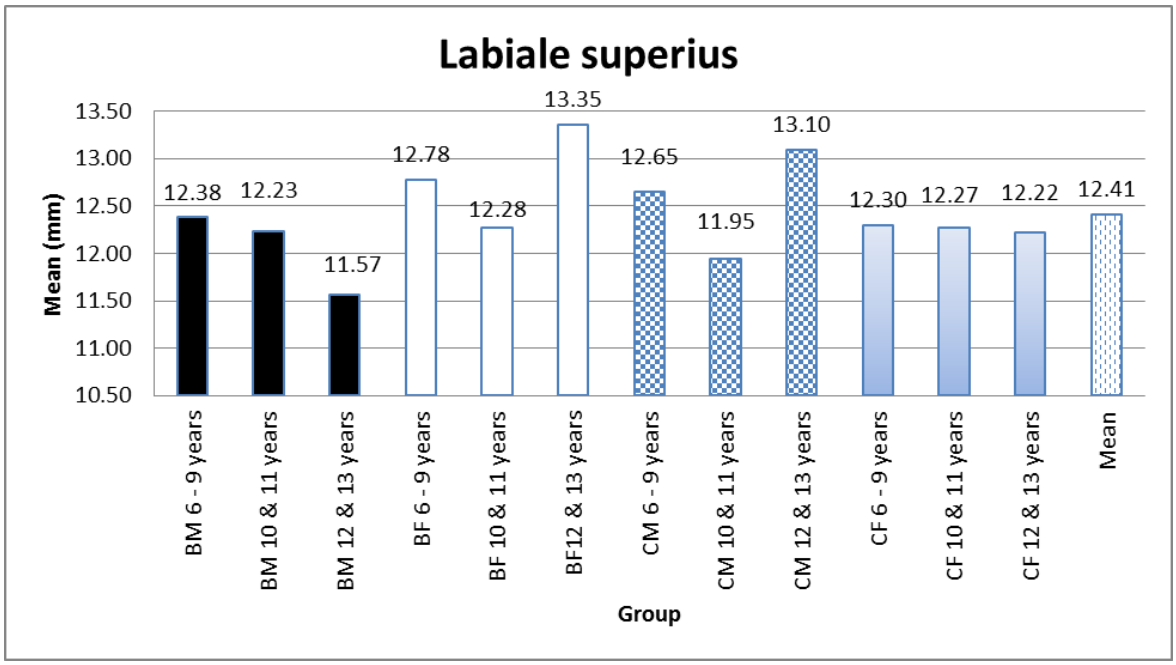

Figure 4.36: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex for the labiale superius

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

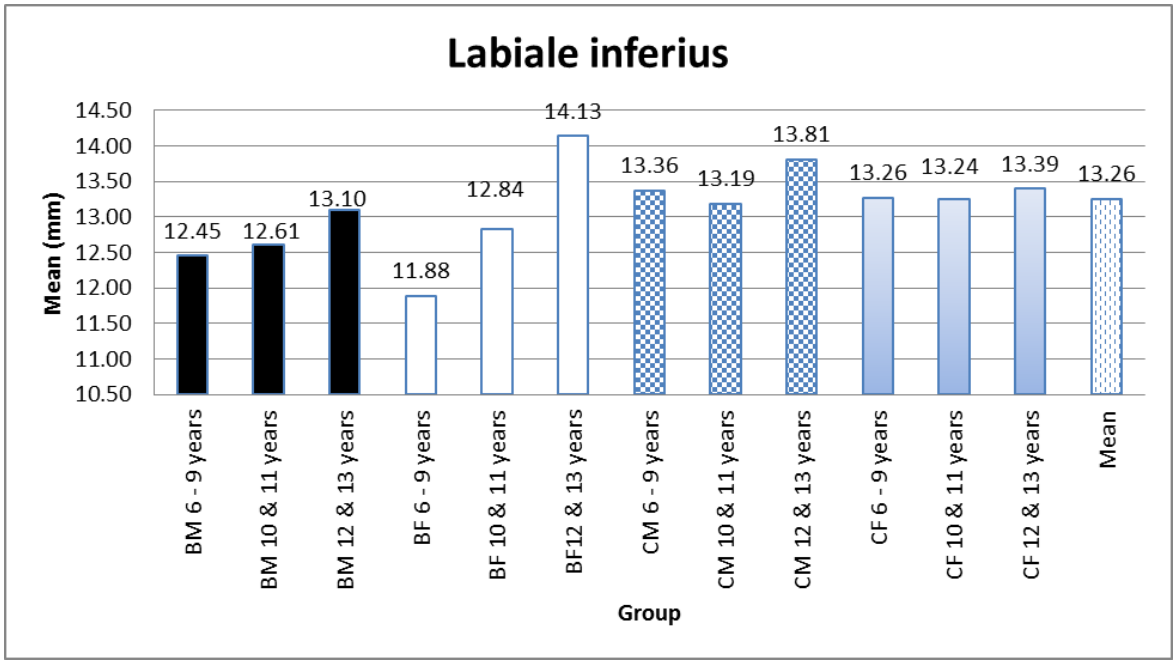

Figure 4.37: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex for the labiale inferius

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

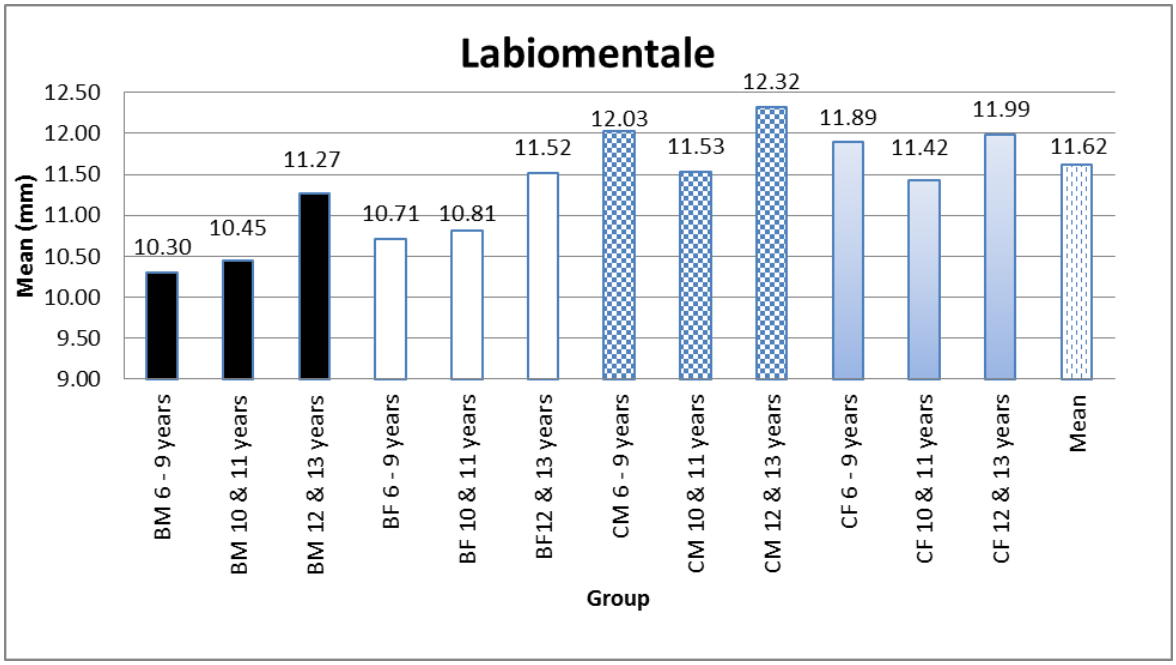

Figure 4.38: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex for the labiomentale

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

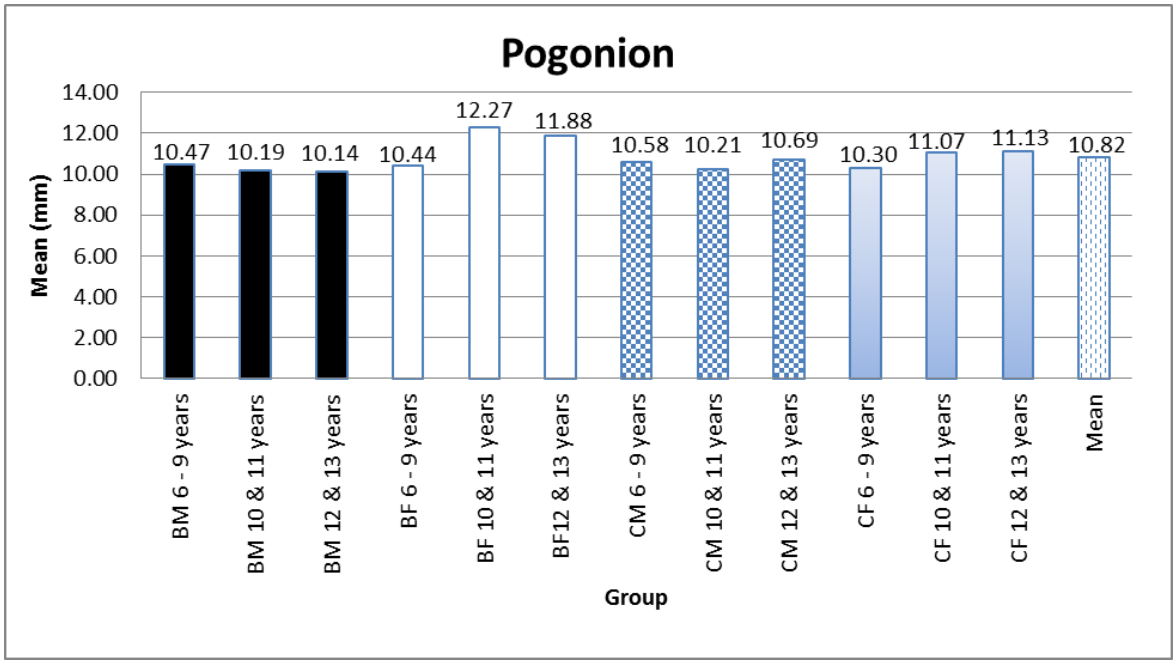

Figure 4.39: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex for the pogonion

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

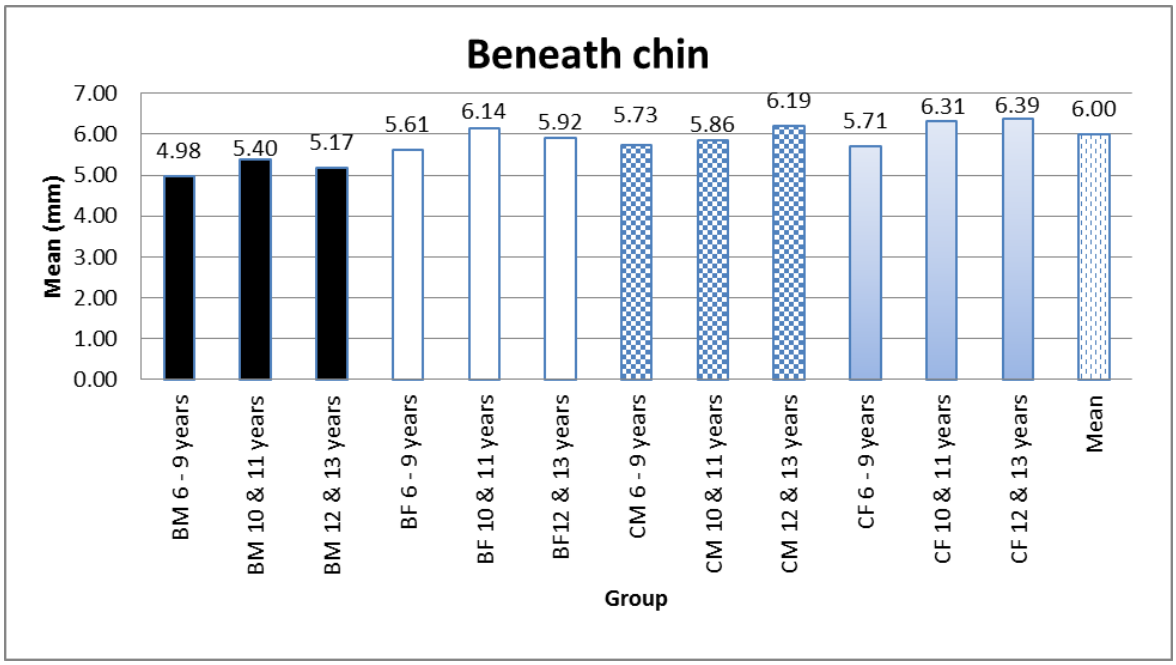

Figure 4.40: Comparison of the tissue thickness in terms of age (6 – 9 years, 10 & 11 years and 12 & 13 years), ancestry and sex for beneath the chin landmark

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

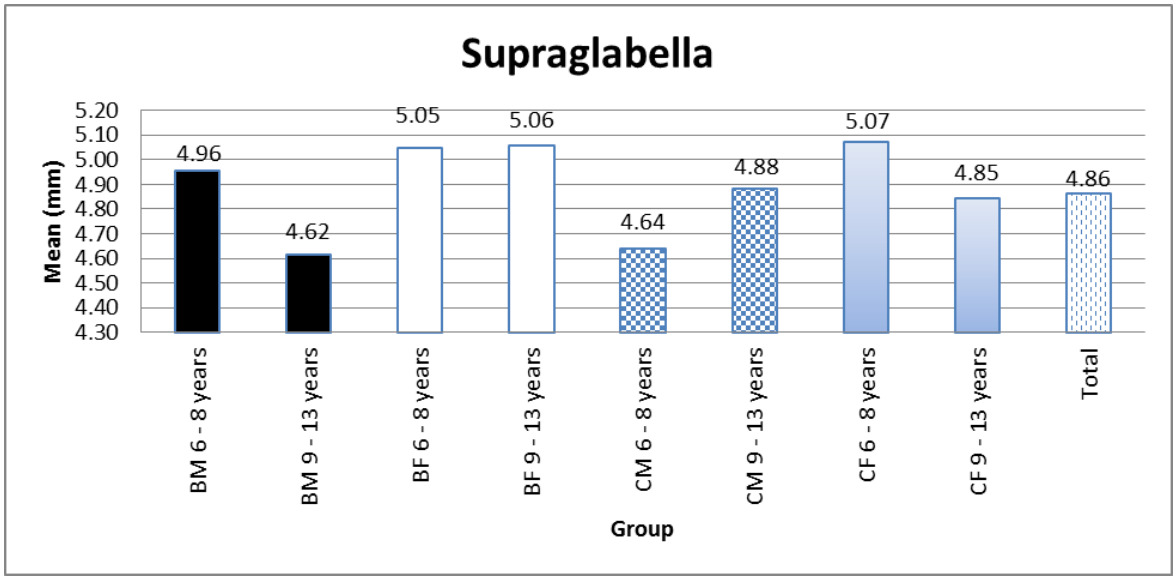

Figure 4.41: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for the supraglabella

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

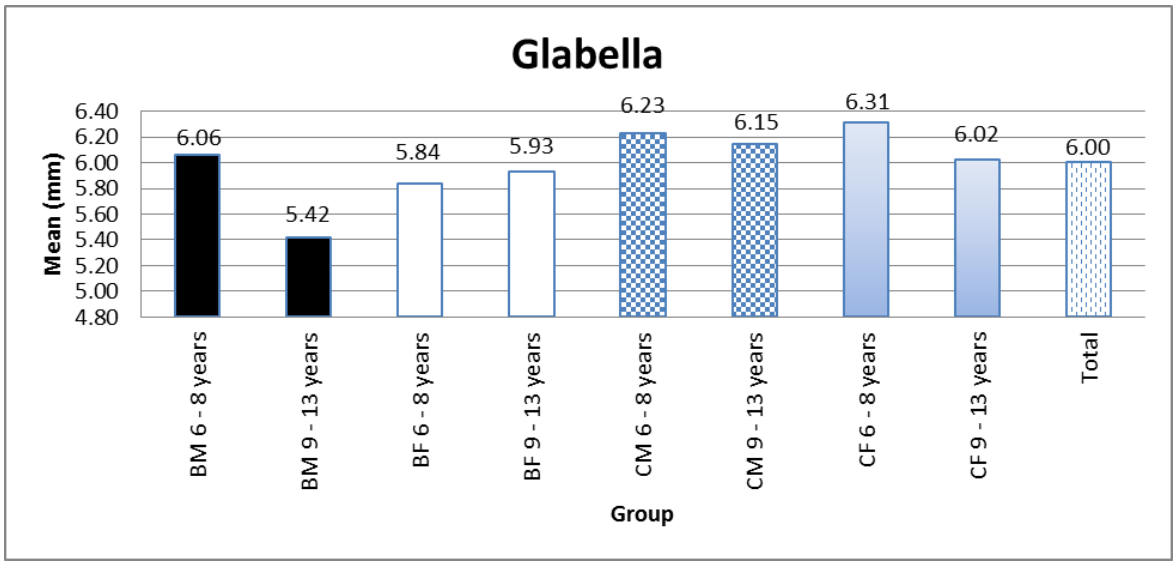

Figure 4.42: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for the glabella

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

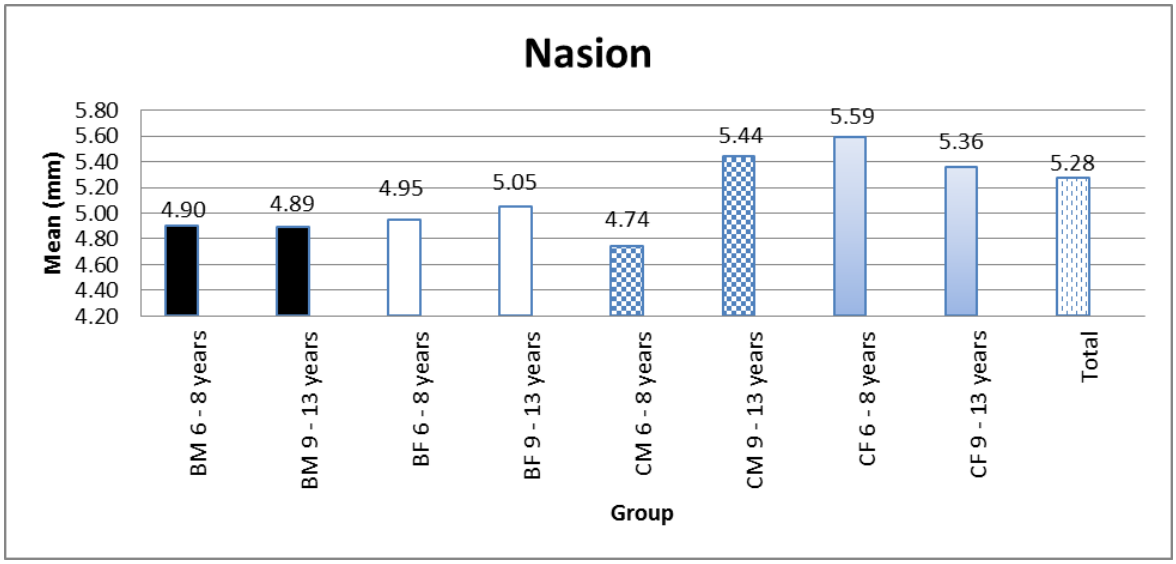

Figure 4.43: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for the nasion

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

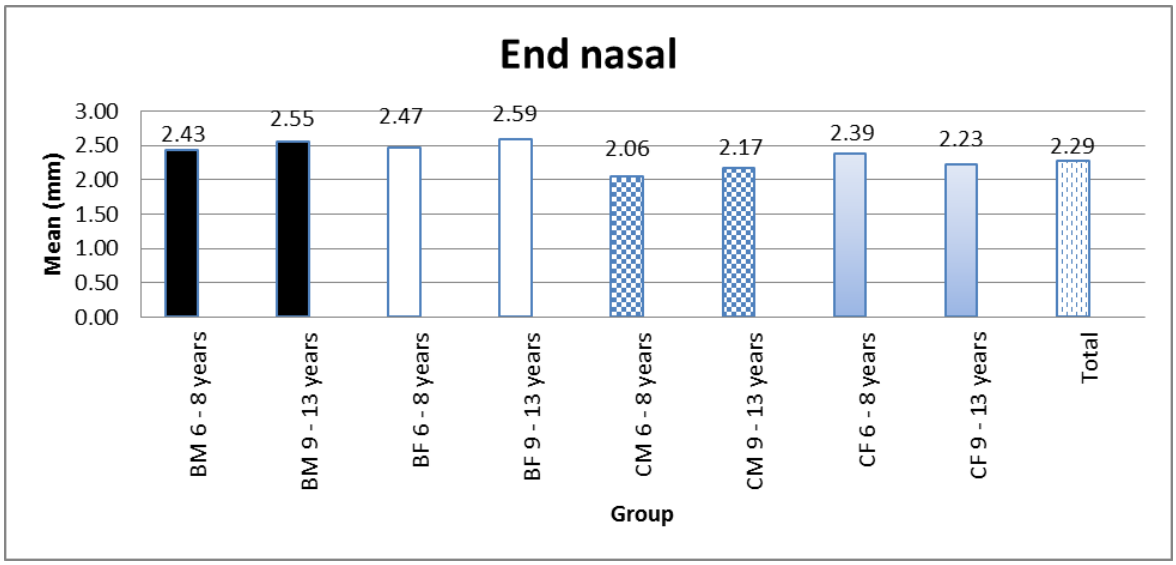

Figure 4.44: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for the end nasal landmark

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

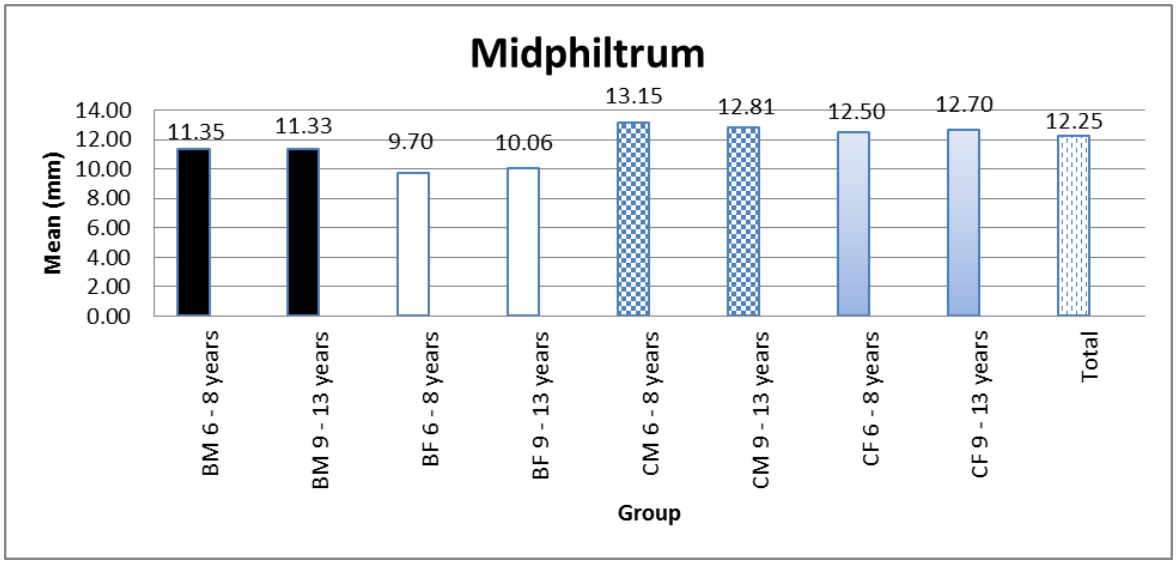

Figure 4.45: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for the midphiltrum

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

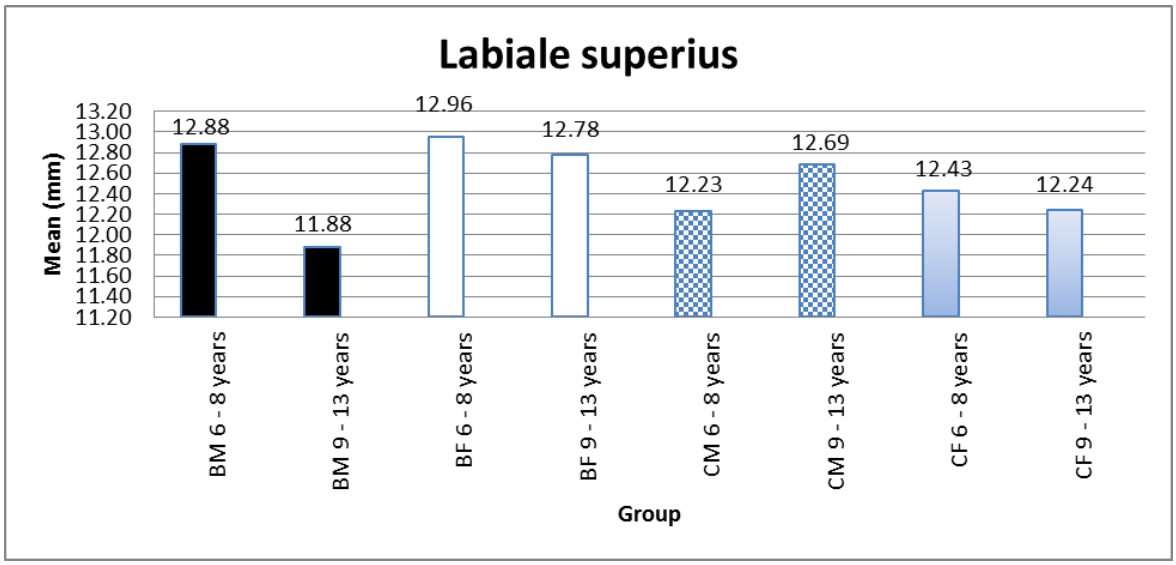

Figure 4.46: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for the labiale superius

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

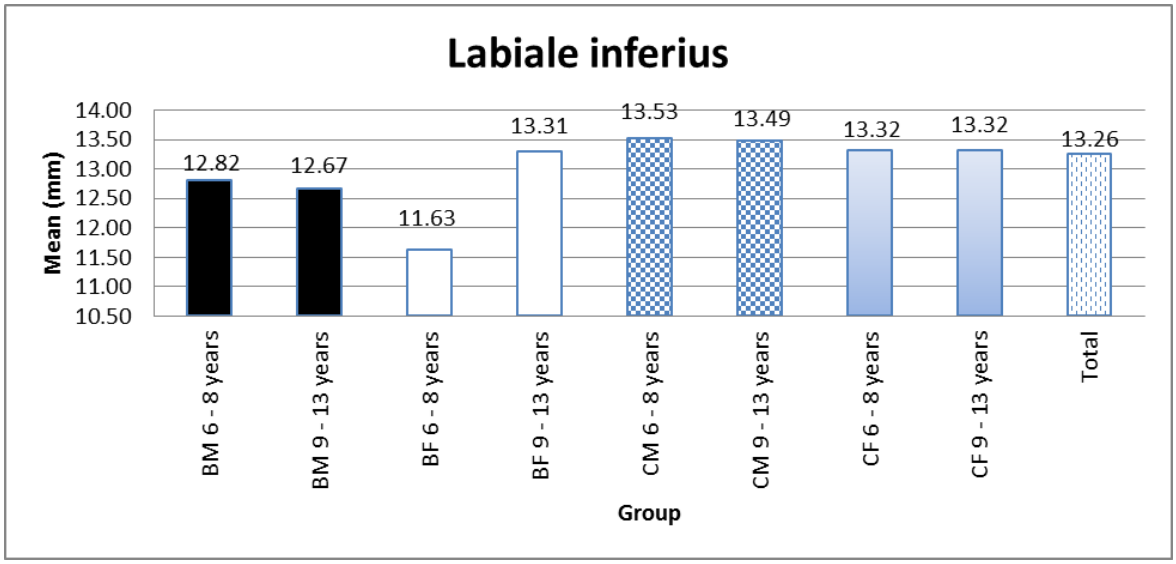

Figure 4.47: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for the labiale inferius

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

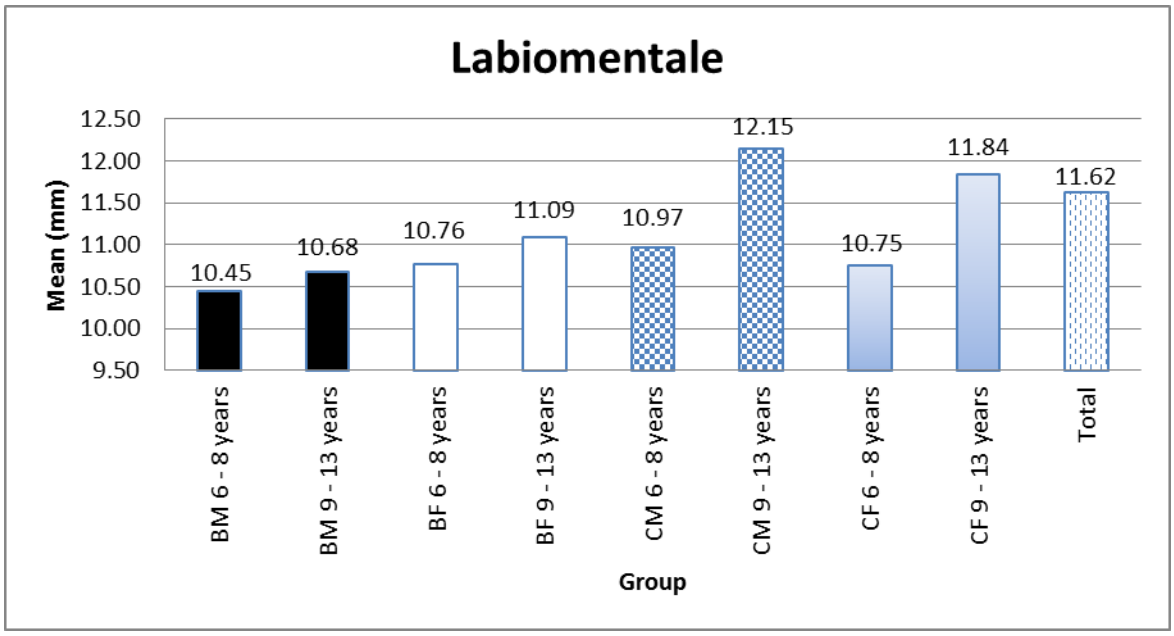

Figure 4.48: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for the labiomentale

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

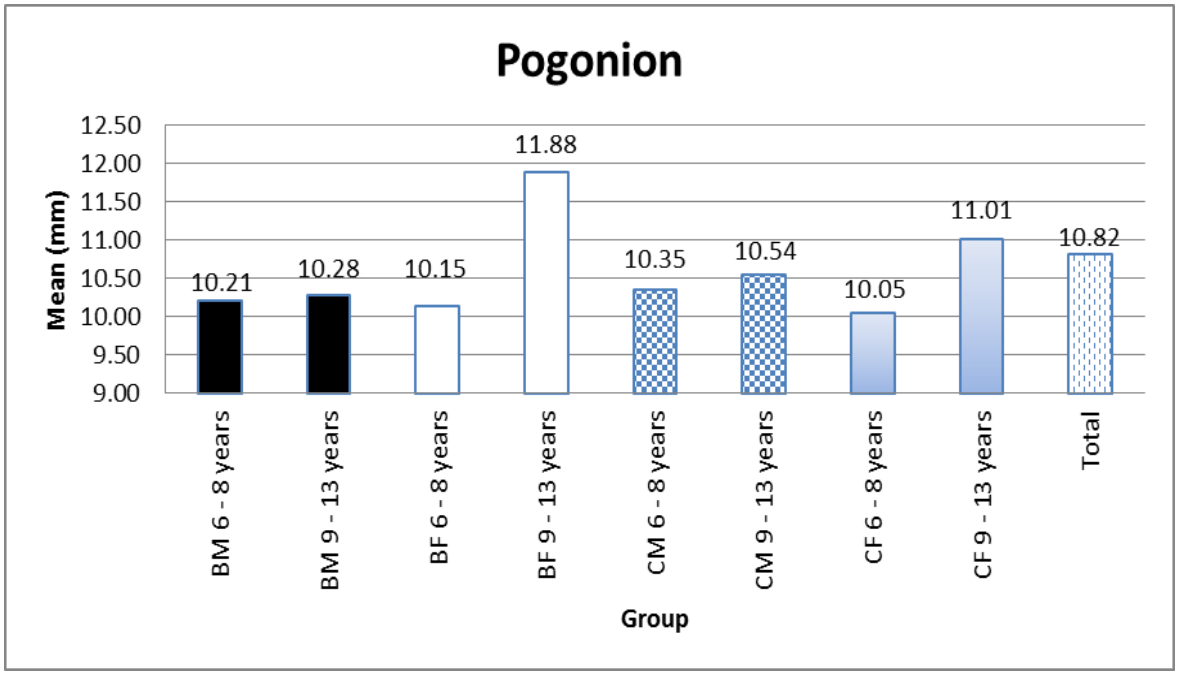

Figure 4.49: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for the pogonion

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

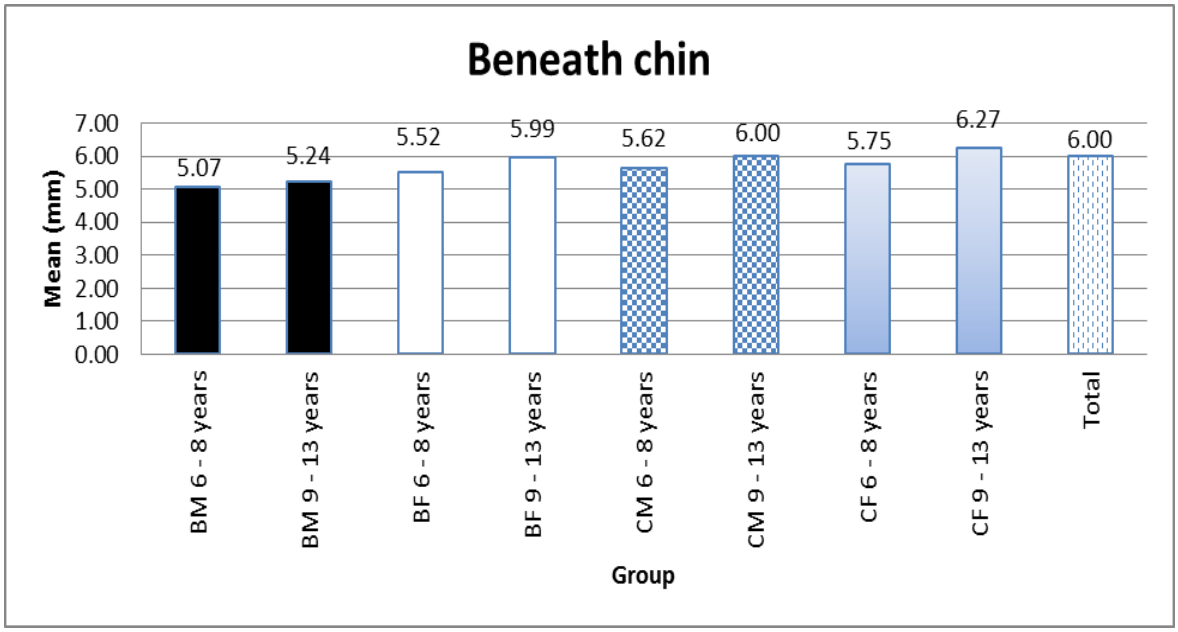

Figure 4.50: Comparison of the tissue thickness in terms of age (6 – 8 years, 9 - 13 years), ancestry and sex for beneath the chin

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

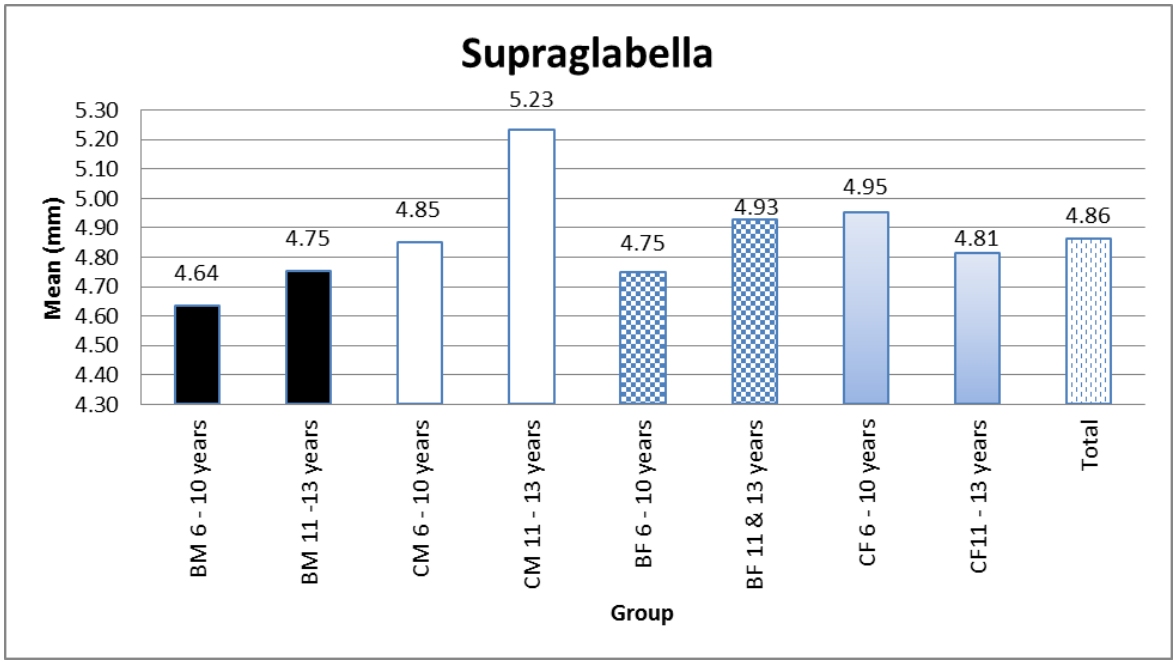

Figure 4.51: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the supraglabella

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

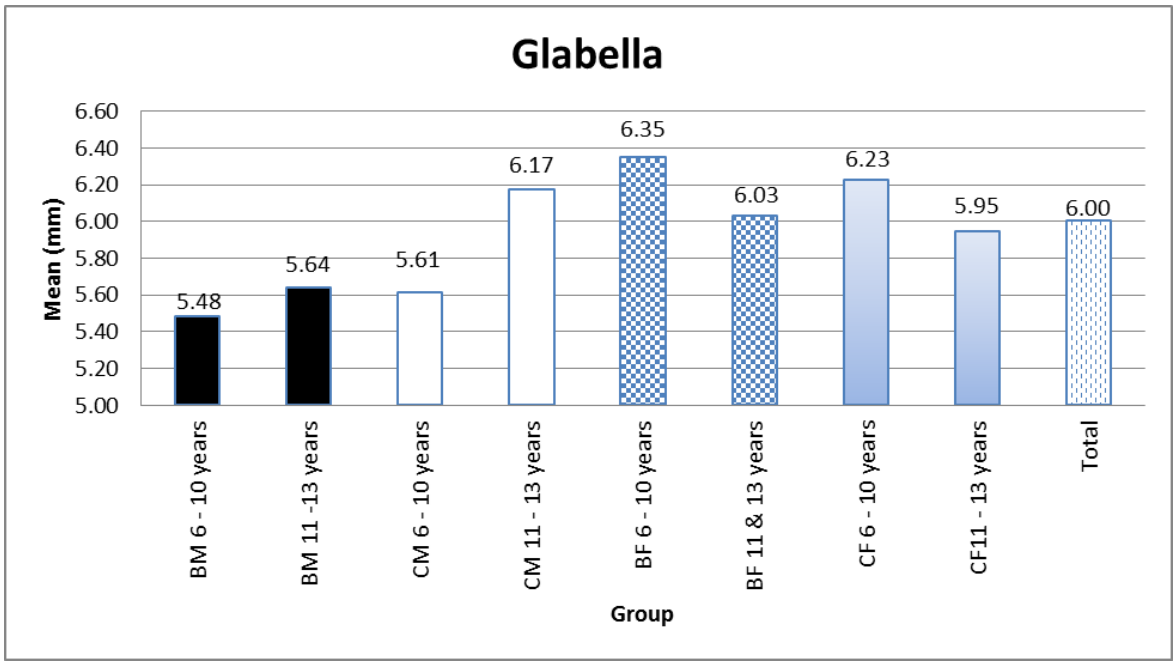

Figure 4.52: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the glabella

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

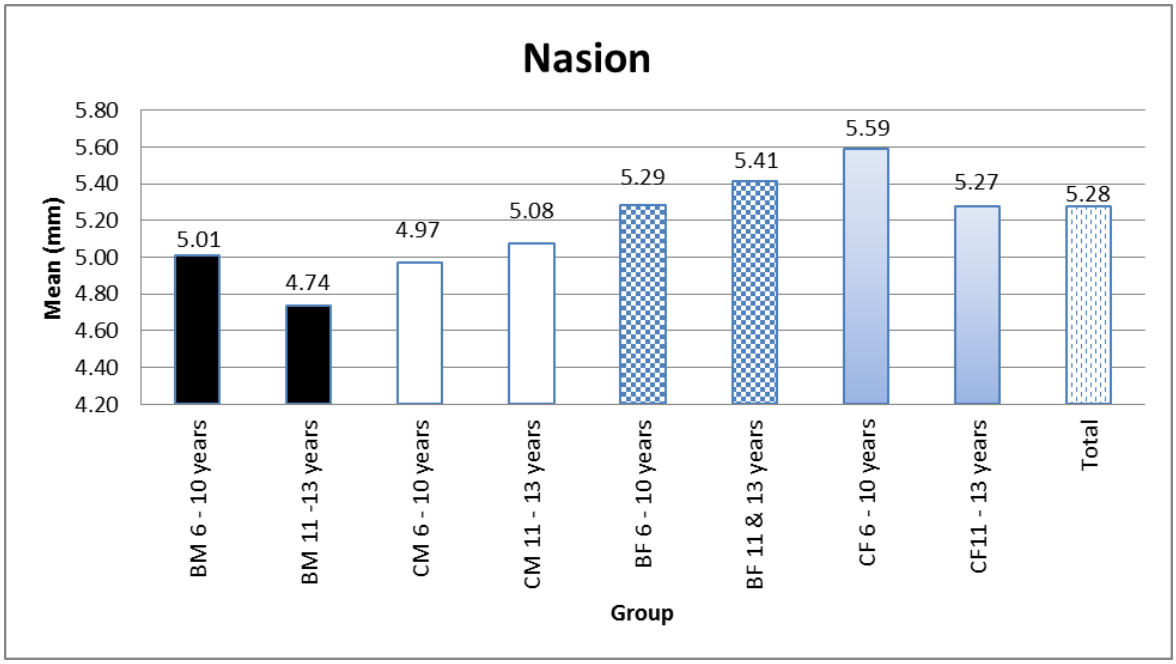

Figure 4.53: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the nasion

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

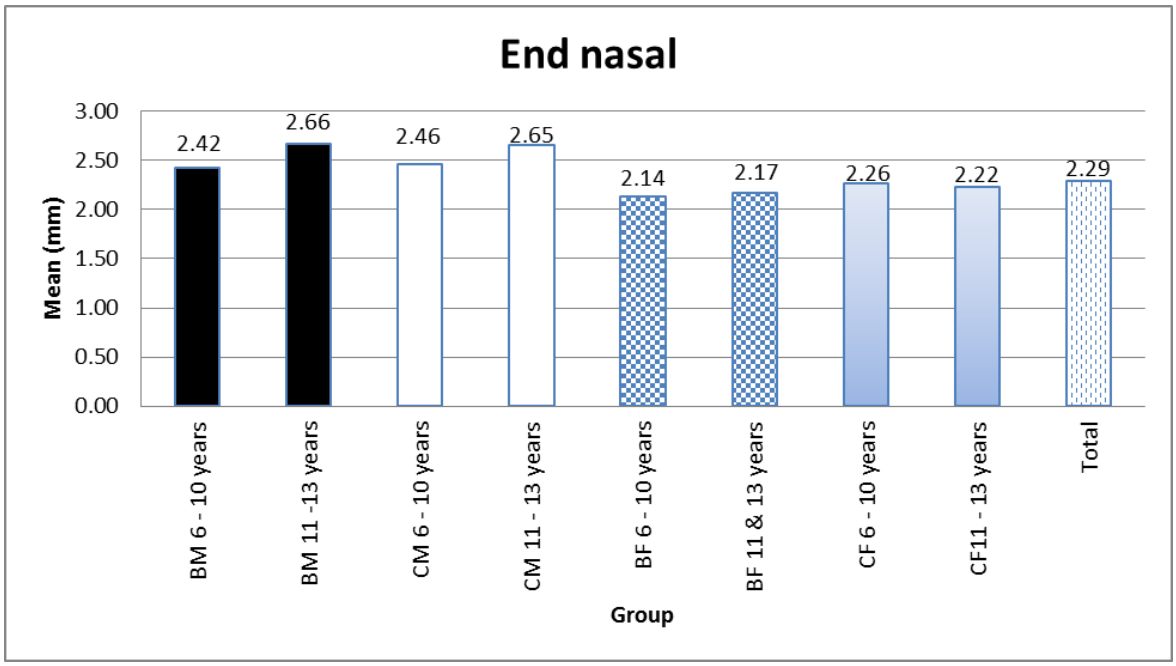

Figure 4.54: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the end nasal landmark

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

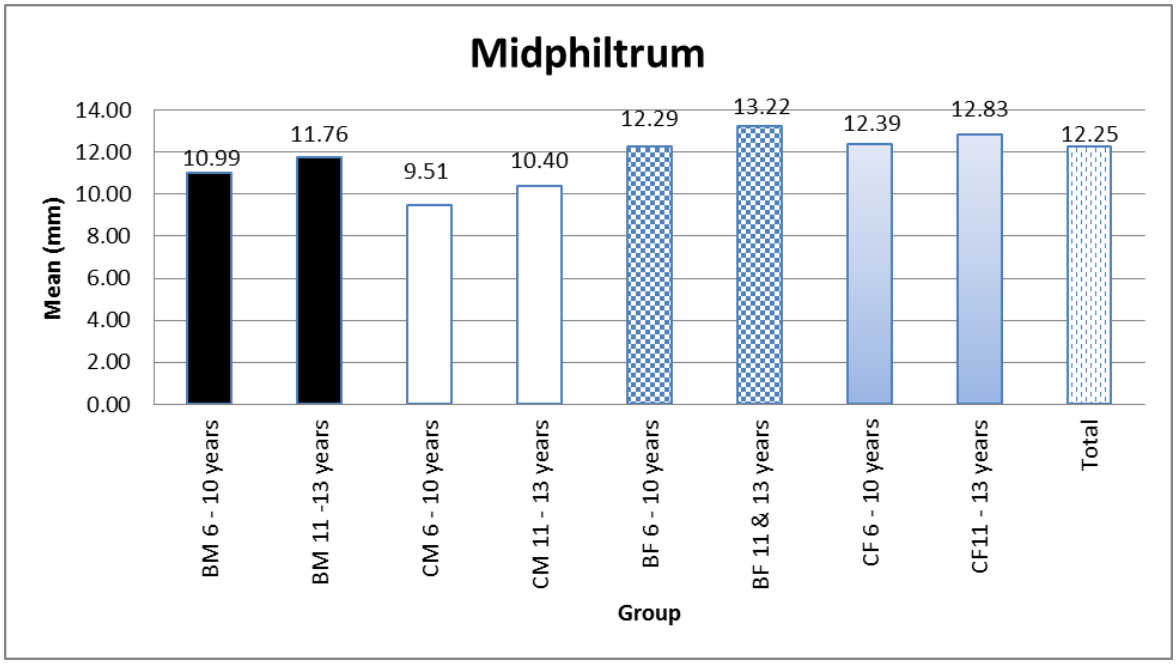

Figure 4.55: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the midphiltrum

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

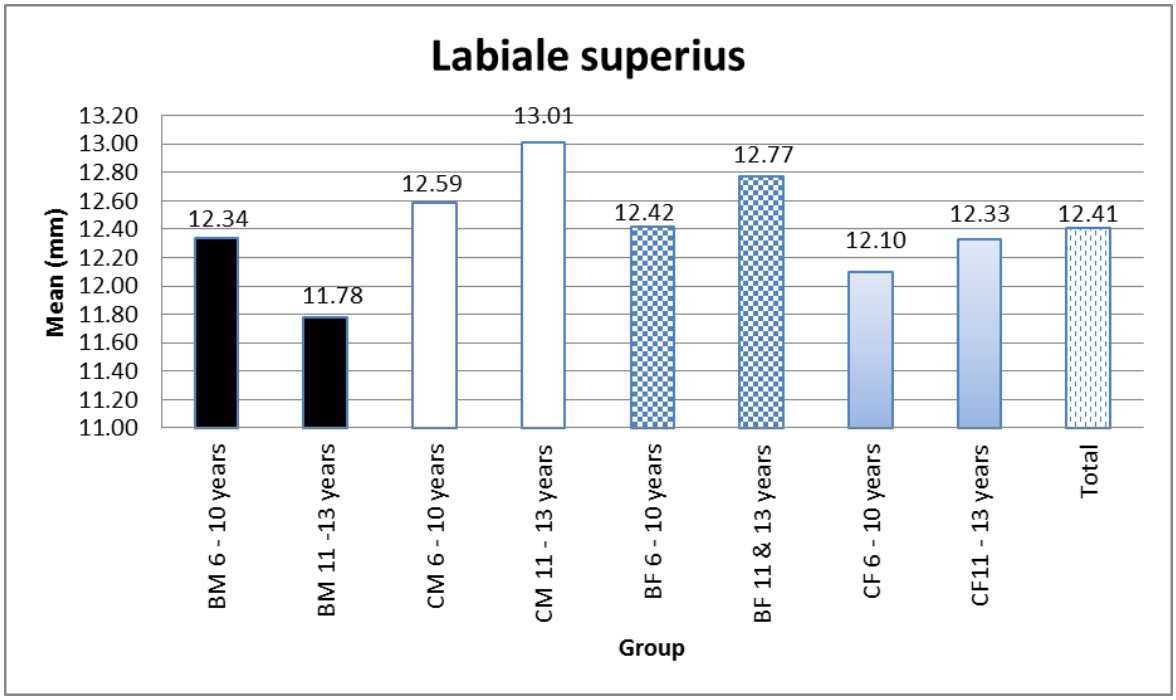

Figure 4.56: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the labiale superius

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

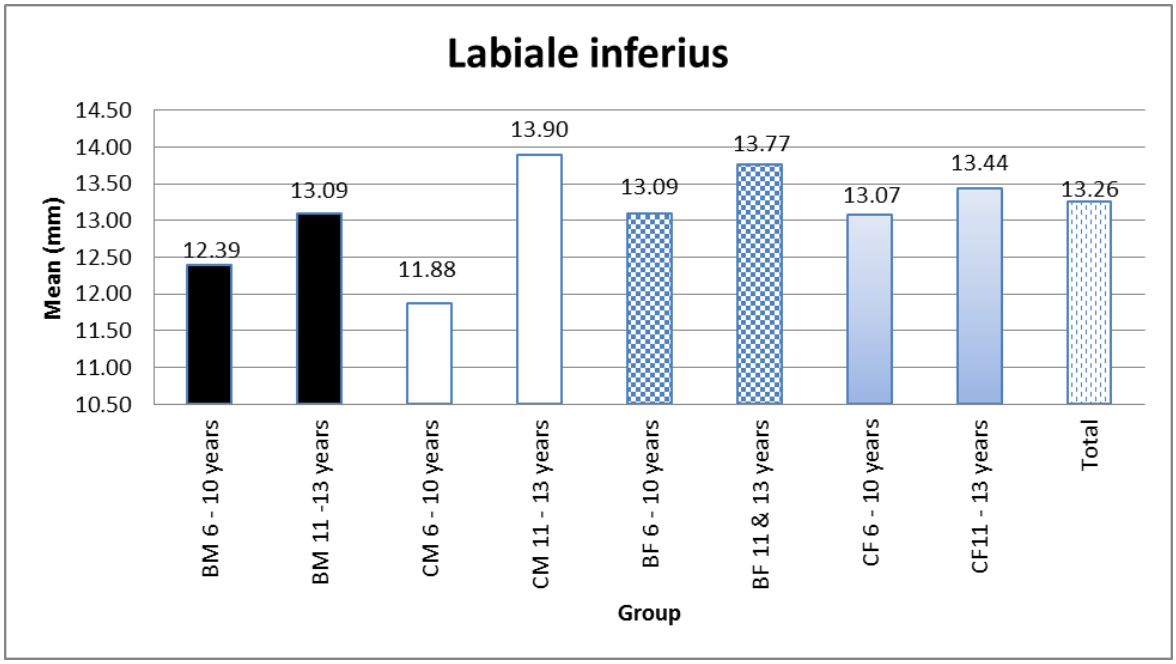

Figure 4.57: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the labiale inferius

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

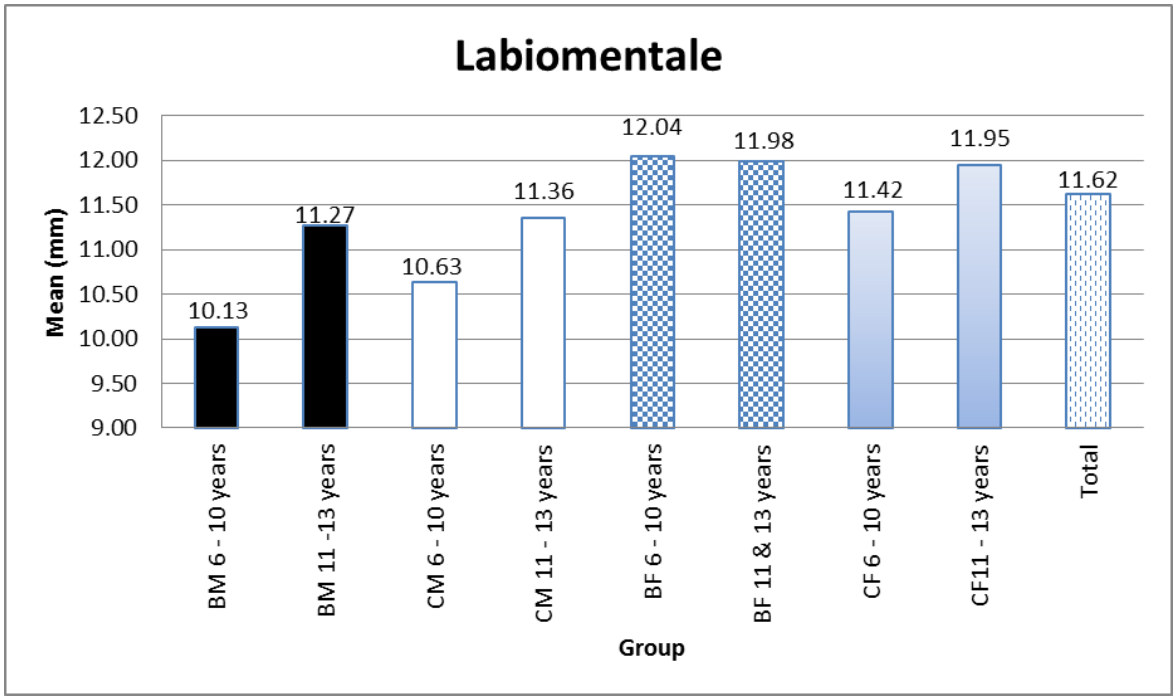

Figure 4.58: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the labiomentale

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

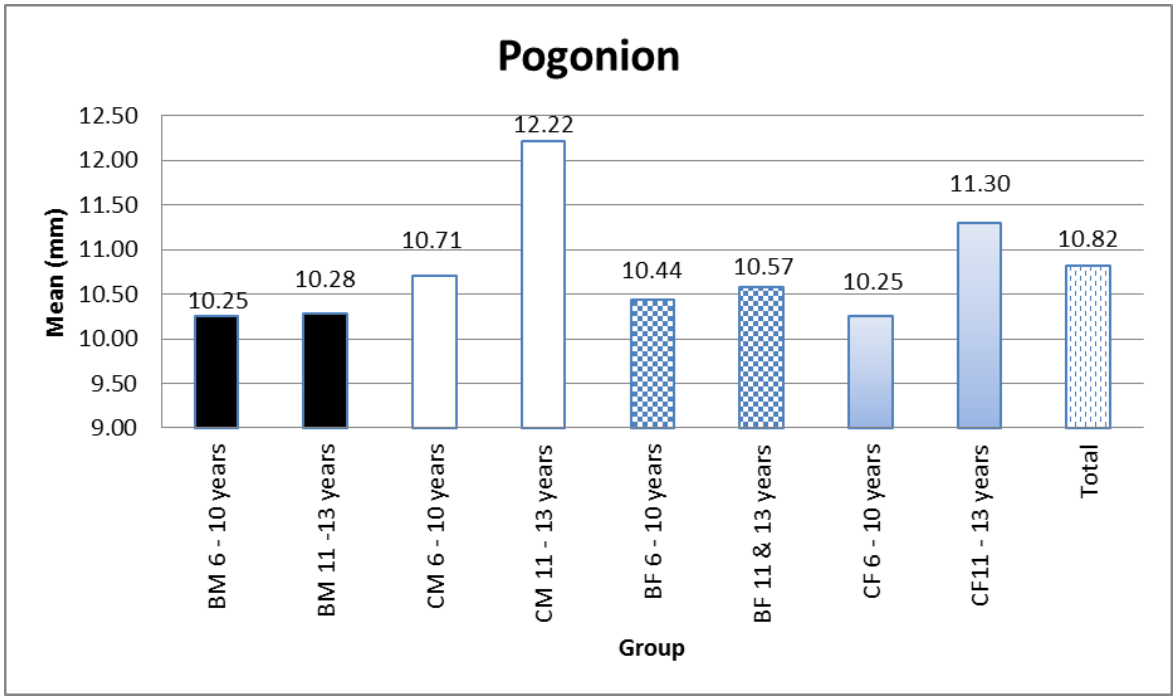

Figure 4.59: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the pogonion

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

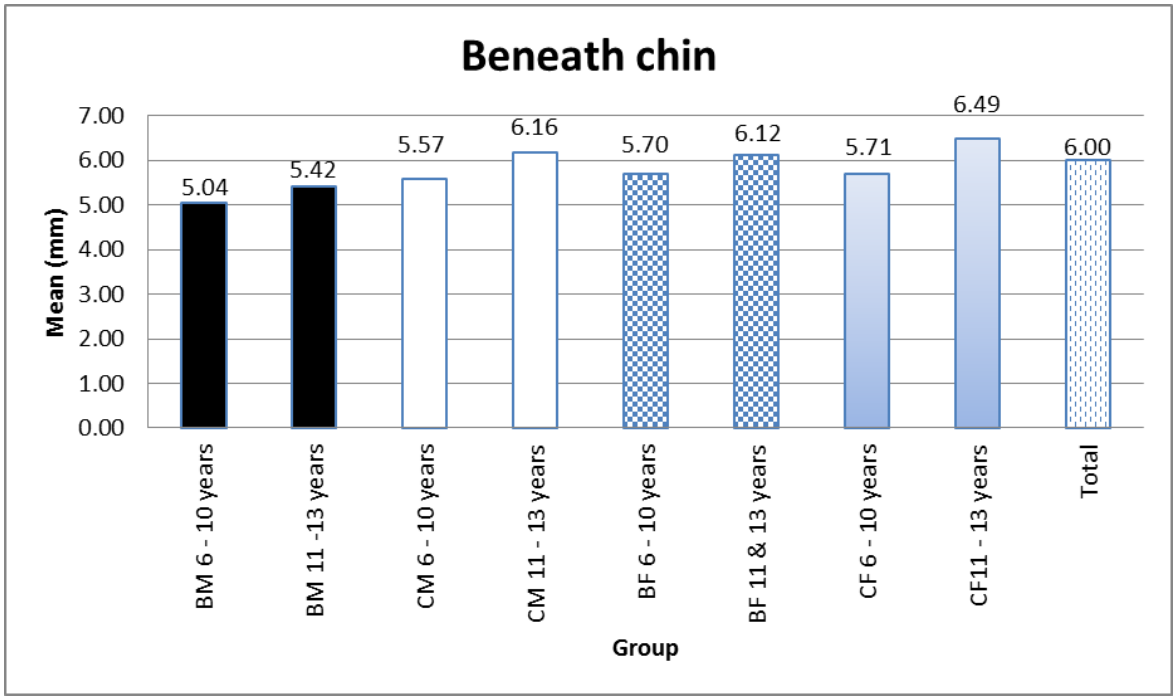

Figure 4.60: Comparison of the tissue thickness in terms of age (6 – 10 years, 11 - 13 years), ancestry and sex for the beneath the chin

(BM – Black males, BF – Black females, CM – Coloured males, CF – Coloured females)

Chapter 5: Results of craniofacial growth and shape

5.1. Introduction

This section provides data on craniofacial indices for South African children aged 6 to 13 per age, sex and ancestry as mean ± 1SD and ± 2 SD. Comparisons between age groups, sex and ancestral groups are also shown. Geometric morphometrics were used to determine at which age level the facial shape changed significantly, and in which regions these changes occurred. In addition, it also enabled the researcher to track the growth trajectories in boys and girls from different ancestry.

5.2. Sample composition

For calculation of craniofacial indices the sample comprised of 1749 children aged 6 to 13 years attending 10 South African schools in 2 provinces, namely Gauteng and the Western Cape (Table 5.1). In total, 7500 forms were sent out to parents / guardians via schools after obtaining relevant permissions. Of these, 2138 forms were returned with positive consent. Therefore the response rate from the parents / guardians was calculated as 28.5%. Unfortunately 389 of the 2138 children (18.2%) did not participate due either retracting their assent, being absent from school, participating in sport or writing tests on the day of data collection. As a result, a final number of 1749 children participated in the study, with 41% participants from the Western Cape and 16% from Gauteng. The majority of children from Gauteng schools were of Black ancestry, while the majority of children from Western Cape schools were Coloured. As a result, 41% of the sample comprised of Black children and 59% were Coloured children (Table 5.2). Figure 5.1 shows the sample composition per age group and ancestry. Only in the 6 year old age group were there more Black children (58%) than Coloured children (42%).

In general, more females were willing to participate and this is reflected in the sample as it comprised of 45.3% males and 54.7% females (Table 5.3). Figure 5.2 indicates the sample composition per age group and sex. The stacked bar chart indicates that age groups 8, 9, 11 and 12, comprised of 10% to 20% more females than males.

Figure 5.3 shows the sample composition for ages 6 to 13 per sex and ancestry. The stacked bar chart indicates that the Coloured females in age groups 8 to 13 comprises of 32% to 38% of the sample, while less than 25% of the sample comprises of Black males from age 7 to 13.

Other reasons for the disparity in sample sizes, except for response rates, are the cross-sectional nature of the study and the result of the combination of data collected at different institutions and schools.

For the geometric morphometrics part of the study, the number of individuals per group had to be equal. Therefore, 25 lateral facial photographs were randomly selected per age, sex and ancestry. As a result the total sample for the geometric morphometrics was 400.

5.3. Intra- and inter-observer repeatability

Craniofacial indices are often used instead of actual measurements in order to minimize criticism on the use of photoanthropometry. Indices compensate for any measurement errors or differences in equipment and methodology (Cummaudo *et al*., 2014). In the current study, intra- and inter-observer repeatability were calculated. Not only was the measurements repeated, but the indices were also recalculated to check for any errors. As landmark position is essential to obtain correct measurements, photographs without landmarks were used for the intra- and inter-observer section. Thus, the re-testing not only involved measuring the distance between two landmarks, but also the placement of the landmarks. Some landmarks such as the nasion, gnathion and tragion were difficult to locate precisely on anterior facial photographs, but better seen on lateral facial photographs. The trichion and vertex were sometimes problematic due to the presence of hair even though effort was made to contain hair by elastic bands.

For craniofacial indices, 20 photographs of different age groups and sex were chosen at random and the primary researcher (inter-observer) and another person familiar with the method (intra-observer) repeated the measurements and calculations. As with the tissue thickness, intra-observer reliability was calculated using the intra-cluster correlation, and inter-observer repeatability used the inter-rater agreement which is restricted to one (Table 5.4). Therefore, a value closer to one will indicate a high level of reliability. The ICC for measurement and calculation of indices by the author and the other person varied between acceptable levels of 0.9870 and 0.9213. The head width – craniofacial height and the forehead – head width index were most reliable (ICC = 0.9892 and 0.9870 respectively). The skull base - head width index showed the lowest ICC for both intra- (0.9285) and interobserver (0.9213) correlation. However, these values still fall within the acceptable range of 0.8 to 1.0, which validate the results.

In terms of lateral face shape data using geometric morphometrics, intra- and inter-observer repeatability were tested using a total of 30 lateral facial photographs of Black male (n =15) and Coloured male (n = 15). These photographs were randomly selected and 11 landmarks were re-assigned by the same operator and a different operator. The newly generated landmark data were then statistically compared to the former dataset using Goodall's F-test and Hotelling's T-test. No significant differences were found when the same operator assigned landmarks or when a different operator assigned the landmarks (Goodall's F-test: $p > 0.05$; Hotteling's T^2-test: $p > 0.05$).

5.4. Craniofacial indices

In the following sections, the anterior and lateral indices will be discussed according to region e.g., head (which includes separate sections for head width and head height), face (which includes total face height, upper-, middle- and lower face height and face depths), mouth (including the lips), mandible, nose and eyes. See Tables 3.6 and 3.7 for a complete list. The index value ranges and change in index values per age, sex and ancestry are noted and compared to the index values and ranges of Farkas and Munro (1987) for North American children. Furthermore, results from Roelofse (2006), who determined 11 similar indices on a sample of adult Black South African males (n = 200) between the ages of 20 and 40, will be mentioned in relation to the results of the 13 year old Black male children in the current study. Index value ranges are rounded in the text to increase readability and discussed as mean values. Appendices II and III provides the datasets for anterior and lateral indices (mean ± 1SD and ± 2SD) per age, sex and ancestry.

5.4.1. Indices related to head width

5.4.1.1. Head width – craniofacial height index ([eu-eu/v-gn] x 100)

The head width–craniofacial height index ([eu-eu/v-gn] x 100) determines the relationship between head width (eu-eu) and craniofacial height.

The index initially decreases from a mean of 67 to 64 in Black males aged 6 to 10 years, 64 to 62 in Black females aged 6 to 9 years, 73 to 66 in Coloured males aged 6 to 9 and again from age 10 to 11 years, and 69 to 65 in Coloured females aged 6 to 8 and 9 to 12 years (Figure 5.4). Figure 5.4 shows that between ages 6 to 8 the index is different between groups, at age 10 little difference is seen between males and females of same ancestry, while differences between all groups are less apparent at age 13. The reason for

this trend is not yet clear, but based on the trends seen the study by Farkas and Munro (1987), differences between sexes can be expected from age 14 onwards.

In their study on White North American children, Farkas and Munro (1987) found a decrease in the head width–craniofacial height index from 70 to 65 in both males in females. The index values of the Black children are smaller compared to the normal range of Farkas and Munro (1987) indicating that the Black children have narrow heads in relation to head and face height (dolicephalic). The larger index values of the Coloured males show that in this group, their heads are wider in relation to height. The index values of the Coloured females fell into the same range as the North American children.

In the South African sample, the index showed a general decrease from the age of 6 to 9 years which indicates lengthwise growth of the face (Figure 5.4). This decrease was followed with a slight increase from age 11 for Black males and females and Coloured males which may be indicative of an increase in head width between the ages of 11 and 13. In the case of Coloured females, the original downward trend continued until age 12 followed by the slight upward trend to age 13. In effect, this means that the faces of Coloured females grow for a longer period of time in length compared to the other groups before head width starts to increase. The difference between the Black and Coloured groups was significant between the ages of 9 and 10 only (ANOVA, $p < 0.05$).

The head width–craniofacial height index value of the Coloured males aged 6 falls in the supernormal range according to Farkas and Munro (1987), which means that the head of this age group is wide in relation to head length. This phenomenon disappears at age 7 and the head width-craniofacial height index of the Coloured males then falls into the normal range as described by Farkas and Munro (1987).

5.4.1.2. Forehead – head width index ([ft–ft/eu–eu] x 100)

The forehead-head width index ([ft-ft/eu-eu] x 100) determines the relationship between the forehead width (ft-ft) and the width of the head (eu-eu).

For all groups this index shows an increase from age 6 to age 13, indicating an enlargement of forehead width relative to head width (Figure 5.5). This increase coincides with the expansion of the neurocranium specifically frontal lobe expansion between the ages of 6 to 7 where a steep increase is seen.

According to Farkas and Munro (1987) the index value of the Black males (with the exception of 10 year olds), as well as 6 year old Coloured males and 6 year old Black females, falls into the subnormal range indicating a narrow forehead in relation to head

width. The forehead – head width index for all other groups are between 74 and 79 which is considered normal, except for the 13 year old Coloured females with an index value of 80.11 indicating that their foreheads are wide in relation to head width (Farkas and Munro, 1987).

5.4.1.3. The skull base – head width index ([zy-zy/eu–eu] x 100)

The skull base – head width index ([zy-zy/eu–eu] x 100) calculates the relationship of the skull base represented by the measurement zy-zy and the head width represented by the measurement eu-eu.

This index generally increased from a mean of 90 to 94 in Black males, 89 to 93 in Black females and Coloured males and 94 to 97 in Coloured females (Figure 5.6). The index values are for all groups are larger than their North American counterparts of the same age and sex (males: 82 – 91 and females: 82 – 90) (Farkas and Munro, 1987). The South African children falls into the supernormal range for this index indicating that their faces are wide (zy-zy) with prominent cheek bones in relation to head width (eu-eu).

5.4.1.4. Forehead width – face width index ([ft–ft/zy-zy] x 100)

The forehead width – face width index ([ft–ft/zy-zy] x 100 determines the relationship between the forehead width (ft-ft) and face width (zy-zy).

Figure 5.7 shows that the forehead width – face index varies between 81 and 84 for all South African groups. The index does not increase or decrease between age groups, except in Black males and Black females, where an increase are seen at age 8 and then again at age 10. These increases were not as pronounced in the Coloured group. In all groups, regardless of sex or ancestry a sudden increase in the index value is seen from between age 12 and 13, indicating that the forehead became wider in relation to head width at between these ages.

In North American males the index increased from 74 to 75 with a peak of 77 at age 9, while the index for North American females ranged between from 75 and 78 with a peak of 77 at age 10 (Farkas and Munro, 1987). The forehead width – face width index range of the South African children is considered as supernormal by Farkas and Munro (1987). In effect the foreheads of South African children are wide in relation to face width.

5.4.2. Indices related to head and face height

5.4.2.1. Auricular head height – skull base width index ([(v–po, l)/t–t] x 100)

The auricular head height – skull base width index ([(v–po, l)/t–t] x 100) calculates the relationship between the auricular head height, as measured between the vertex (v) and the porion (p) at the ear, and the skull base width (t-t).

In all groups a downward trend can be seen in the auricular head height – skull base width index ([(v–po, l)/t–t] x 100) from age 6 to 13 years (Figure 5.8). In Black males the index decreases from 92 to 88, in Black females from 93 to 90, in Coloured males from 91 to 89 and in Coloured females from 91 to 88. This means that the neurocranium (v-po) is lower relative to the skull base wider (t-t) in Coloured children.

The index values for the North American children are higher compared to the South African children, but also show a decrease from age 6 to 13 years: North American male children decreases from 105 to 98 and females from 104 to 100 (Farkas and Munro, 1987). The South African children therefore have a shorter auricular head height (v-po) in relation to the skull base width. In effect the dome of the skull is not as high compared to the American children**.**

5.4.2.2. Facial index ([n-gn/zy-zy] x 100)

The facial index ([n-gn/zy-zy] x 100) indicates the relationship between face height (n-gn) and face width (zy-zy).

The facial index showed progressive increase with age from a mean of 76 to 84 over all age groups regardless of sex and ancestry which clearly illustrates the elongation of the face with age (Figure 5.9).

North American children also increased from age 6 to 13 and the index values ranged between 86 and 87 for males and 85 to 88 for females (Farkas and Munro, 1987). In comparison, the facial index for South African children aged 6 to 13 is smaller than North American children indicating that South African children have short face in relation to face width. Black and Coloured females also have longer faces in relation to face width compared to the males. A study by Roelofse (2006) determined that the facial index of adult Black South African males was 86. Farkas and Munro (1987) also mentions that the facial index of North American males was 89 and females 86 at the age of 18 years. It seems that the facial index in Black South African male children (facial index: 83) (current study) almost reached the adult (facial index: 86) (Roelofse, 2006) value at age 13, which is similar to results from the North American sample of Farkas and Munro (1987).

5.4.2.3. Upper face index ([n-sto/zy-zy] x 100)

The upper face index ([n-sto/zy-zy] x 100) shows the relationship between the length of the upper face (n-sto) and face width (zy-zy).

The upper face index increased with age from age 6 reaching a maximum at age 13 in all groups (Figure 5.10). The index ranged from 50 to 54 in Black children, and from 50 to 53 in Coloured children. This shows that the elongation of the face is also due to growth in the mid-facial region.

The upper face index in North American male children ranged from 52 to 54 with a decrease to 51 at ages 8 and 9 (Farkas and Munro, 1987). The North American females increased linearly from 51 to 53. The upper face index values of South African children are smaller compared to the North American children, although the index values at age 13 is similar. The smaller values indicate that the upper face is short in relation to face width for the younger South African children.

Figure 5.10 shows a peak in both male and female children of Black ancestry at age 8 and again at age 11 in Black males. The peak at age 11 also coincides with a peak value seen in Coloured males in addition to a minor peak at age 9. The female Coloured children also have a peak at age 9. From the trendlines in Figure 5.10, a pattern emerges where the male and female children of the same ancestry group follow the same trend before the age of 10 as can been seen with the peaks at age 8 (Black children) and age 9 (Coloured children). After age 10 a peak is seen at age 11 in male children (both Black and Coloured), but not in the female groups (neither Black nor Coloured females). These trends are somewhat different from Farkas and Munro (1987) as the North American males decreased slightly at age 8 and 9, while the males in the current study peaked. The upper face index of the Black, Coloured and North American females all increased with the exception of the Coloured females where the index value decreased slightly at age 10.

Two phases where dramatic increase in the upper face index is seen are between 6 and 8 years and again between age 12 and 13 for all groups. This means that during these phases elongation of the mid-face region relative to face width was fast.

5.4.2.4. Head – face height index ([n-gn/tr-gn] x 100)

The head-face height index ([n-gn/tr-gn] x 100) is a lateral index that indicates the relationship of the height of the face (n-gn) to the height of the head (tr-gn).

The head-face height index (Figure 5.11) showed a decrease in index values for all groups from age 6 to 7 which corresponds to enlargement of the forehead as described

previously and possibly the frontal lobe and frontal sinus enlargement. After the age of 7 the head-face height index increased reaching a maximum at age 13. The index value ranged from 61 to 65 for Black male children, 61 to 64 for Black female children, 61 to 63 for Coloured male children and 60 to 63 in Coloured female children.

Farkas and Munro (1987) found that the index values ranged from 62 to 64 and 62 to 65 for male and female North American children respectively. The index values suggest that at ages 6 and 7, the faces of South African children are short in relation to the forehead and face height. However, from age 7 in children of Coloured ancestry and age 10 in children of Black ancestry, the face height increases and the head-face height index for Black children are the same as the North American children at age 13. The index is less for the Coloured children at age 13 indicating that the face is short in relation to forehead and face height.

5.4.2.5. Forehead – head height index ([tr-n/v-n] x 100)

The forehead – head height index ([tr-n/v-n] x 100 index is a lateral index which determines the relationship between the forehead (tr-n) and head height measured between the vertex (v) and the nasion (n). The forehead height (tr-n) and head height measurements (v-n) depended on the compliance of the children to wear hairbands in order to visualize the trichion and vertex.

The forehead – head height index shows a decrease from age 6 to age 13 for all groups (Figure 5.12). The index values were higher for males compared to females regardless of ancestry. In Black males the index values decreased from 60 to 56, in Coloured males from 61 to 54, Black females from 59 to 52 and in Coloured females from 59 to 53. Peaks were seen at age 8 and 10 in Coloured males and in Black males although these were less pronounced in the latter. Black females also showed two peaks, the one also at age 8 similar to the males, but the second peak later than the males at age 11. Coloured females showed a peak at age 9. The decrease in index values indicates that the forehead height decreases in relation to head height, possibly due to the expansion of the frontal paranasal sinuses in height. The many peaks in the downward graphs show that the forehead height (v-n) increase is not constant e.g., at age 8 in males and Black females it either slows down or the head height (tr-n) increases. The increase in head height and forehead height are similar in male children because the peaks occur at the same age, but is seem to be slower in females as the peak are seen later at age 9 (Coloured females) and 11(second peak of Black females).

In North American males the index decreased from 58 to 57 with a peak of 60 at age 12, while the index decreased in North American females from 59 to 56 with a low point of 55 at age 12 (Farkas and Munro, 1987). The index values are slightly smaller in the North American children at age 6 (mean forehead – head height index for all 6 year olds: 58.5) compared to the South African children (mean forehead – head height index for all 6 year olds: 59), but the index value at age 13 is larger in the North American children (mean forehead – head height index for all 13 year olds: 56.5) compared to the South African children (mean forehead – head height index for all 13year olds: 54).

However, the index should be interpreted with caution as the correct positioning of landmarks may have been affected by the presence of hair. Also, the hairline of South African children may differ from that of North American children.

5.4.2.6. Upper face – face height index ([n-sto/n-gn] x 100)

The upper face-face height index ([n-sto/n-gn] x 100) is a lateral index which determines the relationship of the upper face (between the nasion, n, and the stomion, s) to the face height (n-gn).

The upper face-face height index increases from the age of 6 to 13 in all groups (Figure 5.13). . Initially, between the ages 6 to 8, a steep increase of the index in all groups is seen which coincides with the eruption of the upper M1 an I1 as well as development of the maxillary sinuses.

Separation is seen between the Coloured and Black children from age 11 to 13 indicating differences between groups of different ancestry after the age of 10. The indices in the Coloured group are larger compared to the Black children from age 11 indicating that the upper face is longer in relation to face height in Coloured children. Therefore, in Coloured children, the face grows faster in the mid-facial region (n-sto) than in the lower region

In North American children the upper face-face height index values increases from 60 to 62 in both sexes (Farkas and Munro, 1987). The index values for South African children ranges from 59 to 63 in Black children, and 60 to 64 in Coloured children. The range of the values is larger in South African children indicating faster change in the relationship of the upper face to the face height. The index values at age 13 is larger in the South African sample compared to the North American sample indicating that the upper face in South African children is larger than North American children.

5.4.2.7. Lower face – face height index ([sn-gn/n-gn] x 100)

The lower face – face height index ([sn-gn/n-gn] x 100) is a lateral index which describes the relationship between the lower face (between the subnasale, sn, and the stomion, s) to the face height (n-gn), in a sense it is the inverse of the previous index.

The lower face – face height index decreases between ages 6 and 13 from a maximum of 60 to a minimum of 58 for Black children and Coloured males and 57 to 55 for Coloured females (Figure 5.14). The index value for Black children is larger than Coloured children until the age of 12. Differences between the ancestry groups are less apparent at ages 12 and 13. Differences between males and females are less pronounced than differences between groups of different ancestry. These differences indicate that the Coloured children, specifically females, have a shorter lower face height in relation to face height.

In North American children the lower face – face height index decreases from 62 to 59 (Farkas and Munro, 1987). The index value ranges of the North American sample are larger compared to the South African sample, indicating that the South Africans generally have shorter lower face regions and as a result, their chins are less prominent.

5.4.2.8. Mandibulo – upper face height index ([sto-gn/n-gn] x 100)

The mandibulo – upper face height index ([sto-gn/n-gn] x 100) determines the relationship between the mandible height as described by the measurement stomion (sto) to gnathion (gn) and the face height (n-gn).

The mandibulo-upper face height index showed a decrease in index values from age 6 to 13 for all groups (Figure 5.15). The index values at all ages are the lowest in the Coloured female group with a small decrease from 37 to 36. The decrease from age 6 to 13 in the other groups were also small (from 38 to 36 for Black children and 37 to 36 for Coloured males).

A similar trend was seen in North American children where the decrease was also 2 index points, although the maximum value was 42 and the minimum 40, which is higher compared to the South African sample (Farkas and Munro, 1987).

This means that the mandible height of the South African sample is smaller in relation to the face height compared to North American children. Furthermore, the mandible height to facial height is also the smallest in Coloured females.

5.4.2.9. Mandibulo – lower face height index ([sto-gn/sn-gn] x 100)

The mandibulo-lower face height index ([sto–gn/sn–gn] x 100) calculates the relationship between the mandible height (sto-gn) and the lower face height as described by the measurement subnasale (sn) to gnathion (gn).

The mandibulo-lower face height index shows a general increase of all the index values per group with age progression. The slope however, is gradual and the changes small (Figure 5.16).

Figure 5.16 showed a decrease of the index value at age 7 to 60, followed by two peaks of at ages 9 and 13 for Coloured males. The index value for Black females followed a similar trend with a maximum value at age 9 of 64 and a lesser peak at age 12 of 63. The index values for Coloured females peaked a year later at age 10 and continued to increase slightly until age 13. The index values for the Black males generally remained around 60. Peaks could be seen value of 61 and again at age 12 with a value of 63, followed by a decline until age 13.

The mandibulo-lower face height index for North American males is reported by Farkas and Munro (1987) to range from 67 to 69 for male children and to remain around 68 for female children.

In comparison, the index values for South African children are smaller compared to the North American sample indicating that the mandible height is lower in relation to the upper face. The peaks seen in the South African sample indicate periods where the mandible expands more than the lower face height thereby contributing more to the growth in facial height. This lengthening of the mandible correlates with the eruption of first permanent teeth around the age of 6 and the eruption of the second permanent molar around the age of 12 (Işcan and Steyn, 2013). Interestingly, this was not the case in North American females despite eruption of teeth around similar ages.

5.4.3. Indices related to the mouth

5.4.3.1. Lip index ([ls-li/ch-ch] x 100)

The lip index ([ls–li/ch–ch] x 100) describes the relation between the lip height of both the upper and lower lips in the midline (ls-li) and the width of the mouth (ch-ch).

Figure 5.17 shows a clear difference in index values between Black and Coloured children, with Black children having thicker lips at all ages. The lip index upper lip-thickness index of male and female Black children ranges between a minimum value of 46

and a maximum value of 51. In the case of Coloured children, the maximum value for Coloured children is 47 and the minimum value 39.

The larger lip index in Black children indicates that the total height of the lips remains relatively constant in relation to the mouth compared to Coloured children. Two peaks are seen in each group with increasing age. In Black females a peak is noted at ages 7 and 10 and at ages 9 and 12 in males. In Coloured females the two peaks are seen at ages 8 and 10. In Coloured males the first peak is noted at age 7 and the second at age 11.

The lip index is not included in the work by Farkas and Munro (1987). Roeloefse (2006) determined a lip index of 44 for adult Black males. The mean index value of Black male children in the current study is 51. It is expected that at some point between age 13 and 21, the mouth width (ch-ch) will increase while total height of the lips (ls-li) will remain constant which may result in a decrease in lip index value from a mean of 51 to 44.

5.4.3.2. Upper lip thickness index ([ls-sto/ls-li] x 100)

The upper lip thickness index ([ls–sto/ls–li] x 100) determines the relationship between the upper lip height (ls-sto) and the total upper lip and lower lip thickness (ls-li).

Figure 5.18 shows differences in the upper lip thickness index values between Black and Coloured children until the age of 12. At age 13 the index value of all groups except for Black male children, are almost the same. In contrast, the upper lip thickness index of Black male children is significantly larger at ages 12 and 13 compared to the other groups. This difference shows that the height of the upper lip of Black male children becomes larger in relation to mouth height.

The upper lip thickness index is not included in the work by Farkas and Munro (1987). Roeloefse (2006) determined the index for adult Black males as 38.9. This means that the total height of the upper lip relative to mouth height will still slightly increase into adulthood.

5.4.3.3. Lower lip thickness index ([li-sto/ls-li] x 100)

The lower lip thickness index ([ls–sto/ls–li] x 100) determines the relationship between the lower lip height (li-sto) and the mouth height (ls-li).

Figure 5.19 indicates differences in the lower lip thickness index values between Black and Coloured children. The index values for Coloured children varied between 52 and 55 and between 49 and 53 in Black children. The lower lip thickness index did not increase in linear fashion from age 6 to 13. Several peaks were seen in all groups. A large

peak was seen at 8 in Black males and a lesser one later at age 12. The trend for the lower lip thickness index was to decrease from age 6 to age 13. The index showed two peaks at age 7 and age 10 in Black females and ended with an upward trend at age 13. The lower lip thickness in Coloured males shows two peaks at aged 8 to 9 and at 12. Despite the two peaks a downward trend for this index was observed in Coloured male children from age 6 to 13. Two lesser peaks were seen at ages 7 and 10 in Coloured female children, however the graph ended with a strong upward trend from age 11 to 13 for this group.

The larger index value found in the Coloured children suggests that the lower lip height of this group is larger in relation to the total height of both the upper and lower lips. The trend of index values to decrease in males indicates an increase in upper and lower lip height, although this trend is more pronounced in Black males. The peaks observed indicate that increase in the lower lip height is similar in females (ages 7 and 10) and males (ages 8 and 12).

The lower lip thickness index is not included in the work by Farkas and Munro (1987). Roeloefse (2006) determined the index for adult Black males as 58.2. The lower lip thickness index for Black males aged 13 is 52. This indicates that between 13 and adulthood, the lower lip thickness for Black male children will decrease in relation to mouth height.

From the upper lip and lower thickness indices, it can be seen that in South African children, the upper lip roughly comprises of 40% of the mouth height and the lower lip 60% of the mouth height.

5.4.3.4. Mouth width index ([ch-ch/ex-ex] x 100)

The mouth width index ([ch-ch/ex-ex] x 100 describes the relationship of the mouth width (ch-ch) to the bi-ocular width (ex-ex).

Figure 5.20 shows an increase in the index from age 6 to 13 for all groups. In Black children the index increases from 48 to 52 in males and 49 to 53 in females. The index values for the Coloured children are smaller than for the Black children. The index for Coloured males increased from 47 to 52 and in Coloured females from 49 to 52. In general, the mouth width index in Black females is larger than all other groups. The general increase of the index from age 6 to 13 for all groups shows that the mouth (ch-ch) becomes wider in relation to the distance between the corners of the eyes (ex-ex). In Black females the mouth width index is the largest which means that their mouths are larger in relation to the distance between the outer corners of the eyes. Although the trend is

upwards for all groups, three peaks can be seen in all children at the same ages (8 years, 10 years and 12 years). The presence of the peaks indicates that the increase in mouth width becomes slower and the distance between the eyes (not the eye itself) becomes larger as head width expands.

The mouth width index is not included in the work by Farkas and Munro (1987). Roeloefse (2006) determined the index for adult Black males as 54.94. This means that the mouth width will increase slightly more as Black male children approaches adulthood.

5.4.3.5. Upper lip height – mouth width index ([sn-sto/ch-ch] x 100)

The upper lip height – mouth width index ([sn-sto/ch-ch] x 100) describes the relationship of sn-sto to mouth width (ch-ch

Figure 5.21 shows a clear difference in index values between Black females and the other groups until the age of 12. The upper lip height – mouth width index of Black male children decreased from 50 to 36 between the ages of 6 and 13. In Black females the decrease ranged between 42 and 37. In the case of Coloured children, the index value decreased from 46 to 39 in Coloured males and 45 to 38 in Coloured females.

The upper lip height – mouth width index for North American males is reported by Farkas and Munro (1987) to range from 48 to 42 for male children and 45 to 41 for female children.

In comparison, the index values for South African children are larger at age 6 compared to the North American sample. However, index values for South African children are smaller at age 13 than the sample of Farkas and Munro (1987). Therefore, the index value indicates that at age 6, the upper lip height is higher in relation to mouth width. However, as the child reaches the age of 13, the upper lip height becomes shorter in relation to mouth width.

5.4.4. Indices related to the mandible

5.4.4.1. Mandibular index ([sto-gn/go-go] x 100)

The mandibular index ([sto-gn/go-go] x 100) determines the relationship between the height of the mandible (sto-gn) and the width of the mandible (go-go).

Figure 5.22 shows an upward trend for all groups from age 6 to age 13. In Black males the index values ranged from 45 to 50, in Black females from 46 to 49, in Coloured males from 48 to 50 and in Coloured females from 48 to 49. At the age of 6, the mandibular index ([sto-gn/go-go] x 100) was significantly different for all sex and

population groups (ANOVA, $p < 0.05$). However, at age 7 and 11 to 13 these differences become significantly less (ANOVA, $p > 0.05$). While differences are seen between groups of different ancestry from age 6 to 9 (except at age 7), differences between males and females are more apparent at age 13. Therefore, at age 6 the mandible height (sto-gn) is short in relation to its width for Black children, but at age 13, the mandible height (sto-gn) is short in relation to its width for females.

The index values for North American children decreases from age 6 to 13 in males from 51 to 48. The index values for South African children are generally smaller (range 46 to 51) between the ages 6 to 13 compared to the North American sample. The implication is that South African children have a short mandible in relation to its width. Also, an increase is seen in the South African sample as opposed to a slight decrease in the North American sample. However, at age 18 North American males have a mandibular index of 52 and females an index of 50. These results indicate that the South African children reach the adult value for the mandibular index earlier than the North American children.

5.4.4.2. Mandible width – face width index ([go-go/zy-zy] x 100)

The mandible width – face width index ([go-go/zy-zy] x 100) determines the relationship between the mandible (go-go) and face width (zy-zy).

Figure 5.23 shows a bell shaped curve for all groups from age 6 to age 13. The ranges of the index values for the mandible-face width index are very narrow and therefore index values will be presented to one decimal number in this section.

A general increase is seen in the index from age 7 to 9 indicating an increase in the width of the mandible. In each group the index generally decreases after age 10 to almost the same value as in the earlier childhood years. The index value for Black males is 73.3 at age 6 and 72.9 at age 13, with the highest values being 74.5 and at age 9. In Black female children it is 72.9 at age 6 and 72.1 at age 13, with the highest value of 73.5 occurring at age 10. In Coloured males the index value at age 6 is 73.0 and 72.8 at age 13, with the highest value of 73.9 seen at age 9. In Coloured females the index value was 74.5 at age 6 and 72.4 at age 13 with the highest value of 73.2 seen at age 11.

The mandible width-face width index values for North American children also have a narrow range and show a flat peak at age 9 to 10 in males and a peak at age 9 in females (Farkas and Munro, 1987). Despite having a downward trend until age 12 the index increases slightly in both sexes: Males age 6: 71.6, age 12: 71.2 and age 13: 73.2; females age 6: 69.8, age 12: 70.4 and age 13: 70.4.

In comparison, the index values for South African children are larger compared to the North American sample indicating that generally the mandible is wide in relation to face width in South African children. The bell shaped curve indicates a period from age 6 to 9 (in males), 6 to 10 (Black females) and 6 to 11 (Coloured females) where the mandible expands in width (go-go), followed by a period where the face width (zy-zy) becomes larger. The process is more pronounced in males and starts at an earlier age compared to the females.

5.4.4.3. Mandible width – face height index ([go-go/n-gn] x 100)

The mandible width-face height index ([go-go/n-gn] x 100) describes the relationship of the width of the mandible (go-go) to the face height (n-gn).

Figure 5.24 shows a tendency for the index to first increase (in Black females and Coloured males from age 6 to age 8 and age 6 to 9 in Black males and Coloured females) and then to decrease until the age of 13. As a result, the trend indicate that the mandible widens to accommodate erupting teeth, but is then dwarfed by the elongation of the face around the age of 9.

The index value for Black males is 86 at age 6 and 84 at age 13, with the highest values being 86 and at age 9. In Black female children it is 86 at age 6 and 85 at age 13, with the highest value of 87 occurring at age 8. In Coloured males the index value at age 6 is 86 and 85 at age 13, with the highest value of 87 seen at age 8. In Coloured females the index value was 86 at age 6 and 85 at age 13 with the highest value of 87 seen at age 9. The initial increase in the index value in all groups suggests an increase in mandible width in relation to face height. This increase is followed by a decrease from ages 8 or 9 were the face height increases in relation to the mandible width.

The mandible width-face height index values for North American male children is 83 at age 6 and 84 at age 13, with the highest values being 87 and at age 9. In female children it is 83 at age 6 and 82 at age 13, with the highest value of 86 occurring at age 9 (Farkas and Munro, 1987).

The index values for South African children are larger compared to the North American sample of Farkas and Munro (1987). The implication is that South African children have a wider mandible in relation to face height than North American children.

5.4.5. Indices related to the nose

5.4.5.1. Nasal index ([al-al/n-sn] x 100)

The nasal index ([al-al/n-sn] x 100) determines the relationship between the width of the nose (al-al) and height of the nose (n-sn).

Figure 5.25 shows separation between groups in terms of ancestry from age 6 to age 8 and then again from age 10 to 12. The nasal index generally decreases in all age groups from age 10 to 13. At the age of 6, there is a significant decrease in the nasal index until the age of 8 for Black children while an increase is seen from 6 to 8 in Coloured children. After 8 years of age, the nasal index starts to increase in all the groups until the age of 10 when it reaches a peak, meaning that the nose is at its widest at age 10. This peak is pronounced in all the groups of Black ancestry and the males of Coloured ancestry. The peak in females of Coloured ancestry is less visible and occurs one year later at the age of 11. The increase in nasal index indicates that the nose is becoming wider in relation to its height while a decrease signals that the nose height is increasing relative to nose width. From the graph it is clear that there are differences between sexes and ancestry groups when these events take place.

The index value for Black males is 98 at age 6 and 93 at age 13, with the highest values being 99 and at age 10. In Black female children it is 98 at age 6 and 92 at age 13, with the highest value of 97 occurring at age 10. In Coloured males the index value at ages 6 and 13 is 91, with the highest value of 95 seen at age 10. In Coloured females the index value was 90 at age 6 and 89 at age 13 with the highest value of 95 seen at age 9. In effect, this means that initially at age 6 Black children have the widest noses. Although the difference decreases with age, the Black children still have wider noses than the Coloured children at any age.

The nasal index values for North American children also vary between 6 and 13 years, but are considerably lower compared to the South African sample (Farkas and Munro, 1987). The large index values correspond with the nasal index of 93 for adult Black males as determined by Roelofse (2006). Large nasal index values in the South African sample indicate that the nose is wide in relation to its height.

5.4.5.2. Nasofacial index ([n-sn/gn-n] x 100)

The nasofacial index ([n–sn/gn–n] x 100 describes the relationship between the nose height (n-sn) and face height (gn-n).

Figure 5.26 shows that this index varies between 38 and 40 for all South African groups. A separation is seen between ancestry groups and also between sexes. The nasofacial index values in Coloured children is generally larger compared to Black children, indicating that noses of Coloured children is longer in relation to their face height. The index value of the males tend to be larger than in females, the exception being the Black females who surpass the Black males at age 12. However, the index value is almost the same in both males and females (Black and Coloured) at age 13. Therefore, all males have longer noses in relation to their face height before the age of 13.

The nasofacial index values for North American children range from 40 to 44 for males and females. The index range of the South African is considered as subnormal when compared to the North American children sampled by Farkas and Munro (1987). In effect, in South African children the nose is short in relation to face height.

5.4.5.3. Nose – face width index ([al-al/zy-zy] x 100)

The nose – face width index ([al-al/zy-zy] x 100) determines the relationship between the nose width (al-al) and face width (zy-zy).

Figure 5.27 shows an increase in the index from age 6 to 13 for all groups. In Black children the index increases from 28 to 30 in males and 29 to 30 in females. The index values for the Coloured children are smaller from ages 6 to 11 than those of Black children. After the age of 11, the nose-face width index is larger in Coloured males than Black males. The index for Coloured males increased from 28 to 30 and in Coloured females from 28 to 29. In general, the index in Black females is larger than in all other groups. The general increase of the index from age 6 to 13 for all groups shows that the nose width (al-al) becomes wider in relation to face width (zy-zy). In Black females the index is the largest which means that their noses are wider in relation to their faces. Although the trend is upwards for all groups, at least two clear peaks can be seen in all children from age 9 to 10 and age 12 to 13. The exception is the Coloured females as their second peak is earlier at age 11. The presence of the peaks indicates that the increase in nose width becomes slower while the head width expands between 10 and 11 and 12 and 13 years.

The nose – face width index values for North American children range from 24 to 26 for males and females. The index range of the South African is considered as supernormal when compared to the North American children sampled by Farkas and

Munro (1987). In effect, in South African children the nose is wide in relation to face width.

5.4.6. Indices related to the eyes

5.4.6.1. Intercanthal index ([en-en/ex-ex] x 100)

The intercanthal index ([en-en/ex-ex] x 100) describes the relationship of the intercanthal width (from endocanthion to endocanthion, en-en) to the bi-ocular width (from ectocanthion to ectocanthion, ex-ex).

Figure 5.28 show a general decrease in the index value for all groups with a steep decline from age 9 to 11, followed by an increase to age 12 and another downward trend from age 12 to 13. Separation between groups is seen in terms of ancestry; however the index differs mostly with only one index point between the various groups from 6 and 13 years. In Black males and females the index decreased from 38 to 37. In Coloured males and females the index decreased from 37 to 36. The index values for Black children are slightly larger compared to Coloured children, but the differences were not significant.

The intercanthal index values for North American children from decreases from 38 to 37 for males and females from the age of 6 to 13 years. The index range of the South African children is similar to the North American children sampled by Farkas and Munro (1987). In effect, no difference is seen between the South African children and North American children. Farkas (1986) only considers an intercanthal index below 34 as an indication of orbital hypotelorism and an intercanthal index above 39 as an indication of orbital hypertelorism.

Roelofse (2006) determined the intercanthal index for adult Black males as 36. The index for Black males aged 13 is 37. Therefore it is expected that an increase of at least one index point of the intercanthal index will take place from age 13 into adulthood. In practical terms, the distance ex-ex will increase somewhat in relation to en-en from age 13 to adulthood in Black males.

5.4.6.2. Eye fissure index ([(ps-pi, l)/(ex-en, l)] x 100)

The eye fissure index ([(ps-pi, l)/(ex-en, l)] describes the relationship between the distance between the upper and lower eye lids (ps-pi) and width of the eye (ex-en).

Figure 5.29 shows that this index decreases in Black children from 35 to 34 and from 34 to 33 in Coloured children. In Black children a decrease in values are observed from age 6 to age 13, while the index values decrease in Black females until the age of 10,

after which is has an upward trend. In Coloured children two peaks are seen at age 7 and 10. The graph for Coloured children ends in an upward trend for the index at age 13.

The eye fissure index values in Black children is slightly larger compared to Coloured children. The values are also larger in males compared to females, however at age 13 the eye fissure index value is larger in females compared to males. This means that in Black children and in males until the age of 12, the eye fissure height is more in relation to eye fissure width.

The eye fissure index values for North American children range from 33 to 34 for males and females. The index range of the South African is similar to that of North American children sampled by Farkas and Munro (1987).

5.4.6.3. Bi-ocular face width index ([ex-ex/zy-zy] x 100)

The bi-ocular face width index ([ex-ex/zy-zy] x 100) describes the relationship of the bi-ocular width (ex-ex) to the width of the face (zy-zy).

Figure 5.30 shows a general decrease in the index value for all groups with a steep decline from age 6 to 8. The index values decreased from 69 to 68 for all groups. The range is narrow, therefore index values in this section will be provided to one decimal number.

The index values decreased from 69.5 to 68.5 in Black males and 69.3 to 68.4 in Black females. In Coloured males the decrease was seen from an index value of 69.5 to 68.4 and in Coloured females from 69.6 to 68.3. Separation between groups is seen in terms of sex; except at age 7 and again at age 13 where Black females and Coloured males have similar index values.

The bi-ocular face width index values for North American children decreased from 69.7 to 67.6 in males and 68.7 to 67.4 in females. The index range of South African children is similar to the North American children, and falls within the normal range as determined by Farkas and Munro (1987).

5.4.6.4. Intercanthal width – upper face height index ([en-en/n-sto] x 100)

The intercanthal width-upper face height index ([en-en/n-sto] x 100) describes the relationship of the height of the upper face (n-sto) to the intercanthal width (en-en).

Figure 5.31 shows a general decrease in the index value for all groups with a steep decline from age 10 to 13. The index values decreased from 54 to 50 in Black males and 53 to 49 in Black females. In Coloured males the decrease was seen from an index value of

53 to 50 and Coloured females from 53 to 49. Separation between groups is seen in terms of sex; except at age 10 to 11 where Black males and all females have similar index values.

The upper face height – bi-ocular width index values for North American children decreased from 51 to 48 in males and 52 to 48 in females. The index range of South African children is slightly more compared to the North American children, but still falls within the normal range as determined by Farkas and Munro (1987).

5.4.7. Indices for facial depth

5.4.7.1. Upper middle third face depth index ([t-n, l/t-sn, l] x 100)

The upper middle third face depth index ([t-n, l/t-sn, l] is a lateral index and describes relationship of the depth of the upper third of the face (t-n) to the depth of the middle third of the face (t-sn).

Figure 5.32 shows a general decrease in the index value for all groups with several peaks within each group. In Black males the index decreases from 89.5 to 85.5, in Black females from 89 to 85.5, in Coloured males from 88 to 86 and in Coloured females from 87 to 86. Peaks are seen in Black males and Coloured females at ages 8 and 12 and in Black females at ages 9 and 12. The trend was different in Coloured males as only a slight peak was seen at age 10. The general decrease in the index suggests that the middle third of the face expands in an anterior posterior direction in relation to the upper third face depth. This expansion is not linear in any group and therefor the graphs present with peaks at different ages.

The middle upper third face depth index values for Black children is larger compared to that of Coloured children, which show that the distance t-sn is becoming larger with age, indicating that the maxilla in Black children becoming more prognathic.

The upper middle third face depth index values for North American children decrease from 100 to 98 in males and females (Farkas and Munro, 1987). The index range of South African children decreases from 95 to 90. Farkas and Munro (1987) uses the term “shallow” to describe index values below the normal range seen in North American children. The index values of South African children in the current study indicate that the upper third of the face of South African children is “shallow” in relation to the middle third face depth compared to North American children. In practical terms, it means that the middle third of the face (t-sn) increased relative to the upper third of the face (t-n) from

age 6 to 13, which resulted in the decrease of the index values. The term “shallow” is problematic and is discussed in detail in the next section.

5.4.7.2. Lower middle third face depth index ([t-sn, l/gn-t, l] x 100)

The lower middle third face depth index ([t-sn, l/gn-t, l] is a lateral index and describes relationship of the depth of the middle third of the face (t-n) to the depth of the lower third of the face (t-sn).

Figure 5.33 shows a general decrease in the index value for all groups with several peaks noted with age progression in all groups. In addition, Figure 5.35 indicates that the females have larger index values than the males. The index values for the females decreased from 93 to 91 and in males from 92 to 90 with age progression. In Black males, a slight peak (age 8) is seen in the steep downward trend until age 10 where it that evens out. In Coloured males, a peak is seen age 10 after a steep downward trend from age 6 to 9. After age 10, the downward slope seen in Coloured males is moderate until age 13. In Black females, the trend is down from age 6 to age 13, with a small peak at age 9. In Coloured females, a similar pattern is observed, except that a small peak is seen between ages 9 and 10 again at age 12.

According to Farkas and Munro (1987) a decrease in this index indicates that the middle third of the face is “shallow” in relation to the lower part of the face. However, the term “shallow” is confusing. The lower middle third face depth index is a lateral index that consists of the relationship between t-sn and gn-t, which are anterior-posterior measurements on a lateral view. If measurement t-sn becomes larger (relative to gn-t) due to growth in the anterior-posterior direction of the middle face region, the index value will increase. If measurement gn-t becomes larger (relative to t-sn) due to growth in the lower face region, the index will decrease. In this regard it would be more advisable to refer to an increase as maxillary anterior-posterior expansion and a decrease as mandibular anterior-posterior expansion. When the index values fall outside the normal range, the terms maxillary prognathism and mandibular prognathism would be appropriate.

The middle lower third face depth index values for males is smaller compared to that of the females, which indicates that the lower third of the face is becoming larger with age, indicating that the mandible in males is becoming more prognathic.

The middle lower third face depth index values for North American children decreased from 94 to 92 in males and females. The index range of South African children decreases from 93 to 90. These index values indicate that the middle third of the face of

South African children is shallow in relation to the lower third face depth compared to North American children. From a different perspective, the lower third of the face is larger in the South African sample indicating a more prognathic mandible.

5.5. Summary of results from craniofacial indices

This section provides a summary of the craniofacial index results. Indices related to the head and face width and height, as well as indices related to the nose and lower region of the face showed marked differences between age, sex and ancestry groups. Indices related to the eyes, such as the relationship between the bi-ocular distance (ex-ex) and the intercanthal distance (en-en) and the eye fissure index remained relatively constant regardless of sex and ancestry, although fluctuations were seen with age progression. The following trends were seen with age progression:

- Mandible height increases relative to lower face height. This increase corresponds to eruption of first permanent teeth around the age of 6 and the eruption of the second permanent molar around the age of 12 (Işcan and Steyn, 2013).
- Face width (zy-zy) increases relative to bi-ocular width (ex-ex) from age 6 to 8.
- The intercanthal width-upper face height index shows a general decrease in the index value for all groups with a steep decline from age 10 to 13.
- The upper third of the face (t-n) expands in an anterior posterior direction in relation to the middle third face depth (t-sn) for all age groups per sex and ancestry.
- The lower middle third face index shows a general decrease in the index value for all groups. This decrease is indicative of expansion of the mandible relative to the maxilla in an anterior posterior direction.
- Expansion of the lower third of the face (t-gn) relative to the middle third of the face (t-sn) coincides with tooth eruption and increase in mandibular height.

The main differences between Black children and Coloured children were noticed in indices related to head-, forehead- and face width, nose- and lip height as well as face depth. The specific details are as follow:

- Coloured children have wider heads, foreheads and faces compared to Black children.
- In Coloured children, mandibular height and lower face height is shorter in relation to total face height.
- In Coloured children, the lower lip height is larger in relation to the total mouth height of both the upper and lower lips.

- Noses of Coloured children are longer in relation to their face height compared to Black children.
- The facial index in Black South African male children almost reached the adult size at age 13.
- In Black children the total height of the lips increases more in relation to the mouth width compared to Coloured children.
- In Black males between 12 and 13 the height of the upper lip becomes larger in relation to total mouth height.
- In Black children, specifically females, the mouth (ch-ch) becomes wider in relation to the bi-ocular width (ex-ex) until age 12.
- The height of the mandible is short in relation to its width in Black children from ages 6 to 9 years. After the age of 11, to the height of the mandible in females is shorter in comparison to males.
- In Black females, the nose width (al-al) is wider in relation to face width (zy-zy).
- In Black children, the middle upper third face depth index values are larger compared to that of Coloured children, which indicate that the maxilla in Black children becoming more prognathic.

The main differences between male children and female children were noticed in indices related to head-, forehead-, face- and mandible width, forehead-, nose-, lip- and mandible height as well as face depth. The specific details are as follow:

- In females, the elongation of the face as indicated by the increase of the upper face index is similar to that of males, but age 13, the Black and Coloured females follow a similar pattern.
- From at age 13, the mandible height (sto-gn) is shorter in relation to its width for females.
- Males have shorter faces in relation to face width compared to the females.
- The male forehead expands in height faster than that of the females.
- Males have wider heads, foreheads, mandibles and faces compared to females.
- In males the total height of the lips (ls-li) relative to lower lip thickness increases with age.
- Males have longer noses in relation to their face height and intercanthal width before the age of 13.

- The middle lower third face depth index values for males is smaller compared to that of the females indicating that the mandible in males is becoming more prognathic with age.

The main differences between South African children and North American children were noticed in indices related to head-, forehead-, face-, mouth-, nose and intercanthal width, as well as head-, forehead-, mandibular-, nose- and upper lip height and face depth. The specific details are as follow:

- Indices associated to head width (head width–craniofacial height index, forehead-head width index, skull base – head width index, forehead width – face width index) showed that South African children have wider heads compared to North American children.
- Indices related to head and face height (auricular head height – skull base width index facial index, upper face index, head-face height index, forehead – head height, upper face-face height index, lower face – face height index, mandibulo – upper face height index, mandibulo-lower face height index) showed that South African children have shorter mandible height relative to the upper- and lower face height compared to North American children. In South African children, the relationship of the upper face to the face height change at a faster rate compared to North American children.
- The upper lip-mouth width index showed that in South African children, upper lip height is larger in relation to mouth width, but at the age of 13, the upper lip height becomes smaller in relation to mouth width compared to North American children.
- Indices related to the mandible (mandibular index, mandible width-face width, mandible width-face height index) showed that South African children have shorter and wider mandibles in relation to mandible height, face width and face height than North American children.
- Indices related to the nose (nasal index, nasofacial index, nose–face width index) showed that noses of South African children are shorter and wider relative to nose height and face height compared to the noses of North American children.
- Indices related to the eyes (intercanthal index, eye fissure index, bi-ocular face width index) showed little differences between the South African children and North American children, except for the intercanthal width-upper face height index. This index showed that the intercanthal width is larger relative to upper face height in South African children.
- Indices related to the face depth (upper middle third face depth index and lower middle third face depth) showed that North American children have a relative straight

lateral facial profile compared to the convex lateral facial profile of South African children. This is the result of the mandible being more prognathic in the South African sample.

5.6. BMI & SES

5.6.1. Introduction

Although the BMI and the analysis thereof do not form an essential part of the study, it is included here as the schools requested information as part of the anthropometric assessment of the children. In essence, this detail was recorded as part of the agreement with the schools to conduct the anthropometric part of the study. This information will be made available to the schools, and is documented here as a permanent record of the complete study assessment. The results will be outlined briefly, but no attempt will be made to correlate the BMI with various facial indices or geometric morphometric assessment. This falls outside the scope of this study and was not expected to have a major influence on these aspects. It will also not be included in detail in the "Discussion", other than to comment on the overall health / nutrition of the group and how this may have influenced their overall growth.

5.6.2. BMI of different age groups per region

A summary of the BMI and SES for each school per region is presented in Table 5.5. In general, more children were underweight in low SES schools in the Western Cape (predominantly Coloured children) compared to low SES schools in Gauteng (mainly Black children). The chart also shows that more overweight and obese children are found in Gauteng schools compared to Western Cape schools, and is especially prominent in the single high SES school. Of concern is the one school in the Western Cape (W1), where nearly 22% of children were underweight. This information will be fed back to the school.

5.6.3. BMI of different age groups per sex

The mean BMI per age, ancestry and sex is provided in Table 5.7. The standard mean BMI values for males and females per age are provided in Tables 5.8 and 5.9. When the mean BMI per age, ancestry and sex (Table 5.7) is compared to the standard BMI values (Tables 5.8 and 5.9), several groups, of which the mean BMI per age and sex falls into the underweight category, were noticed. These include three Black male age groups (6-, 9- and 13 year olds), most Coloured males (ages 8 to 13) and five Coloured female groups (6-, 7-,

9 to 11 year olds) which can be classified as underweight. The largest increase in mean BMI from age 6 to 13 was seen in Black females (mean BMI at age 6: 15.51; at age 13: 21.45), while the smallest increase in mean BMI with progressive age was seen in Coloured males (mean BMI at age 6: 15.56; at age 13: 17.59).

Figure 5.34 shows that the mean BMI of Black females was consistently higher in the 7-, 9-, 10-, 12- and 13 year old age groups. In the 8-year old and 11-year-old groups, the BMI of Black males were higher compared to Black females. The BMI of Black females was generally higher than all the Coloured children, with the exception of 8-year-old Coloured males. The BMI of the Coloured females was higher than the Coloured males in most age groups, except the 6-year old and 7-year-old groups. In general, the BMI of Coloured males was the lowest of all the groups.

5.6.4. BMI of different age groups per ancestry

Table 5.6 shows that 79.1% of Coloured children (age and sex combined) and 68.8% of Black children are found in the normal weight range. More Coloured children (12.7%) were underweight compared to Black children (8.4%). In contrast, more Black children were overweight (10.9%) and obese (12.0%) than Coloured children where 5.6% were overweight and 2.6% obese.

In Tables 5.9 and 5.10 results of the current study are compared to the results by Armstrong *et al.* (2006) and Tathiah *et al.* (2013). Armstrong *et al.* (2006) indicated that 9.9% of Black children were overweight, and 9.7% of Coloured children were overweight. Tathiah *et al.* (2013) found that 9.0% of Black female children from rural areas in KwaZulu-Natal were overweight, with the highest number overweight children seen between 9 and 10 years (Table 5.9). The current study found that 10.9% of Black children and 5.6% of Coloured children were overweight. Similar to Tathiah *et al.* (2013), the highest number of overweight children was seen in Black females 9 to 10 years, but also between 12 and 13 years.

In the obese category, Armstrong *et al.* (2006) determined that 3.4% of Black children and 6.8% of Coloured children were obese. Tathiah *et al.* (2013) determined that 3.8% of rural Black female children were obese, which is similar to the results of Armstrong *et al.* (2006). In contrast, the current study determined that 12.1% of Black children and 2.6% of Coloured children were obese with the 12 and 13 year old age groups being most affected. These results are similar to that of Tathiah *et al.* (2013), who found the highest prevalence of obesity in the 12 year old age group. Monyeki *et al.* (2008) and

Kimani-Murage *et al*. (2010) also support these findings. Monyeki *et al*. (2008) conducted a longitudinal growth study over a period of eight years of rural South African children aged 3 – 10 years in Ellisras, Limpopo province (n = 1771). They determined that girls between the ages of 9 and 15 years were significantly more overweight (range 2 - 16%) compared to boys (range 0.3 - 5%) from the same age group. In their study involving children from a Black rural community from the Mpumalanga, Kimani-Murage *et al*. (2010) determined that girls in late adolescence are more likely to be overweight or obese than boys.

In the current study it was found that underweight children were mostly between the ages 6 to 9 years. More Coloured children (12.7%) were underweight compared to Black children (8.4%). Armstrong *et al*. (2006) did not report on the underweight children, but Tathiah *et al.* (2013) found that 4% of children were underweight with the highest prevalence in the 10 year old group.

In summary, comparison of the results from the current study to others show an increase in obesity under Black children, as well as an increase in the number of underweight Coloured children.

5.7. Geometric morphometrics

For assessing changes to the face with geometric morphometrics, the lateral facial profile was chosen as it enables visualization of shape changes regarding the forehead, nose, mouth and chin as well as the degree of prognathism. In this section, geometric morphometrics will be used to firstly describe the lateral facial profile shape at each of the different age levels (6 to 13 years).

Secondly, successive age groups will be compared in order to assess the shape differences between groups, e.g., the lateral facial profile of the 6 year old group will be compared to the 7 year old group, and the lateral facial profile of the 7 year old group will be compared to the 8 year old group etc.

Thirdly, a description of how the mean shape of males and females differs from each other and from the mean shape of the sample will be provided.

The last part of the section will analyze each age group to determine whether significant differences are apparent between age groups per sex and ancestry.

5.7.1. Lateral facial profile per age

5.7.1.1. Lateral facial shape change over all age groups

A relative warp analysis of the mean lateral facial profiles for all age groups is presented in Figure 5.35. The relative warp analysis shows a clear difference between the younger age groups (6 - 7-year old group) and the older age groups. As expected, the middle age groups (8 – 11-year old groups) cluster together between the younger and older age groups.

In vector mode, the specific landmarks that contribute to the lateral face shape change can be visualized (Figure 5.36). This figure shows the overall changes (sexes and ancestry combined) from the youngest age group (6 year old group) to the oldest (13 year old group).

A posterior and slightly superior displacement was seen of the supraglabella, while glabella was anteriorly and inferiorly displaced. The combined effect of these displacements is the enlargement of the forehead from age 6 to age 13. The nasal tip, subnasal, stomion, labiale inferius and labiomentale were anteriorly and inferiorly displaced, indicating enlargement of the nose, lengthening of the nasal region and increase in the anterior-posterior length of the mandible.

The age groups appear to differ primarily at the forehead as well as the lower third of the face which includes the mouth and part of the mandible. Prognathism becomes more pronounced with age progression as most of the deformation is seen in the lower third of the face. The forehead also appears more rounded.

5.7.1.2. Lateral facial shape of successive age groups

The changes at specific landmarks of the lateral facial profile between successive age groups are presented in Figure 5.37 (6 year olds *vs* 7 year olds), followed by a CVA plot of the 6 and 7 year old groups (Figure 5.38). This pattern will be repeated for the 7 year old and 8 year old groups, 8 year old and 9 year old groups, 9 year old and 10 year old groups, 10 year old and 11 year old groups 11 year old and 12 year old groups, and 12 year old and 13 year old groups.

5.7.1.2.1. Comparison between ages 6 and 7 years

Differences in landmark position between 6 and 7 year old children were seen at all landmarks, except the trichion. Anterior and inferior displacements were seen at the supraglabella, nasion and nasal tip, however, differences were more pronounced at the

subnasal, labiale superius, stomion, labiale inferius and labiomentale (Figure 5.37). The glabella showed a small anterior and slightly superior displacement.

A mean CVA plot (Figure 5.38) showed that the mean shape of the 6 year old children and 7 year old children were moderately separated. A significant difference was confirmed by both Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p=0.0248; Hotteling's T^2-test: p=0.0001) (Table 5.12). CVA assignment was 68% accurate in assigning children to the 6 year old group and 71% accurate when assigning children to the 7 year old group based on shape data (Table 5.13).

5.7.1.2.2. Comparison between ages 7 and 8 years

Landmark differences in the lower face region were also pronounced when comparing the 7 year old children to the 8 year old children (Figure 5.39). Although superior and anterior displacement was seen at the glabella and nasion, these displacements were small in comparison to the nasal tip, subnasal, labiale superius, stomion, labiale inferius and labiomentale.

A mean CVA plot was generated that indicated some separation between groups (Figure 5.40). The plot indicated the mean lateral facial shape of the 7 year old children and 8 year old children were possibly significantly different. A significant difference was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 0.0000; Hotteling's T^2-test: p= 0.0000) (Table 5.12). CVA assignment was 69% accurate in assigning children to the 7 year old group and 72% accurate when assigning children to the 8 year old group based on shape data (Table 5.14).

5.7.1.2.3. Comparison between ages 8 and 9 years

The landmark displacement between 8 and 9 year old children are shown in Figure 5.41. The glabella continues its displacement to anterior and slightly inferior while the supraglabella seems to recede. The net effect of the displacement of these two landmarks is the enlargement of the brow ridge that also coincides with the enlargement of the frontal sinuses at this age. Not only is the displacement of the landmarks in the lower face region is less compared to previous age groups, the labiale inferius and labiomentale are inferiorly displaced, while the stomion has a slight superior displacement. In general, displacements of landmarks were small between these two age groups.

A mean CVA plot showed that the mean shape of the 8 year old children and 9 year old children were relatively close together (Figure 5.42). A significant difference was

found by Goodall's F-test and with Hotteling's T^2-test (Goodall's F-test: p=0.0024; Hotteling's T^2-test: p=0.0281) (Table 5.15). CVA assignment was 69% accurate in assigning children to the 8 year old group and 72% accurate when assigning children to the 9 year old group based on shape data (Table 5.15).

5.7.1.2.4. Comparison between ages 9 and 10 years

Vectors indicating the change in lateral facial shape between 9 and 10 year old children show anterior displacement of the labiale superius and labiale inferius and an upward displacement of the stomion and subnasal (Figure 5.43). The nasion tip and nasion continue to be anteriorly and inferiorly displaced. The supraglabella and glabella move toward one another at this age.

The mean CVA plot indicated that the mean shape of the 9 year old children and 10 year old children were relatively close together (Figure 5.44). This relative proximity suggested that the facial profile of 9 year old children and 10 year old children may not be significantly different. No significant difference was found by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p=0.7603; Hotteling's T^2-test: p=0.079) (Table 5.12).

5.7.1.2.5. Comparison between ages 10 and 11 years

Comparison of landmark positions between the 10 and 11 year old children revealed only small displacements at the supraglabella and nasion (Figure 5.45). The nasal tip, subnasal, labiale superius, labiale inferius, labiomentale were displaced anteriorly and superiorly, while the glabella continued to be anteriorly and slightly inferiorly displaced.

The mean CVA plot indicated that the mean shape of the 10 year old children and 11 year old children were close together (Figure 5.46). This proximity suggested that the facial profile of 10 year old children and 11 year old children may not be significantly different. No significant difference was found by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p=0.9310; Hotteling's T^2-test: p=0.1036) (Table 5.12).

5.7.1.2.6. Comparison between ages 11 and 12 years

Vectors in Figure 5.47 show displacement of landmarks related to the nose and lower face region when comparing the 11 and 12 year old children. The nasion, nasal tip and subnasal are moving superiorly, although the displacement of the subnasal is also posterior which will sharpen the nasiolabial angle, and nasion is displaced almost vertically upward. The labiale superius continued to be anteriorly and superiorly displaced, while the

displacement of the labiale inferius and labiomentale were superior and slightly anterior. Together with the small posterior displacement of the stomion, the displacement of the landmarks related to the lips indicates enlargement of the lips and forward displacement of the upper part of the mandible.

The mean CVA plot indicating the mean lateral facial shape of the 11 year old children and 12 year old children, showed some separation (Figure 5.48). A significant difference was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 0.0079; Hotteling's T^2-test: p= 0.0041) (Table 5.12). CVA assignment was 61% accurate in assigning children to the 11 year old group and 70% accurate when assigning children to the 12 year old group based on shape data (Table 5.16).

5.7.1.2.7. Comparison between ages 12 and 13 years

Figure 5.49 indicates that the frontal sinus enlarges between ages 12 and 13, as seen by the posterior displacement of the supraglabella and the prominent anterior and inferior displacement of the glabella. The nasal tip, subnasal, labiale superius, labiale inferius and labiomentale project inferiorly and anteriorly, while the stomion is displaced inferiorly and posteriorly. The combined effect of the displacement of these landmarks in the lower region is that it lengthens the face and the mandible becomes more prominent.

The mean CVA plot shows the mean lateral facial shape of the 11 year old children and 12 year old children (Figure 5.50). A significant difference was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 0.0010; Hotteling's T^2-test: p= 0.0102) (Table 5.12). CVA assignment was 69% accurate in assigning children to the 12 year old group and 70% accurate when assigning children to the 13 year old group based on shape data (Table 5.17).

5.7.2. Geometric morphometrics per sex

5.7.2.1. Lateral facial shape change between all males and all females

In order to determine differences between sexes, all males (n = 400) and all females (n = 400) were pooled together.

In vector mode, the specific landmarks that contribute to the deformation of the grid of the mean male facial shape and the mean female facial shape can be visualized (Figure 5.51). The supraglabella, glabella and nasion were superiorly and slightly posteriorly displaced in males creating a more rounded forehead. The nasal tip were more anterior in males and the stomion, labiale inferius and labiomentale were more inferiorly displaced

creating a profile with nose that projects more anteriorly than females as well as a larger lower face region in males. The subnasal, midphiltrum and labiale superius remain constant.

Both Goodall's F-test and Hotteling's T^2-test indicated significant differences between the mean shape of the lateral facial profile between sexes (Goodall's F-test: p=2.1705e-007; Hotteling's T^2-test: p=3.9157e-005).

5.7.2.2. Lateral facial shape differences between males and females per age group

In the following section, differences between males and females within the same age group (with ancestry combined) were investigated.

5.7.2.2.1. Lateral facial shape differences between 6 year old males and 6 year old females

A vector plot (Figure 5.52) showed anterior and slightly superior displacement of landmarks from the nasion to labiale inferius in males (circles), except at the midphiltrum where no displacement was seen. In males, the glabella was anteriorly and slightly inferiorly displaced, while very little displacement was seen at the supraglabella. These displacements indicate that 6 year old males have more prominent foreheads and prognathic mid-face and lower face region compared to the 6 year old females. A mean CVA plot was generated to visualize the mean position of the landmarks (Figure 5.53), which showed that the mean shape of the 6 year old males and 6 year old females were relatively close together. This relative close proximity suggested that 6 year old males and 6 year old females are not significantly different. This lack of difference was confirmed by both Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p=0.9839; Hotteling's T^2-test: p=0.6402) (Table 5.18).

5.7.2.2.2. Lateral facial shape differences between 7 year old males and 7 year old females

A vector plot (Figure 5.54) showed displacement of inferior and slightly anterior displacement of landmarks at the glabella, labiale superius, stomion and labiomentale of 7 year old male children. The supraglabella, nasion, nasal tip and labiale inferius were inferiorly and somewhat posteriorly displaced. The labiale superius, stomion and labiomentale was inferiorly displaced. The combined effect of the landmark displacement indicated that the face of the males became longer. A mean CVA plot was generated to

visualize the position of the landmarks (Figure 5.55), indicating the mean of the 7 year old males and 7 year old females were moderately close together. The difference was indicated as significant by Goodall's F-test and with Hotteling's T^2-test (Goodall's F-test: p=0.0152; Hotteling's T^2-test: p=0.0165) (Table 5.18). CVA assignment was 70% accurate in assigning children to the 7 year old male group and 76% accurate when assigning children to the 7 year old female group based on shape data (Table 5.19).

5.7.2.2.3. Lateral facial shape differences between 8 year old males and 8 year old females

A vector plot (Figure 5.56) showed superior and anterior displacement of the nasion, subnasal, labiale superius, stomion and labiale inferius in males. The nasal tip and labiomentale proceeded to be anteriorly and inferiorly displaced.

A mean CVA plot was generated to visualize the mean position of the landmarks (Figure 5.57), where the mean of the 8 year old males and 8 year old females were moderately close to the same value. This relative moderate proximity suggested that 8 year old males and 8 year old females may be significantly different. This difference was found to be significant by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p=0.0286; Hotteling's T^2-test: p=0.0001) (Table 5.18). The CVA assignment accurately classified 72% of 8 year old males and 76% of 8 year old females based on shape data (Table 5.20).

5.7.2.2.4. Lateral facial shape differences between 9 year old males and 9 year old females

A vector plot (Figure 5.58) showed slight displacement of the supraglabella to anterior and a larger displacement of the glabella to posterior and inferior in males. The nasal tip, subnasal, stomion, labiale inferius and labiomentale were more inferiorly and slightly posteriorly displaced in males.

A mean CVA plot was generated to visualize the mean position of the landmarks (Figure 5.59), indicating the mean of the 9 year old males and 9 year old females were relatively close together. This relative proximity suggested that 9 year old males and 9 year old females may not be significantly different. No significant difference was found by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p=0.1624; Hotteling's T^2-test: p=0.1942) (Table 5.18).

5.7.2.2.5. Lateral facial shape differences between 10 year old males and 10 year old females

A vector plot (Figure 5.60) showed that the supraglabella, nasal tip, labiale superius and labiale inferius were inferiorly and anteriorly displaced in males, while the subnasal landmark were superiorly and posteriorly displaced. Small or no displacement was seen at the other landmarks.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.61), indicating the mean shape of the 10 year old males and 10 year old females were could be significantly different. Significant differences were found with Goodall's F-test and with Hotteling's T^2-test (Goodall's F-test: p=0.0126; Hotteling's T^2-test: p=0.0039) (Table 5.18). CVA assignment was 72% accurate in assigning children to the 10 year old male group and 66% accurate when assigning children to the 10 year old female group based on shape data (Table 5.21).

5.7.2.2.6. Lateral facial shape differences between 11 year old males and 11 year old females

A vector plot (Figure 5.62) showed anterior and slightly superior displacement of landmarks at the supraglabella and nasal tip, subnasal and stomion, while the labiale superius and labiomentale were anteriorly displaced in males. A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.63), indicating the mean of the 11 year old males and 11 year old females were relatively close together. This relative proximity suggested that 11 year old males and 11 year old females may not be significantly different. No significant difference was found by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p=0.8907; Hotteling's T^2-test: p=0.4832) (Table 5.18).

5.7.2.2.7. Lateral facial shape differences between 12 year old males and 12 year old females

A vector plot (Figure 5.64) showed anterior and superior displacement at the supraglabella in males. Anterior and inferior displacements were seen at the nasal tip, stomion and labiomentale. Inferior and slightly anterior displacement was seen at the subnasal. The labiale inferius was inferiorly displaced.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.65), indicating the mean of the 12 year old males and 12 year old females were

moderately close together. This relative moderate proximity suggested that 12 year old males and 12 year old females may not be significantly different. Both Goodall's F-test and Hotteling's T^2-test confirmed the lateral facial profile of 12 year old males and 12 year old females as not being significantly different (Goodall's F-test: p=0.5133, Hotteling's T^2-test: p=0.0.088 (Table 5.18).

5.7.2.2.8. Lateral facial shape differences between 13 year old males and 13 year old females

A vector plot (Figure 5.66) showed anterior and superior displacement of the supraglabella, nasal tip, subnasal, labiale superius, stomion and labiale inferius in males. A small anterior displacement was seen at the labiomentale.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.67), where the mean of the 13 year old males and 13 year old females the groups may be significantly different. The difference was indicated as being significant by Goodall's F-test, but as significant with Hotteling's T^2-test (Goodall's F-test: p=0.0037; Hotteling's T^2-test: p=0.0111) (Table 5.18). The CVA assignment accurately classified 74% of males and 72% of females based on shape data (Table 5.22).

5.7.3. Geometric morphometrics per age and ancestry

5.7.3.1. Lateral facial shape change between all Black children and all Coloured children

In order to determine differences between ancestral groups, all Black and all Coloured children were pooled together.

In vector mode, the specific landmarks that contribute to the facial shape difference between Black and Coloured children are shown in Figure 5.68. The supraglabella was superiorly and posteriorly displaced, while only a small displacement of the glabella in the same direction as the supraglabella was seen. The displacement of these landmarks corresponds with the enlargement of the frontal paranasal sinus during childhood and also indicates that the brow ridge in Black children is somewhat more pronounced compared to Coloured children. The nasal tip, labiale superius, stomion, labiale inferius and labiomentale were displaced a considerable distance anteriorly and superiorly, indicating enlargement of the lips and mandible. As a result, the lower part of the face in in Black children projects more forward compared to Coloured children.

5.7.3.2. Lateral facial shape differences between Black and Coloured children per age group

The extent of the differences seen when comparing all Black children to all Coloured children promoted the next level of investigation that addressed possible differences of between Black and Coloured children within the same age group.

5.7.3.2.1. Lateral facial shape differences between 6 year old Black children and 6 year old Coloured children

A vector plot (Figure 5.69) showed superior and anterior displacement of landmarks at the glabella, nasion, labiale superius and labiale inferius in Black children. In addition, anterior and slightly downward displacement was seen at the subnasal, stomion and labiomentale. Displacement at the supraglabella and nasal tip were small.

A mean CVA plot was generated to visualize the mean position of the landmarks relative to one another (Figure 5.70). The plot showed that the mean shape of the 6 year old Black children and the mean shape of the 6 year old Coloured children were relatively far from one another. This relative distance suggested that 6 year old Black children and 6 year old Coloured children are significantly different. This difference was confirmed by both Goodall's F-test and Hotteling's T^2-test as being significant (Goodall's F-test: p=0.000; Hotteling's T^2-test: p= 1.64E-11) (Table 5.23). As a result, CVA assignment was 94% accurate in assigning Black children and 84% accurate in assigning Coloured children based on shape data (Table 5.24).

5.7.3.2.2. Lateral facial shape differences between 7 year old Black children and 7 year old Coloured children

A vector plot (Figure 5.71) showed anterior and superior displacement of the glabella, subnasal and labiale superius in Black children. The nasion, nasal tip, labiale inferius and labiomentale were anteriorly and inferiorly displaced. The supraglabella was displaced vertically downward and the stomion posteriorly.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.72), indicating the mean lateral facial shape of the 7 year old Black children and 7 year old Coloured were potentially significantly different. A significant difference was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 1.11E-16; Hotteling's T^2-test: p= 4.50E-08) (Table 5.23). CVA assignment was 86% accurate in assigning both Black and Coloured children based on shape data (Table 5.25). It can be

deducted that a significant difference exists between 7 year old Black children and 7 year old Coloured children in terms of lateral facial profile shape.

5.7.3.2.3. Lateral facial shape differences between 8 year old Black children and 8 year old Coloured children

A vector plot (Figure 5.73) showed anterior displacement of the supraglabella and nasal tip, but a posterior displacement of the glabella in Black children. Inferior and anterior displacements were seen at the stomion and labiale inferius, while the nasion and labiomentale showed slight anterior displacements. Very little displacement was seen at the labiale superius and none at the trichion, subnasal and midphiltrum.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.74), indicating the mean lateral facial shape of the 8 year old Black children and 8 year old Coloured children were possibly significantly different. A significant difference was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 0.0000; Hotteling's T^2-test: p= 4.18E-10) (Table 5.23). CVA assignment was 88% accurate in assigning Black children and 82% accurate in assigning Coloured children based on shape data (Table 5.26).

5.7.3.2.4. Lateral facial shape differences between 9 year old Black children and 9 year old Coloured children

A vector plot (Figure 5.75) again showed anterior displacement of the supraglabella and posterior displacement of the glabella in Black children. The nasion was anteriorly and superiorly displaced. The subnasal and midphiltrum were displaced superiorly and slightly posteriorly. The displacement of the labiale superius, stomion, labiale inferius and labiomentale were superiorly and slightly anteriorly.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.76), indicating the mean lateral facial shape of the 9 year old Black children and 9 year old Coloured children were possibly significantly different. A significant difference was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 0.0000; Hotteling's T^2-test: p= 1.23E-10) (Table 5.23). CVA assignment was 84% accurate in assigning Black children and 90% accurate in assigning Coloured children based on shape data (Table 5.27).

5.7.3.2.5. Lateral facial shape differences between 10 year old Black children and 10 year old Coloured children

A vector plot (Figure 5.77) showed anterior and inferior displacement of the glabella, nasal tip, subnasal, labiale superius, stomion, labiale inferius and labiomentale. The supraglabella showed only a small posterior displacement.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.78), indicating the mean lateral facial shape of the 10 year old Black children and 10 year old Coloured children were possibly significantly different. A significant difference was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 0.0000; Hotteling's T^2-test: p= 3.27E-07) (Table 5.23). CVA assignment was 86% accurate in assigning both Black children and Coloured children based on shape data (Table 5.28).

5.7.3.2.6. Lateral facial shape differences between 11 year old Black children and 11 year old Coloured children

A vector plot (Figure 5.79) showed anterior displacement of the glabella, while the subnasal landmark was inferiorly displaced in Black children. The supraglabella, nasion, labiale superius, stomion and labiale inferius were displaced posteriorly. The subnasal and labiomentale were displaced inferiorly and slightly posteriorly.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.80), indicating the mean lateral facial shape of the 11 year old Black children and 11 year old Coloured children were possibly significantly different. A significant difference was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 0.0000; Hotteling's T^2-test: p= 2.55E-08) (Table 5.23). CVA assignment was 86% accurate in assigning both Black children and Coloured children based on shape data (Table 5.29).

5.7.3.2.7. Lateral facial shape differences between 12 year old Black children and 12 year old Coloured children

A vector plot (Figure 5.81) showed inferior and slightly posterior displacement at the supraglabella, labiale superius, stomion, labiale inferius and labiomentale in Black children. The nasal tip was displaced inferiorly, while the glabella was displaced superiorly and anteriorly.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.82), indicating the mean lateral facial shape of the 12 year old Black children and 12 year old Coloured children were possibly significantly different. A significant difference

was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 0.0000; Hotteling's T^2-test: p= 6.25E-07) (Table 5.23). CVA assignment was 86% accurate in assigning Black children and 82% accurate in assigning Coloured children based on shape data (Table 5.30).

5.7.3.2.8. Lateral facial shape differences between 13 year old Black children and 13 year old Coloured children

A vector plot (Figure 5.83) showed superior and anterior displacement of the glabella and nasion in Black children. The nasal tip and labiale superius were displaced anteriorly and inferiorly. The subnasal, stomion and labiale inferius were predominantly anteriorly and slightly superiorly displaced.

A CVA plot was generated to visualize the mean position of the landmarks (Figure 5.84), indicating the mean lateral facial shape of the 13 year old Black children and 13 year old Coloured children were possibly significantly different. A significant difference was confirmed by Goodall's F-test and Hotteling's T^2-test (Goodall's F-test: p= 0.0000; Hotteling's T^2-test: p= 2.82E-07) (Table 5.23). CVA assignment was 92% accurate in assigning Black children and 86% accurate in assigning Coloured children based on shape data (Table 5.31).

5.8. Summary of results from geometric morphometrics

In summary, vectors are valuable to determine change in facial shape by means of displacement of landmarks. The landmark displacements in the current study is summarized as follow:

- As far as lateral facial shape is concerned, the younger age groups (6 - 8 year old group) are similar in shape, while the older age groups (12 and 13 year old group) are also more similar. The lateral facial shape of the middle age groups (9 - 11 year old groups) are similar and has features of both the younger and older groups
- Assessment of the change in lateral face profile from age 6 to age 13, posterior displacement of the supraglabella and anterior displacement of the glabella coincided with the enlargement of the frontal sinuses between ages 7 to 9 and again between 12 to 13 years. Inferior and anterior displacement of the labiale superior, stomion, labiale inferius and labiomentale indicated lengthening of the mandible in an anterior-posterior direction.

- In terms of sex differences, large brow ridges, longer faces and increasing prognathism are more prominent in males (age and ancestry combined). These differences were seen by inferior and anterior landmark displacements of the forehead (supraglabella, glabella, and nasion) and mandible (stomion, labiale inferius and labiomentale).
- Landmark displacement in the lower face (labiale superius, stomion, labiale inferius and labiomentale) was anterior and superior indicating a more proganthic alveolar and mandibular prognathism in Black children. Minor inferior and anterior displacements were seen of the supraglabella and glabella indicating that differences are less prominent in the forehead region in terms of ancestry.
- Facial shape differences between Black and Coloured children can be attributed to displacement upper face landmarks which corresponds with the enlargement of the frontal paranasal sinus during childhood and also indicate that the brow ridge in Black children is somewhat more pronounced compared to Coloured children. Displacement of the lower face landmarks coincides with the enlargement of the lower lip and mandible. As a result, prognathism in Black children is more pronounced compared to Coloured children.

The specific changes in landmark positions of the lateral facial profile are provided as seen between successive age groups:

- Between 6 and 7 year old children: Anterior and inferior displacements were seen at the supraglabella, nasion and nasal tip, however, differences were more pronounced at the subnasal, labiale superius, stomion, labiale inferius and labiomentale. The glabella showed a small anterior and slightly superior displacement.
- Between 7 year old children and 8 year old children: Small superior and anterior displacement were seen at the glabella and nasion, while pronounced superior and anterior displacement were seen at the nasal tip, subnasal, labiale superius, stomion, labiale inferius and labiomentale.
- Between 8 and 9 year old children: The glabella continued its displacement anteriorly and slightly inferiorly, while the supraglabella seemed to recede. Displacement of the landmarks in the lower face region were less compared to previous age groups, and the labiale inferius and labiomentale were displaced inferiorly, while the stomion has a slight superior displacement
- Between 9 and 10 year old children: Anterior displacement of the labiale superius and labiale inferius is seen and an upward displacement of the stomion and subnasal points.

The nasion tip and nasion continued to be displaced anteriorly and downwards. The supraglabella and glabella move towards one another at this age.

- Between 10 and 11 year old children: Small displacement at the supraglabella and nasion were seen when comparing landmarks. The nasal tip, subnasal, labiale superius, labiale inferius, labiomentale were anteriorly and superiorly displaced, while the glabella continued to be anteriorly and slightly inferiorly displaced.
- Between 11 and 12 year old children: The nasion, nasal tip and subnasal are displaced superiorly, although the displacement of the subnasal was also posterior which result in the nasiolabial angle becoming more obtuse. The nasal tip is displaced anteriorly, while the nasion is displaced almost vertically upward. The labiale superius continued to be displaced anteriorly and superiorly, while the labiale inferius and labiomentale were superiorly and anteriorly displaced.
- Between the ages 12 and 13 old children: Displacement of the supraglabella posteriorly and anterior and inferior displacement of the glabella were detected when comparing 12 year old and 13 year old children. The nasal tip, subnasal, labiale superius, labiale inferius and labiomentale show predominantly inferior and slightly anterior displacement. The stomion was displaced inferiorly and posteriorly. The combined effect of the displacement of these landmarks in the lower region is that it lengthens the face and the mandible becomes more prominent.

The following specific differences in landmark position were noted when comparing males and females of the same age group:

- 6 year old males to 6 year old females: In males the nasion, nasal tip, subnasal, labiale superius, stomion, labiale inferius showed anterior and slightly superior displacement. No displacement was seen at the midphiltrum. In addition, the glabella was anteriorly and slightly inferiorly displaced, while very little displacement was seen at the supraglabella.
- 7 year old males and 7 year old females: The supraglabella, nasion, nasal tip and labiale inferius were displaced inferiorly and somewhat posteriorly in males, while the labiale superius, stomion and labiomentale were inferiorly displaced. No landmark displacement was seen at the midphiltrum.
- 8 year old males and 8 year old females: Superior and anterior displacement of the nasion, subnasal, labiale superius, stomion and labiale inferius in males. The nasal tip and labiomentale proceeded to be anteriorly and inferiorly displaced.

- 9 year old males and 9 year old females: Slight displacement of the supraglabella to anterior and a larger displacement of the glabella to posterior and inferior in males. The nasal tip, subnasal, stomion, labiale inferius and labiomentale were more inferiorly and slightly posteriorly displaced in males.
- 10 year old males and 10 year old females: Inferior and anterior displacement of the supraglabella, nasal tip, labiale superius and labiale inferius were observed in males, while the subnasal landmark was superiorly and posteriorly displaced. Small or no displacement was seen in males at glabella, nasion, subnasal, midphiltrum, stomion and labiomentale.
- 11 year old males and 11 year old females: Anterior and slightly superior displacement of landmarks at the supraglabella and nasal tip, subnasal and stomion were seen in males. Also, the labiale superius and labiomentale were only anteriorly displaced in males.
- 12 year old males and 12 year old females: Anterior and superior displacement of the supraglabella was seen in males. Anterior and inferior displacements were also seen at the nasal tip, stomion and labiomentale. Males also showed inferior and slightly anterior displacement at the subnasal, while the labiale inferius was inferiorly displaced.
- 13 year old males and 13 year old females: In males, anterior and superior displacement of the supraglabella, nasal tip, subnasal, labiale superius, stomion and labiale inferius were seen, while a small anterior displacement was seen at the labiomentale.

The following specific differences in landmark position were noted when comparing Black and Coloured children of the same age group:

- 6 year old Black children and 6 year old Coloured children: Anterior displacement of landmarks at the glabella, nasion, labiale superius and labiale inferius were seen in Black children. In addition, anterior and slightly downward displacement was seen at the subnasal, stomion and labiomentale. Displacement at the supraglabella and nasal tip were small.
- 7 year old Black children and 7 year old Coloured children: In Black children the glabella, subnasal and labiale superius were anteriorly and superiorly displaced. The nasion, nasal tip, labiale inferius and labiomentale were all anteriorly and inferiorly displaced. The supraglabella was vertically downward and the stomion posteriorly displaced.

- 8 year old Black children and 8 year old Coloured children: Anterior displacement of the supraglabella and nasal tip were seen in Black children. The glabella was posteriorly displacement in Black children. Inferior and anterior displacements were seen at the stomion and labiale inferius, while the nasion and labiomentale showed slight anterior displacements. Very little displacement was seen at the labiale superius and none at the trichion, subnasal and midphiltrum.
- 9 year old Black children and 9 year old Coloured children: Anterior displacement of the supraglabella and posterior displacement of the glabella were seen in Black children. In Black children, the nasion was anteriorly and superiorly displaced, while the subnasal and midphiltrum were superiorly and slightly posteriorly displaced. The labiale superius, stomion, labiale inferius and labiomentale were superiorly and slightly anteriorly dsipalced.
- 10 year old Black children and 10 year old Coloured children: In Black children, anterior and inferior displacement of the glabella, nasal tip, subnasal, labiale superius, stomion, labiale inferius and labiomentale were seen. The supraglabella showed only a small posterior displacement.
- 11 year old Black children and 11 year old Coloured children: In Black children, anterior displacement of the glabella were seen, while the subnasal landmark was inferiorly displaced. The supraglabella, nasion, labiale superius, stomion and labiale inferius were all posteriorly displaced. The subnasal and labiomentale were displaced downwards and slightly posteriorly.
- 12 year old Black children and 12 year old Coloured children: In Black children, inferior and slightly posterior displacement at the supraglabella, labiale superius, stomion, labiale inferius and labiomentale were seen. The nasal tip was inferiorly displaced, while the glabella was superiorly and anteriorly displaced.
- 13 year old Black children and 13 year old Coloured children: In Black children, superior and anterior displacement of the glabella and nasion were evident. The nasal tip and labiale superius were both anteriorly and inferiorly displaced. The subnasal, stomion and labiale inferius were predominantly anteriorly and slightly superiorly displaced in Black children.

Table 5.1: Sample composition for calculation of craniofacial indices

Ancestry	Age	Sex	Sample size	Ancestry	Age	Sex	Sample size	Total
Black	6	Male	53	Coloured	6	Male	44	97
Black	7	Male	42	Coloured	7	Male	54	96
Black	8	Male	38	Coloured	8	Male	59	97
Black	9	Male	44	Coloured	9	Male	58	102
Black	10	Male	47	Coloured	10	Male	54	101
Black	11	Male	36	Coloured	11	Male	56	92
Black	12	Male	43	Coloured	12	Male	48	91
Black	13	Male	37	Coloured	13	Male	80	117
Black	6	Female	57	Coloured	6	Female	35	92
Black	7	Female	49	Coloured	7	Female	57	106
Black	8	Female	46	Coloured	8	Female	86	132
Black	9	Female	56	Coloured	9	Female	75	131
Black	10	Female	36	Coloured	10	Female	71	107
Black	11	Female	50	Coloured	11	Female	87	137
Black	12	Female	44	Coloured	12	Female	81	125
Black	13	Female	38	Coloured	13	Female	88	126
Total	-	-	**716**	-	-	-	**1033**	**1749**

Table 5.2: Sample composition for calculation of craniofacial indices per age and ancestry

Ancestry	Age								Total
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	
Black	110	91	84	100	83	86	87	75	716 (41%)
Coloured	79	111	145	133	125	143	129	168	1033 (59%)
Total	**189 (11%)**	**202 (12%)**	**229 (13%)**	**233 (13%)**	**208 (12%)**	**229 (13%)**	**216 (12%)**	**243 (14%)**	**1749 (100%)**

Table 5.3: Sample composition for calculation of craniofacial indices per age and sex

Sex	Age								Total
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	
Male	97	96	97	102	101	92	91	117	793 (45.3%)
Female	92	106	132	131	107	137	125	126	956 (54.7%)
Total	**189 (11%)**	**202 (12%)**	**229 (13%)**	**233 (13%)**	**208 (12%)**	**229 (13%)**	**216 (12%)**	**243 (14%)**	**1749 (100%)**

Table 5.4: Intra- and interobserver repeatability for craniofacial indices (n=21)

Index	Intraobserver repeatability	Interobserver repeatability
Head width - craniofacial height index	0.9870	0.9350
Forehead - head width index	0.9373	0.9892
Skull base - head width index	0.9285	0.9213
Head - craniofacial height index	0.9552	0.9860
Forehead - head height index	0.9539	0.9760
Upper face - face height index	0.9638	0.9227

Table 5.5: Summary of socio-economic status and BMI (% of children in each category) per school per region.

School number	Socio-economic status	n	Underweight	Normal weight	Overweight	Obese
G1	Low	114	7.89	75.01	6.58	10.53 [b]
G2	Low	187	8.06	69.89	11.83	10.22 [b]
G3	Low	201	14.15	74.53	4.72	6.60 [b]
G4	Low	214	6.58	65.79	17.11	10.53 [c]
W1	Low	125	21.97 [a]	74.24	0.76	3.03 [b]
W2	Low	142	14.19	77.70	6.80	2.03 [b]
W3	Low	178	10.10	81.82	4.04	4.04 [b]
W4	Low	158	9.62	80.13	8.97	1.28 [b]
W5	Low	315	7.81	81.77	7.55	2.86 [b]
G5	High	115	5.26	58.77	14.04	21.93 [a]
-	**Total**	**1749**	**9.86**	**74.30**	**8.46**	**7.38**

[a-c] Significant differences ($p < 0.05$)
G- Gauteng; W – Western Cape; the number indicates various schools

Table 5.6: Percentage of Black children (n = 716) and Coloured children (n = 1033) in each BMI category.

Sample	Underweight	Normal weight	Overweight	Obese
Black	8.4%	68.8%	10.9%	12.0%
Coloured	12.7%	79.1%	5.6%	2.6%
Mean	**10.6%**	**74.0%**	**8.2%**	**7.3%**

Table 5.7: Mean BMI of Black males and female children (n = 716) and Coloured male and female children (n = 1033)

Age	Black males	Black females	Coloured males	Coloured females
6	15.00[a]	15.51[a]	15.56	14.80[a]
7	15.82	16.79	15.53	14.79[a]
8	17.21	16.44	15.47[a]	15. 20[a]
9	16.15[a]	17.98	15.75[a]	15.96[a]
10	17.06	18.41	15.89[a]	16.70[a]
11	19.73	19.21	16.26[a]	17.36[a]
12	18.15	18.89	17.01[a]	18.34
13	18.17[a]	21.45	17.59[a]	19.68

[a] Underweight for age and sex

Table 5.8: Standard BMI categories for male children aged 6 – 13 years

Age	BMI categories			
	Underweight	Normal	Overweight	Obese
	5th percentile	50th percentile	85th percentile	95th percentile
6	13.8	15.5	17.0	18.4
7	13.7	15.5	17.4	19.1
8	13.8	15.8	17.9	20.0
9	14.0	16.2	18.6	21.0
10	14.2	16.6	19.4	22.0
11	14.6	17.2	20.2	23.1
12	15.0	17.8	21.0	24.1
13	15.4	18.4	21.8	25.2

Table 5.9: Standard BMI categories for female children aged 6 – 13 years

Age	BMI categories			
	Underweight	**Normal**	**Overweight**	**Obese**
	5th percentile	**50th percentile**	**85th percentile**	**95th percentile**
6	13.4	15.2	17.0	18.8
7	13.4	15.4	17.5	19.6
8	13.6	15.8	18.2	20.6
9	13.7	16.2	19.0	21.8
10	14.0	16.8	20.0	22.9
11	14.4	17.5	20.8	24.0
12	14.8	18.0	21.6	25.2
13	15.2	18.7	22.6	26.2

Table 5.10: Comparison of percentage Black children per BMI category from Armstrong *et al.* (2006) and Tathiah *et al.* (2013) to results of current study

Author	n	BMI category				
		Underweight	**Normal weight**	**Overweight**	**Obese**	**Total**
Armstrong *et al.* (2006)*	2423	-	-	9.9	3.4	-
Tathiah *et al.* (2013)**	963	4.0	83.2	9.0	3.8	100
Current study	960	8.4	68.6	10.9	12.1	100

*Only overweight and obese categories were considered by Armstrong *et al.* (2006)
**Included only Black females from rural area

Table 5.11: Comparison of percentage Coloured children per BMI category from Armstrong *et al.* (2006) and Tathiah *et al.* (2013) to results of current study

Author	n	BMI category				
		Underweight	**Normal weight**	**Overweight**	**Obese**	**Total**
Armstrong *et al.* (2006)*	880	-	-	9.7	6.8	-
Current study	1018	11.4	79.9	5.9	2.8	100

*Only overweight and obese categories were considered by Armstrong *et al.* (2006)

Table 5.12: Statistical significance between children of successive age groups

Age groups	n	Statistical significance between groups					
		Goodall's F-test (F-statistic)	df	p-value	Hotelling's T^2 test (F-score)	df	p-value
6 years *vs* 7 years	200	2.10	18	0.0248	1.68	22	0.0001
7 years *vs* 8 years	200	3.22	18	0.0000	3.17	22	0.0000
8 years *vs* 9 years	200	1.83	18	0.0024	1.36	22	0.0281
9 years *vs* 10 years	200	0.75	18	0.7603	1.27	22	0.1979
10 years *vs* 11 years	200	0.56	18	0.9310	1.43	22	0.1036
11 years *vs* 12 years	200	1.98	18	0.0079	2.11	22	0.0041
12 years *vs* 13 years	200	2.36	18	0.0010	1.93	22	0.0102

Significant differences between groups are highlighted ($p \leq 0.05$)

Table 5.13: CVA assignment of children aged 6 years *vs* children aged 7 years

Sex	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
6 years	100	68	32	68
7 years	100	71	29	71

Table 5.14: CVA assignment of children aged 7 years *vs* children aged 8 years

Sex	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
7 years	100	69	31	69
8 years	100	72	28	72

Table 5.15: CVA assignment of children aged 8 years *vs* children aged 9 years

Sex	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
8 years	100	68	32	69
9 years	100	71	29	72

Table 5.16: CVA assignment of children aged 11 years *vs* children aged 12 years

Sex	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
11 years	100	61	39	61
12 years	100	70	30	70

Table 5.17: CVA assignment of children aged 12 years *vs* children aged 13 years

Sex	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
12 years	100	69	31	69
13 years	100	66	34	69

Table 5.18: Statistical significance between male children and female children

Age group	n	Statistical significance between groups					
		Goodall's F-test (F-statistic)	df	p-value	Hotelling's T^2 test (F-score)	df	p-value
6 year olds	100	0.42	18	0.9839	0.86	22	0.6402
7 year olds	100	1.95	18	0.0152	1.39	22	0.0165
8 year olds	100	1.20	18	0.0286	1.94	22	0.0001
9 year olds	100	1.32	18	0.1624	1.31	22	0.1942
10 year olds	100	1.78	18	0.0126	1.43	22	0.0039
11 year olds	100	0.62	18	0.8907	0.99	22	0.4832
12 year olds	100	0.95	18	0.5133	1.53	22	0.0888
13 year olds	100	0.84	18	0.0037	2.06	22	0.0111

Significant differences between groups are highlighted ($p \leq 0.05$)

Table 5.19: CVA assignment of children aged 7 years per sex

Sex	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Males	50	35	15	70
Females	50	38	12	76

Table 5.20: CVA assignment of children aged 8 years per sex

Sex	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Males	50	36	14	72
Females	50	38	12	76

Table 5.21: CVA assignment of children aged 10 years per sex

Sex	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Males	50	36	14	72
Females	50	33	17	66

Table 5.22: CVA assignment of children aged 13 years per sex

Sex	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Males	50	37	13	74
Females	50	36	14	72

Table 5.23: Statistical significance between Black children and Coloured children

Age group	n	Statistical significance between groups					
		Goodall's F-test (F-statistic)	df	p-value	Hotelling's T^2 test (F-score)	df	p-value
6-year olds	100	11.42	18	0.000	7.42	22	1.64E-11
7-year olds	100	6.68	18	1.11E-16	5.1	22	4.50E-08
8-year olds	100	10.92	18	0.000	6.42	22	4.18E-10
9-year olds	100	14.34	18	0.000	6.79	22	1.23E-10
10-year olds	100	9.15	18	0.000	4.57	22	3.27E-07
11-year olds	100	17.24	18	0.000	5.25	22	2.55E-08
12-year olds	100	8.85	18	0.000	4.41	22	6.25E-07
13-year olds	100	8.36	18	0.000	4.61	22	2.82E-07

Significant differences between groups are highlighted ($p \leq 0.05$)

Table 5.24: CVA assignment of children aged 6 years per ancestry

Ancestry	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Black	50	47	3	94
Coloured	50	42	8	84

Table 5.25: CVA assignment of children aged 7 years per ancestry

Ancestry	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Black	50	43	7	86
Coloured	50	43	7	86

Table 5.26: CVA assignment of children aged 8 years per ancestry

Ancestry	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Black	50	44	6	88
Coloured	50	41	9	82

Table 5.27: CVA assignment of children aged 9 years per ancestry

Ancestry	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Black	50	42	8	84
Coloured	50	45	5	90

Table 5.28: CVA assignment of children aged 10 years per ancestry

Ancestry	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Black	50	43	7	86
Coloured	50	43	7	86

Table 5.29: CVA assignment of children aged 11 years per ancestry

Ancestry	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Black	50	43	7	86
Coloured	50	43	7	86

Table 5.30: CVA assignment of children aged 12 years per ancestry

Ancestry	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Black	50	43	7	86
Coloured	50	41	9	82

Table 5.31: CVA assignment of children aged 13 years per ancestry

Ancestry	n	CVA assignment based on shape data		Percentage correctly assigned (%)
		Correctly assigned	Incorrectly assigned	
Black	50	46	4	92
Coloured	50	43	7	86

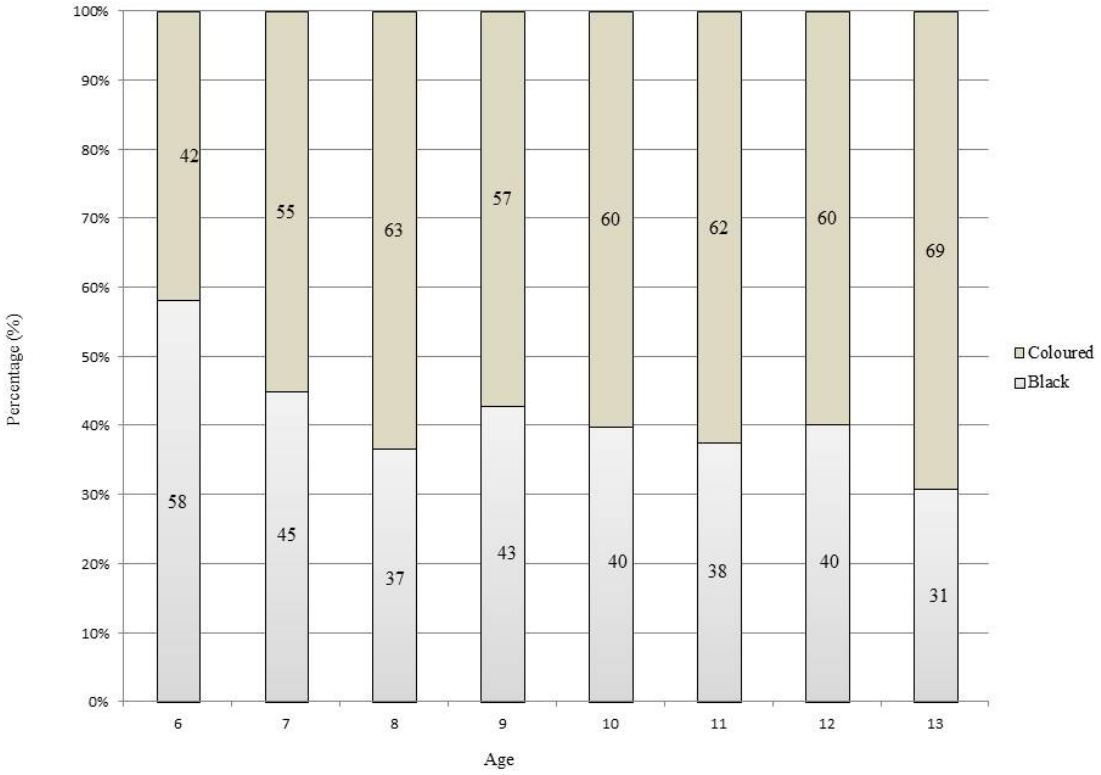

Figure 5.1: Sample composition for craniofacial indices of children aged 6 to 13 years per ancestry.

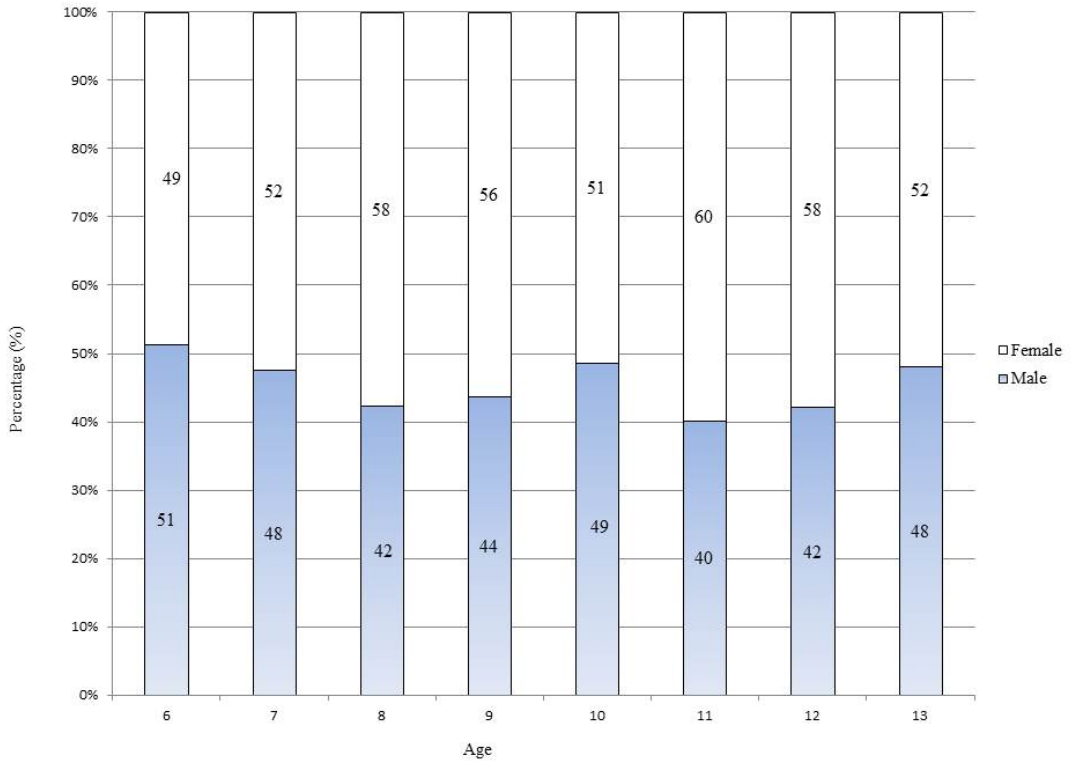

Figure 5.2: Sample composition for craniofacial indices of children aged 6 to 13 years per sex.

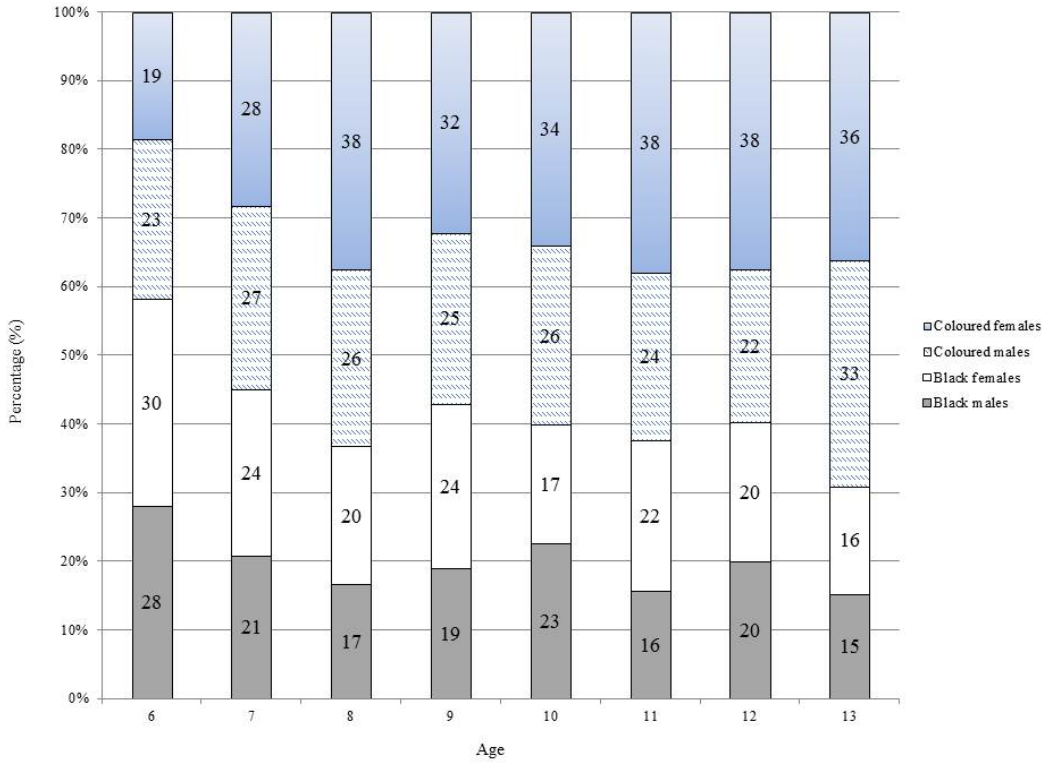

Figure 5.3: Sample composition for craniofacial indices of children aged 6 to 13 years per sex and ancestry.

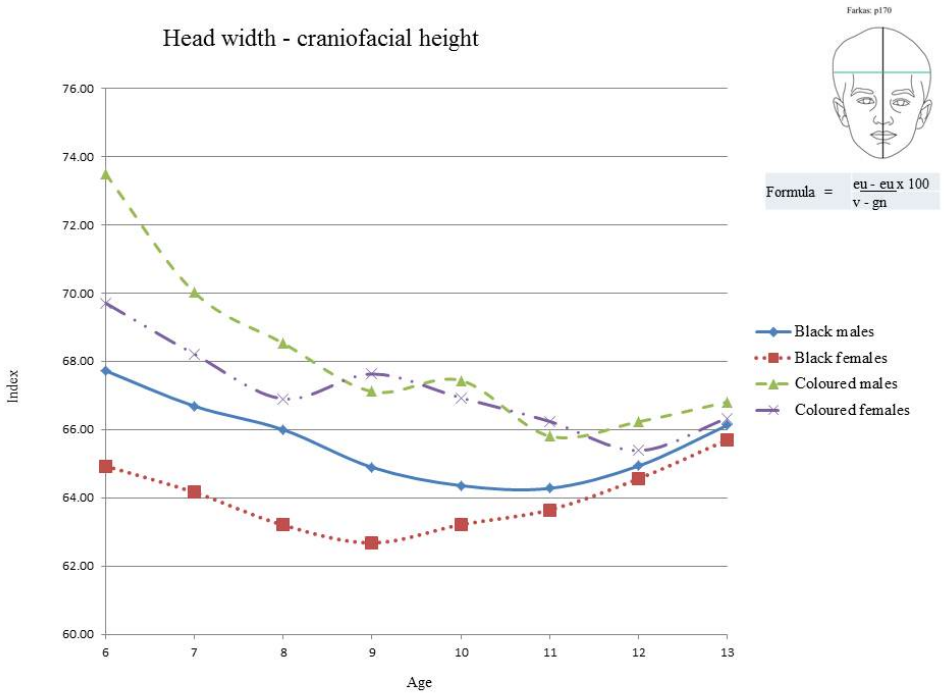

Figure 5.4: Progression of the head width - craniofacial height index from age 6 to age 13 per sex and ancestry.

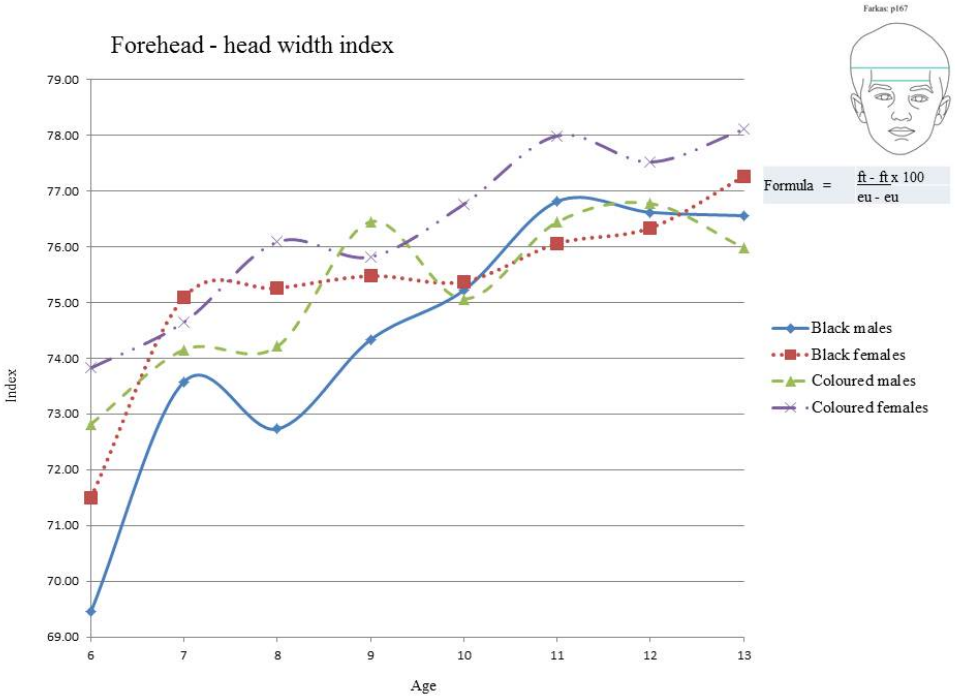

Figure 5.5: Progression of the forehead – head width index from age 6 to age 13 per sex and ancestry.

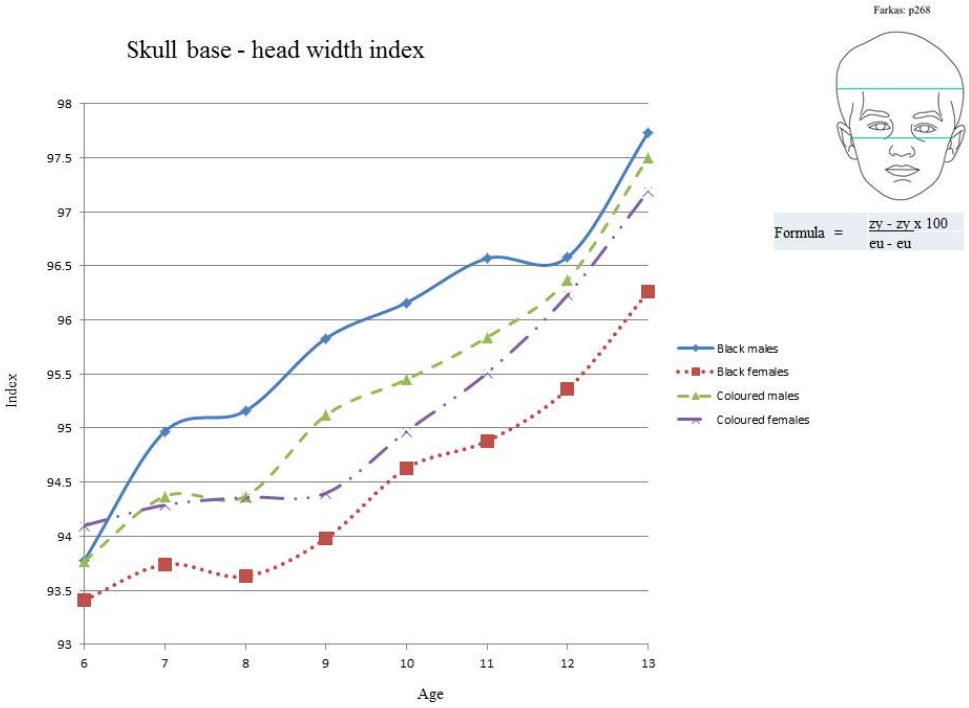

Figure 5.6: Progression of the skull base – head width index from age 6 to age 13 per sex and ancestry.

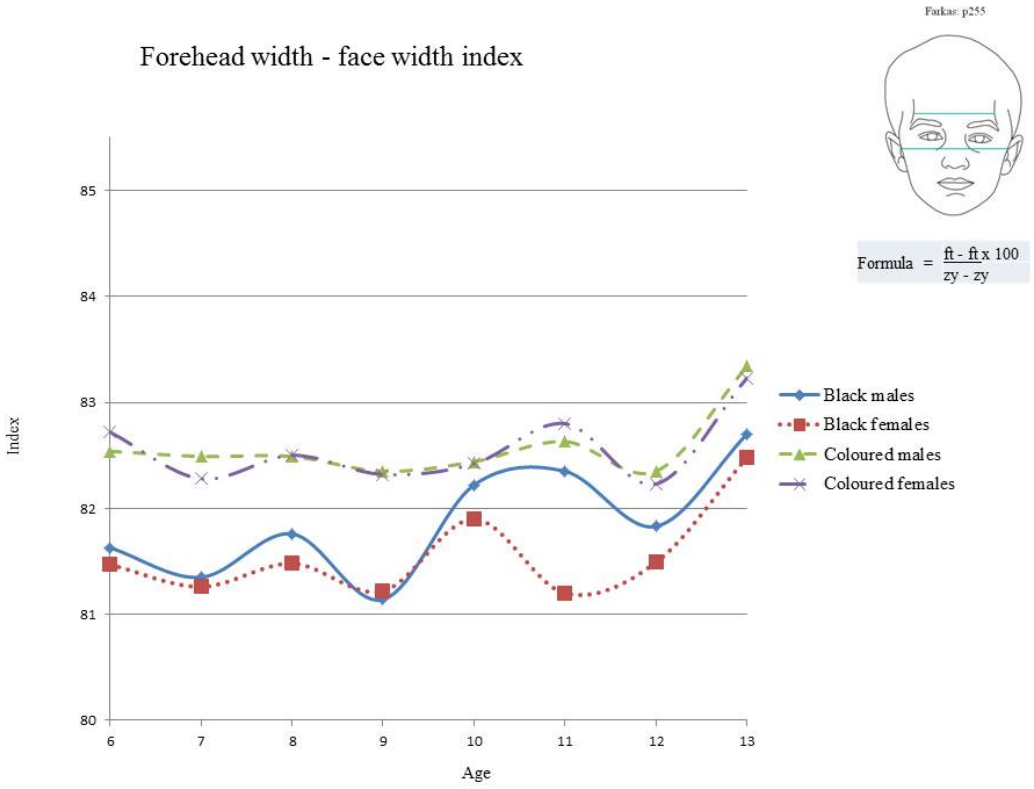

Figure 5.7: Progression of the forehead width – face width index from age 6 to age 13 per sex and ancestry.

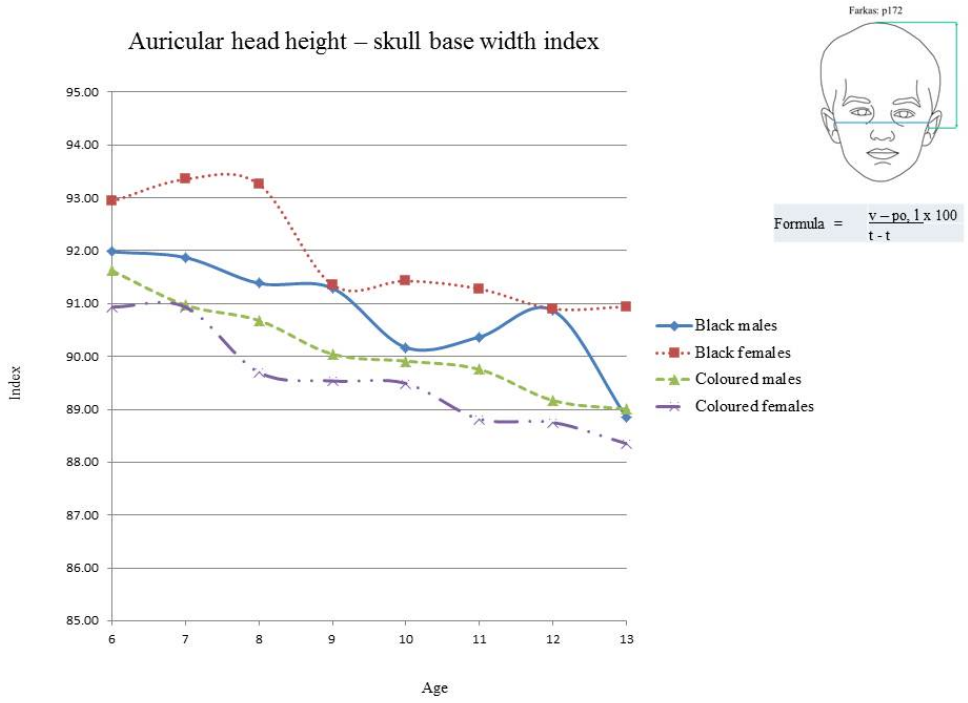

Figure 5.8: Progression of the auricular head height – skull base width index from age 6 to age 13 per sex and ancestry.

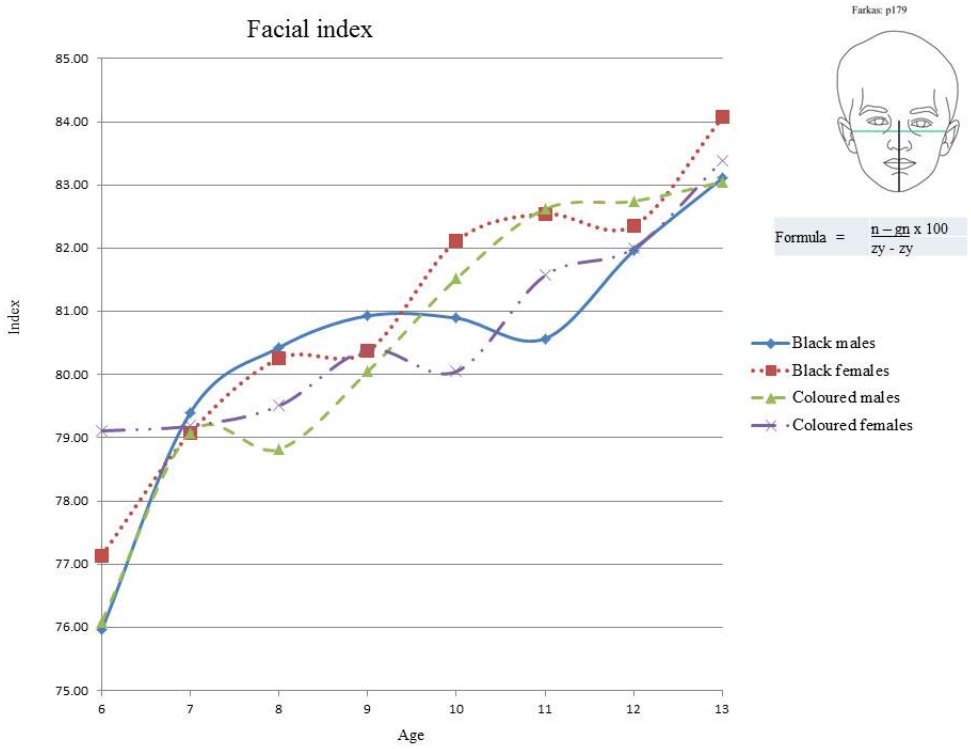

Figure 5.9 Progression of the facial index from age 6 to age 13 per sex and ancestry.

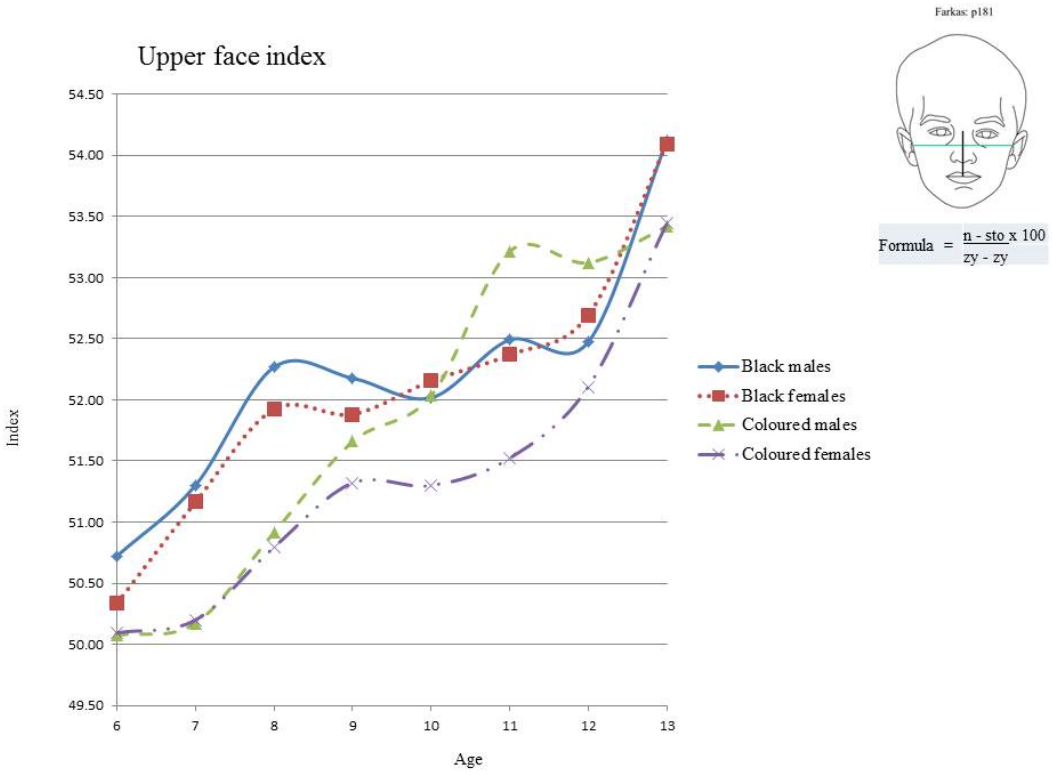

Figure 5.10: Progression of the upper face index from age 6 to age 13 per sex and ancestry.

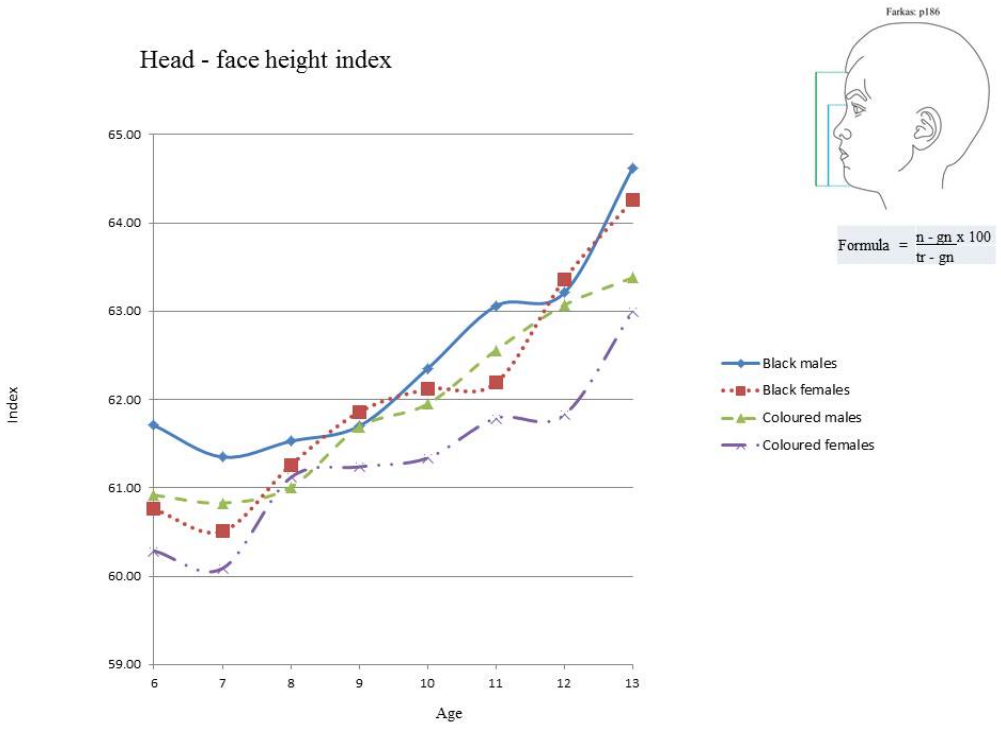

Figure 5.11: Progression of the head – face height index from age 6 to age 13 per sex and ancestry.

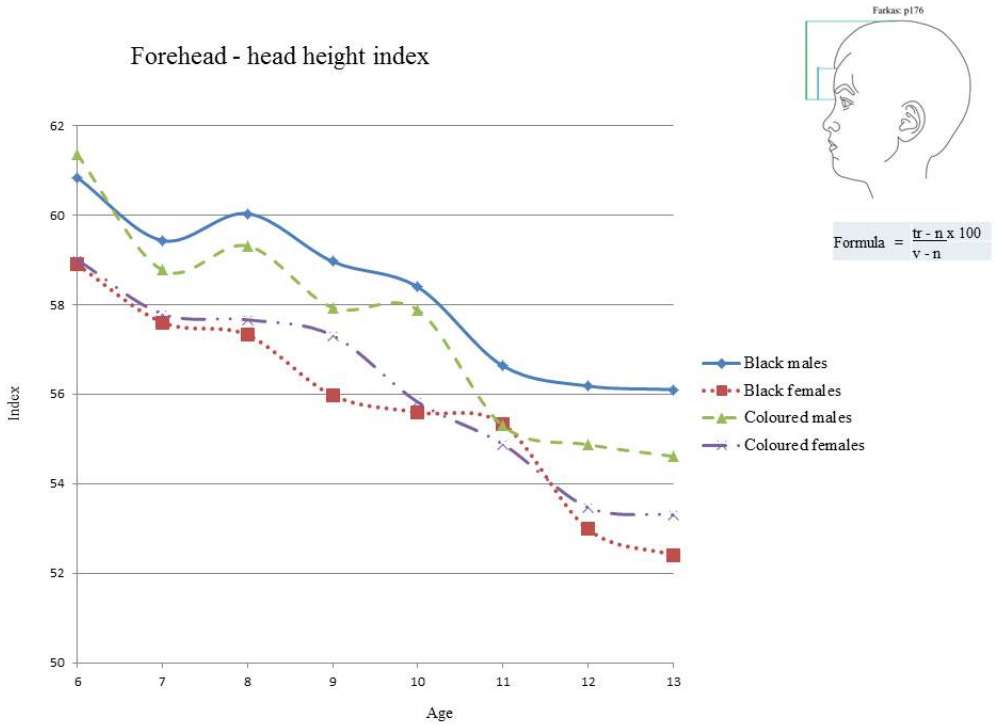

Figure 5.12: Progression of the forehead – head height index from age 6 to age 13 per sex and ancestry.

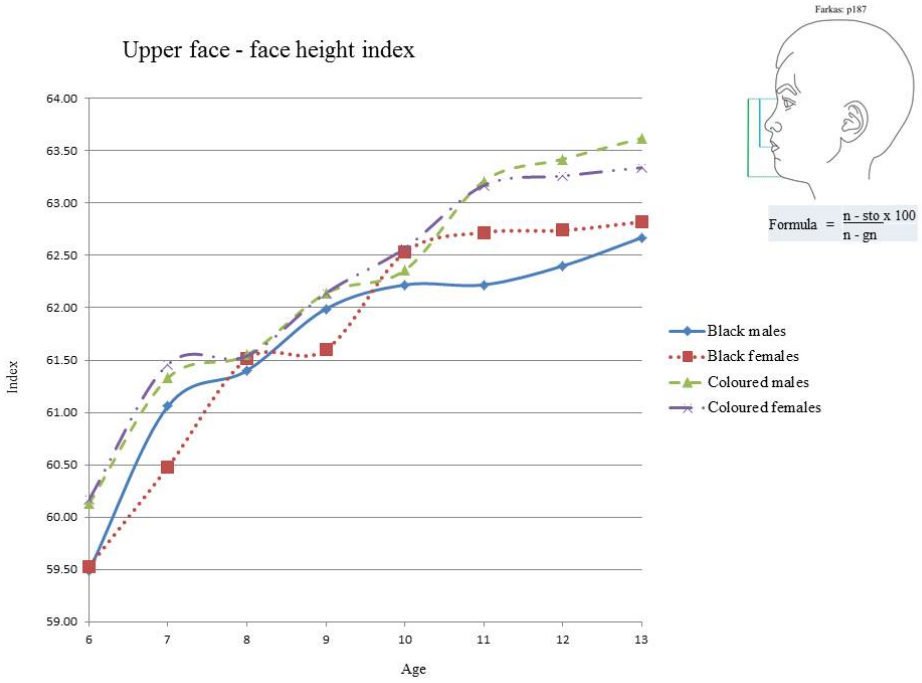

Figure 5.13: Progression of the upper face – face height index from age 6 to age 13 per sex and ancestry.

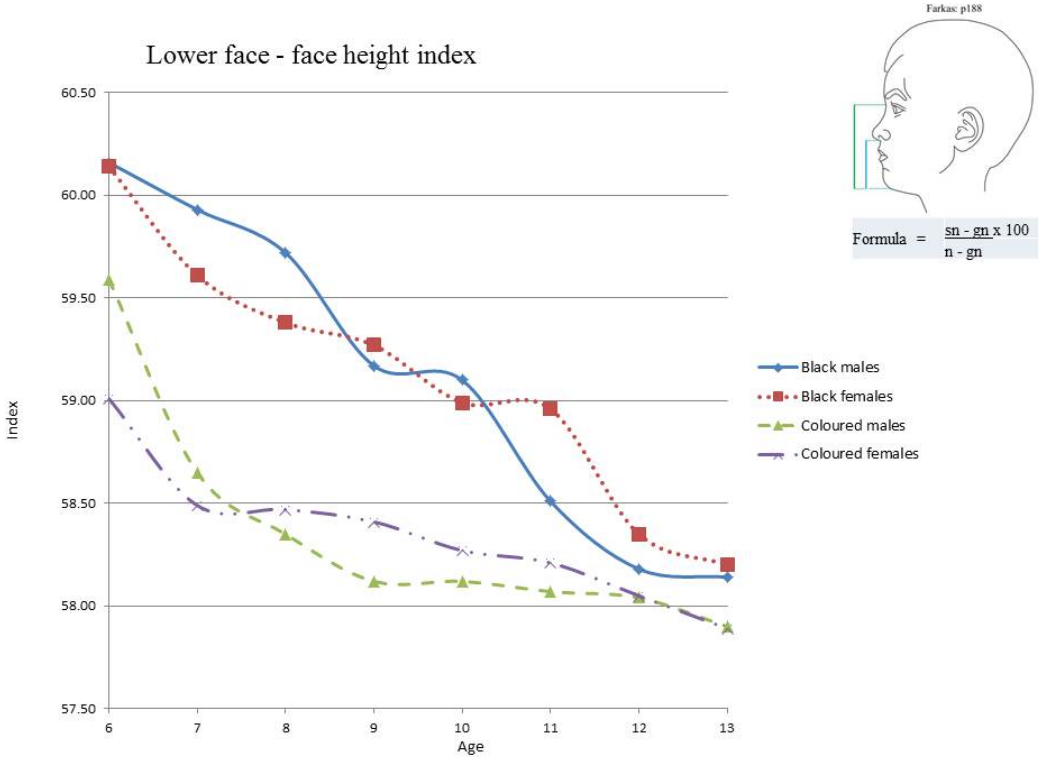

Figure 5.14: Progression of the lower face – face height index from age 6 to age 13 per sex and ancestry.

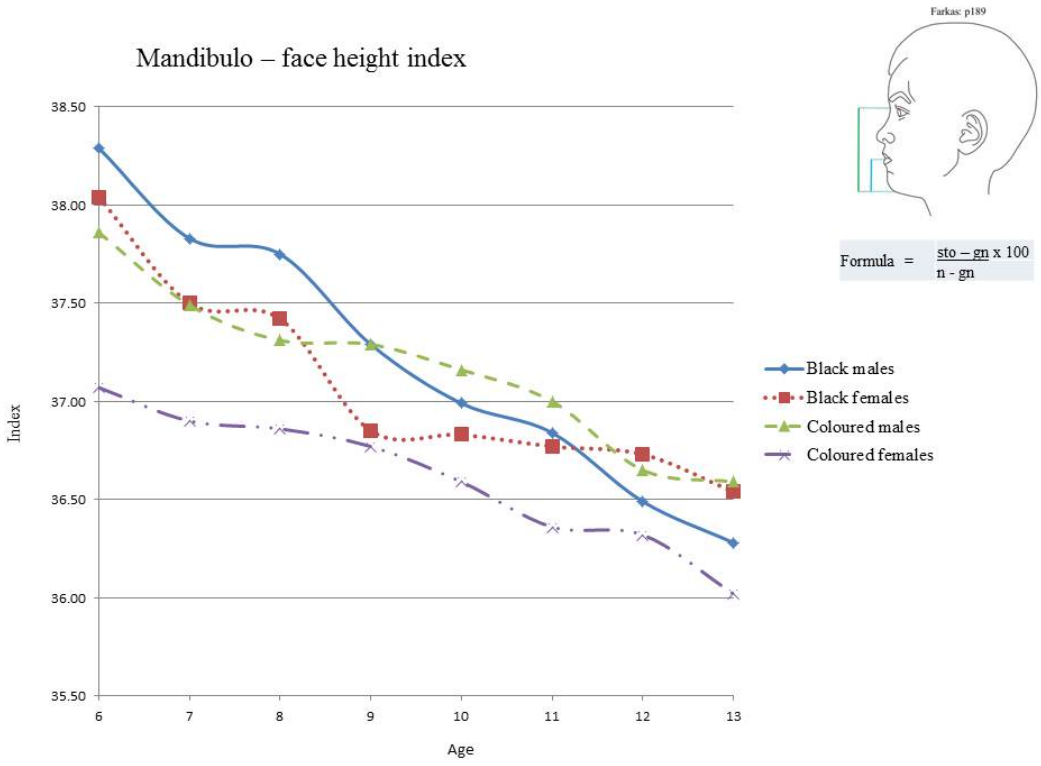

Figure 5.15: Progression of the mandibulo – face height index from age 6 to age 13 per sex and ancestry.

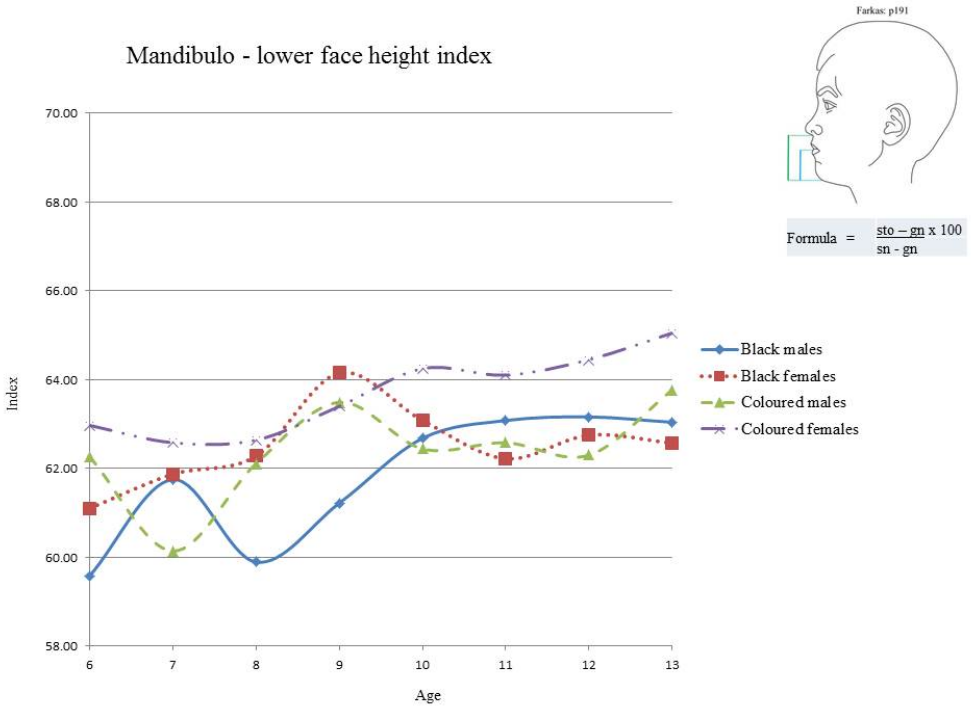

Figure 5.16: Progression of the mandibulo – lower face height index from age 6 to age 13 per sex and ancestry.

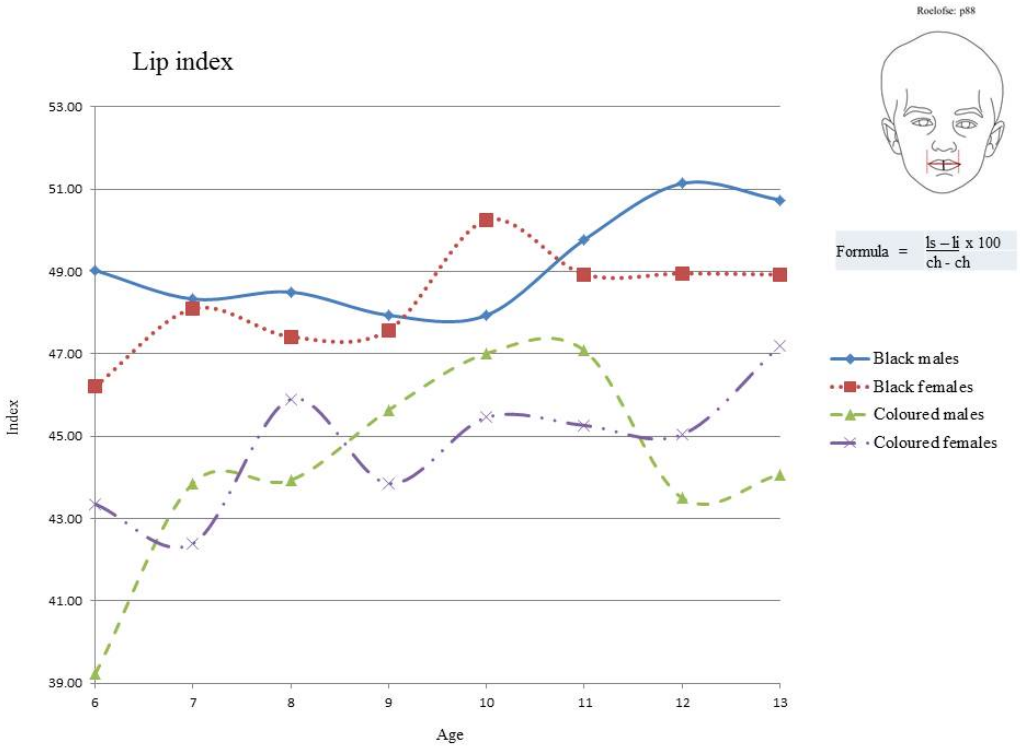

Figure 5.17: Progression of the lip index from age 6 to age 13 per sex and ancestry.

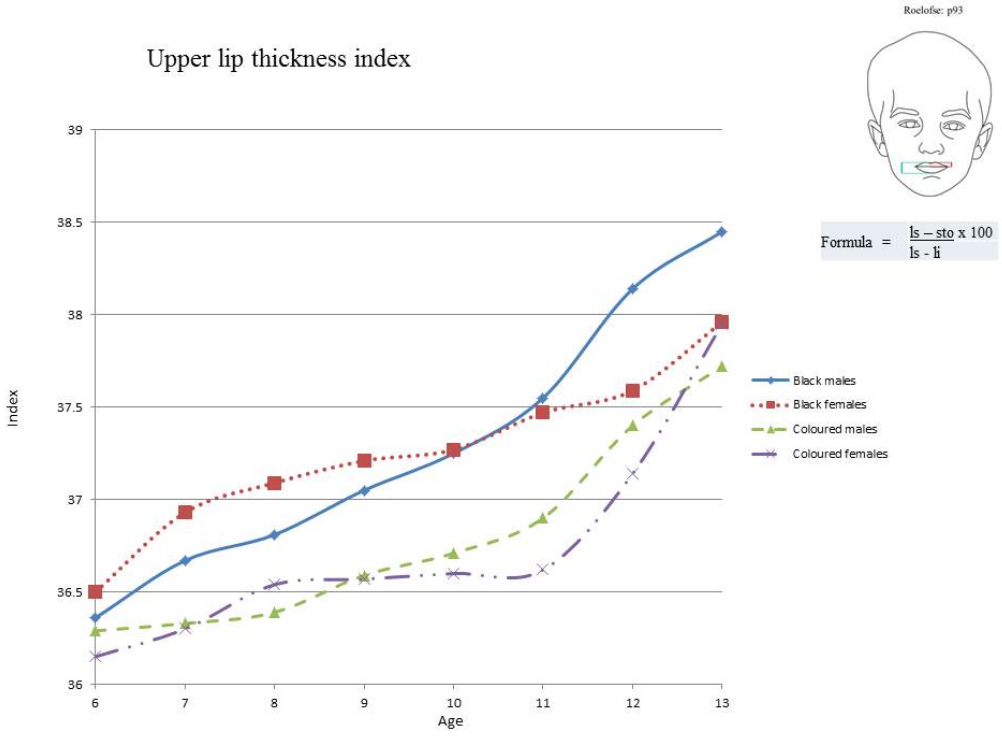

Figure 5.18: Progression of the upper lip thickness index from age 6 to age 13 per sex and ancestry.

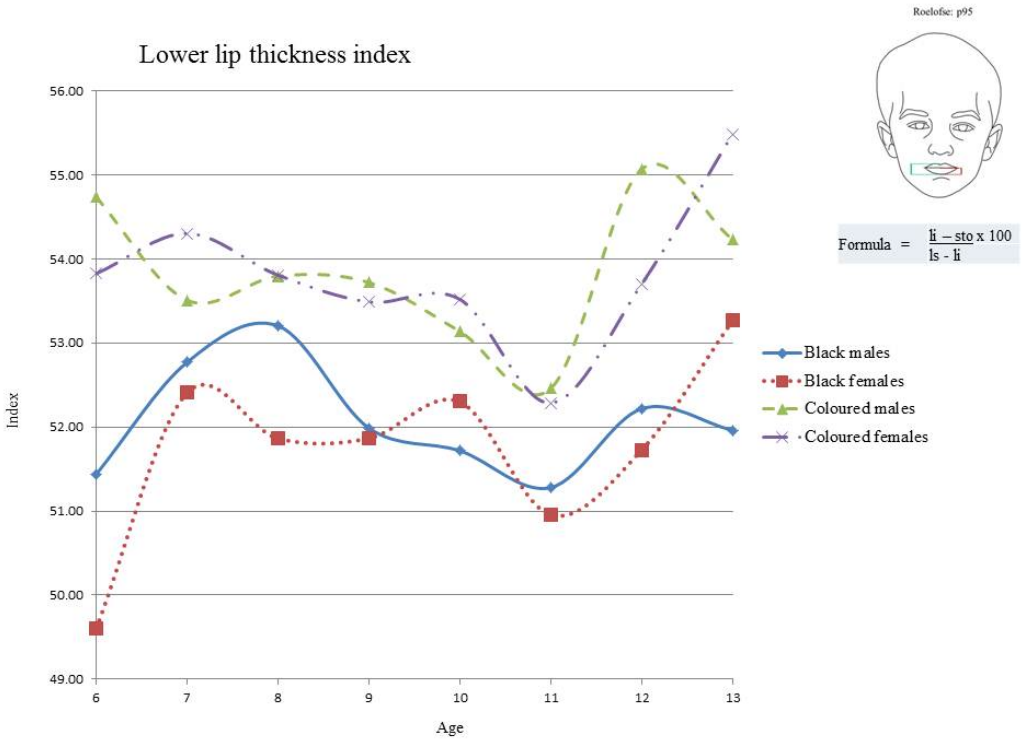

Figure 5.19: Progression of the lower lip thickness index from age 6 to age 13 per sex and ancestry.

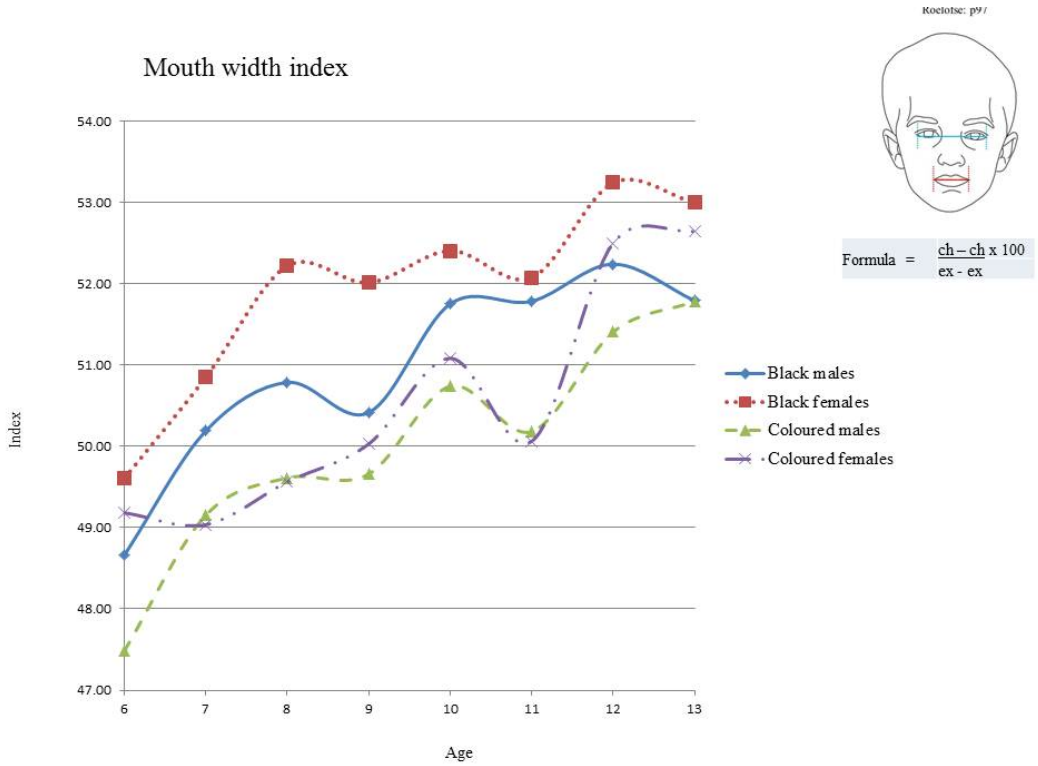

Figure 5.20: Progression of the mouth width index from age 6 to age 13 per sex and ancestry.

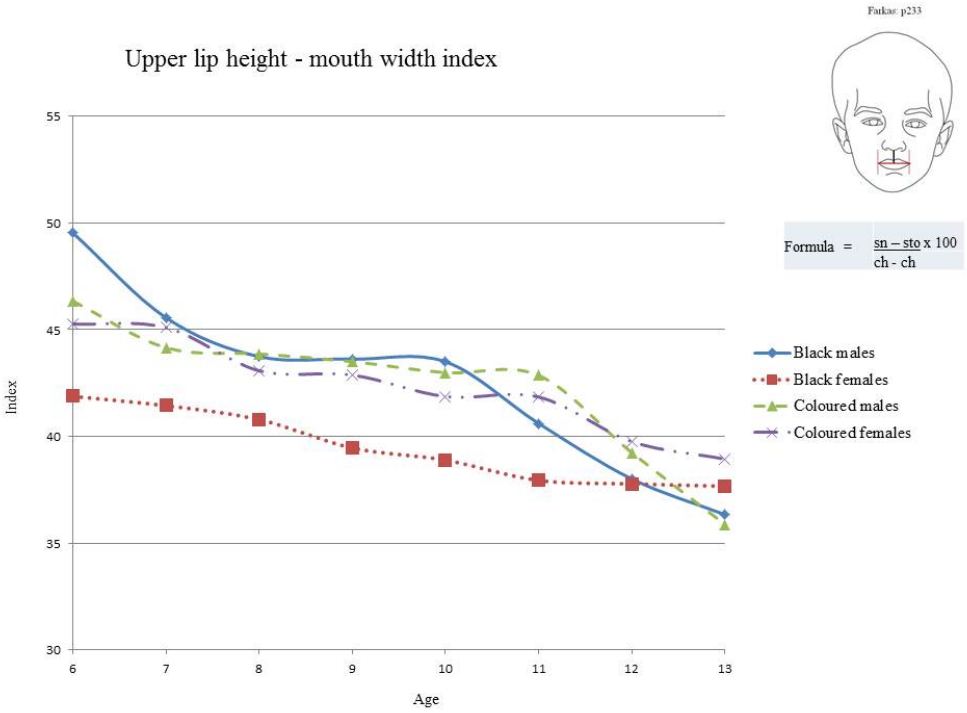

Figure 5.21: Progression of the upper lip height – mouth width index from age 6 to age 13 per sex and ancestry.

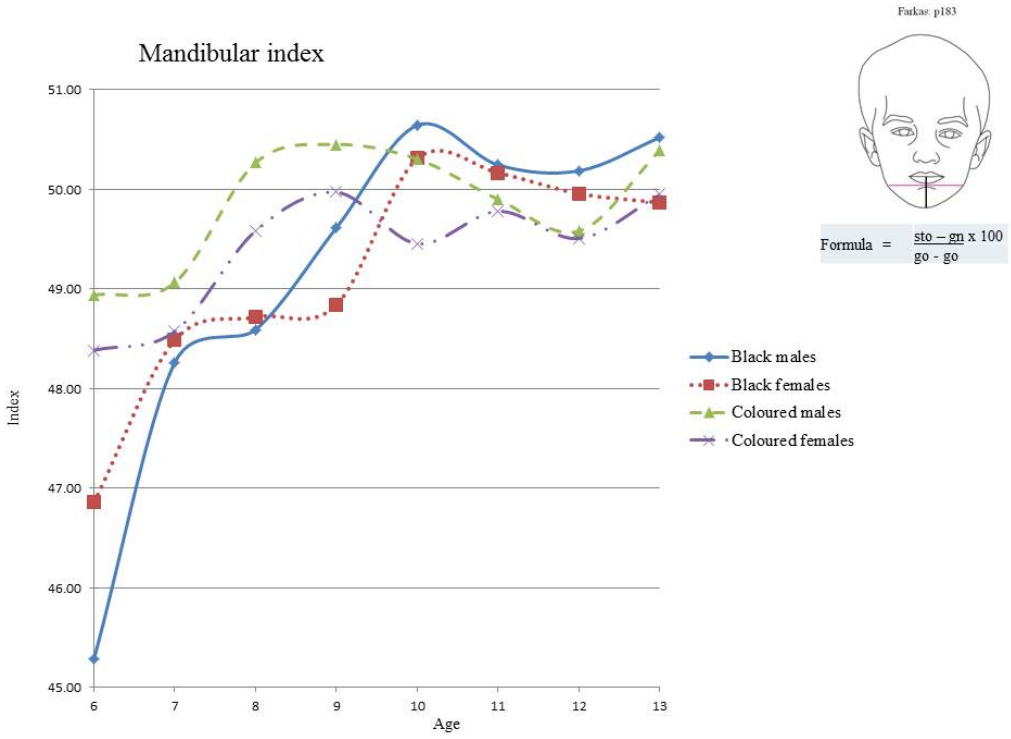

Figure 5.22: Progression of the mandibular index from age 6 to age 13 per sex and ancestry.

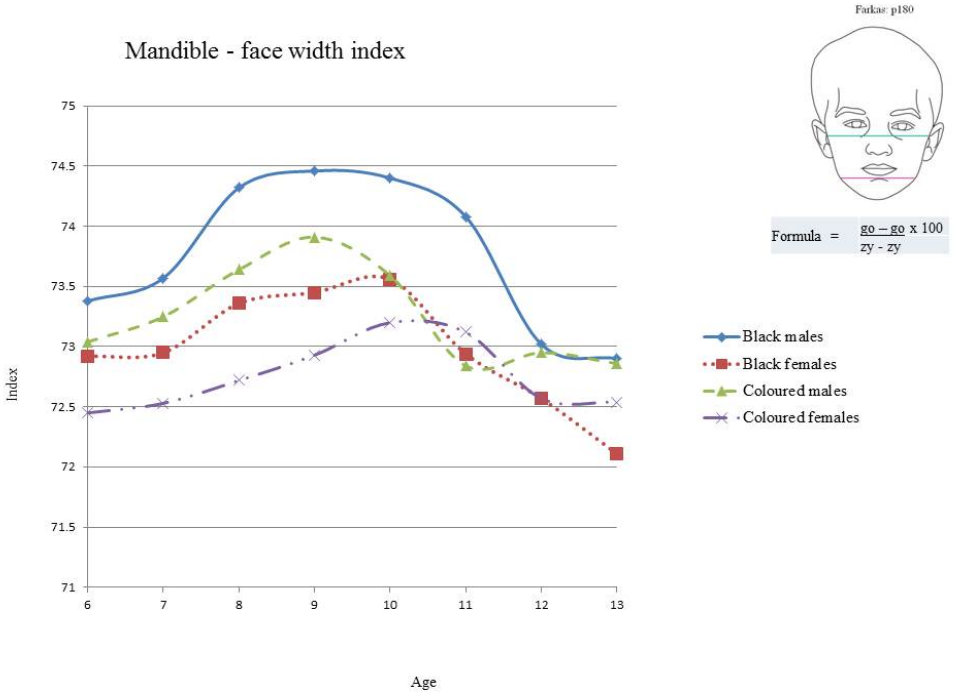

Figure 5.23: Progression of the mandible – face width index from age 6 to age 13 per sex and ancestry.

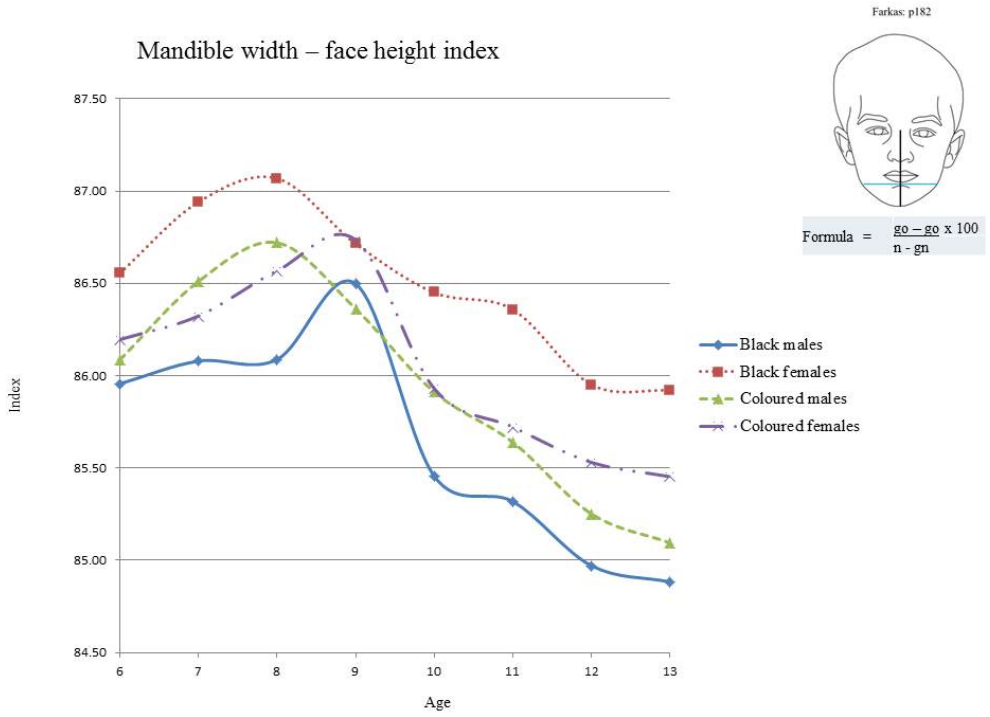

Figure 5.24: Progression of the mandible width face height index from age 6 to age 13 per sex and ancestry.

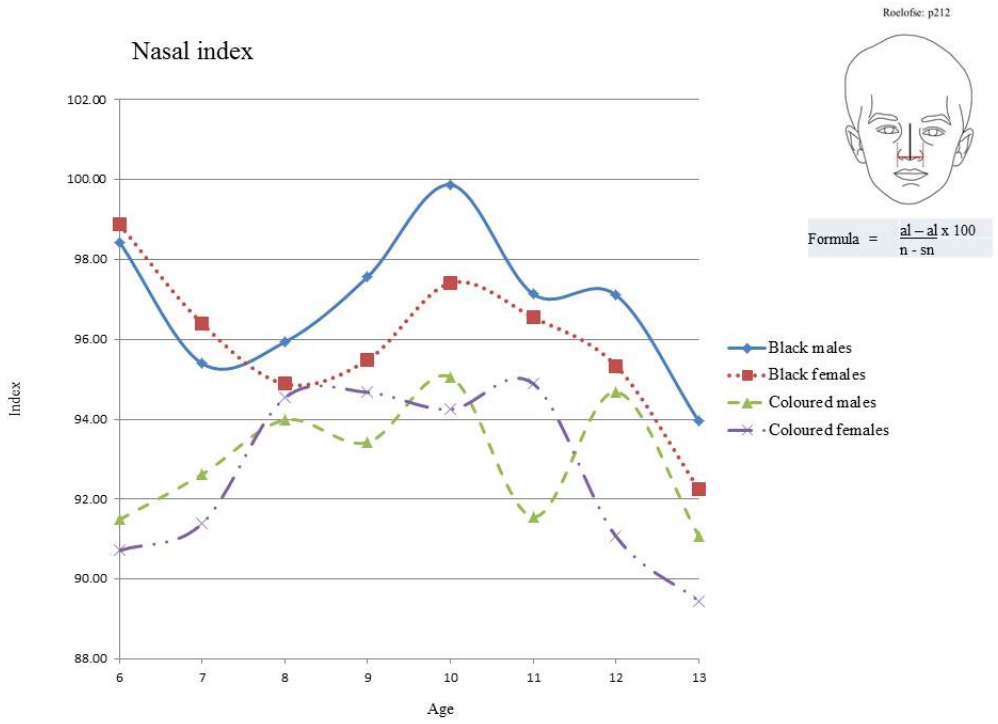

Figure 5.25: Progression of the nasal index from age 6 to age 13 per sex and ancestry.

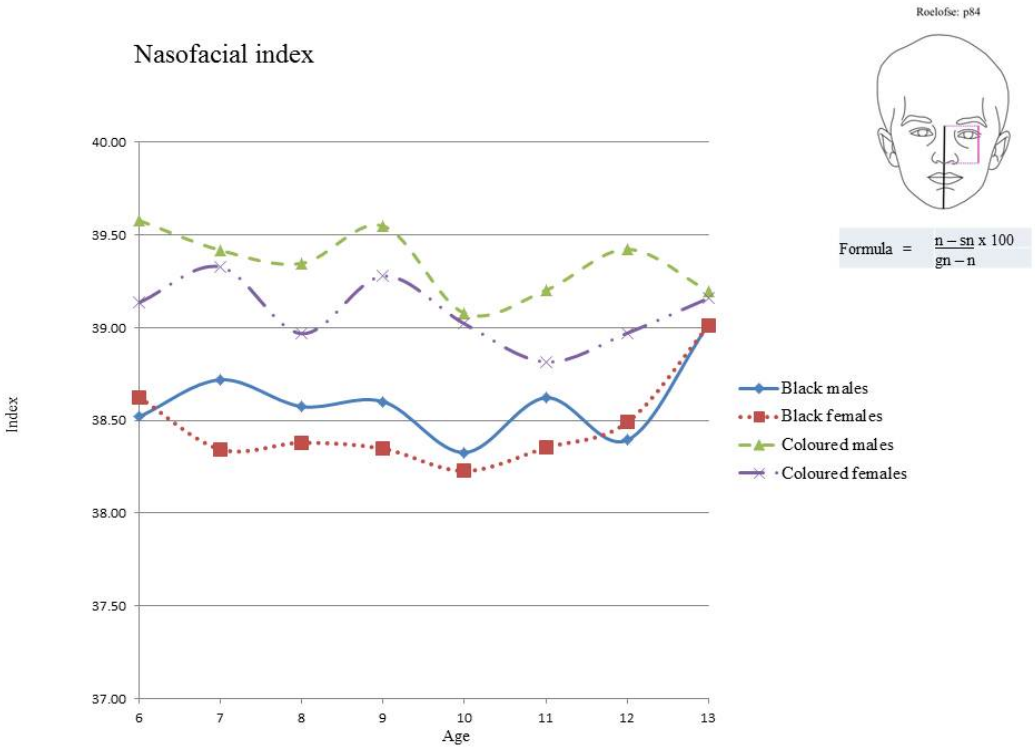

Figure 5.26: Progression of the nasofacial index from age 6 to age 13 per sex and ancestry.

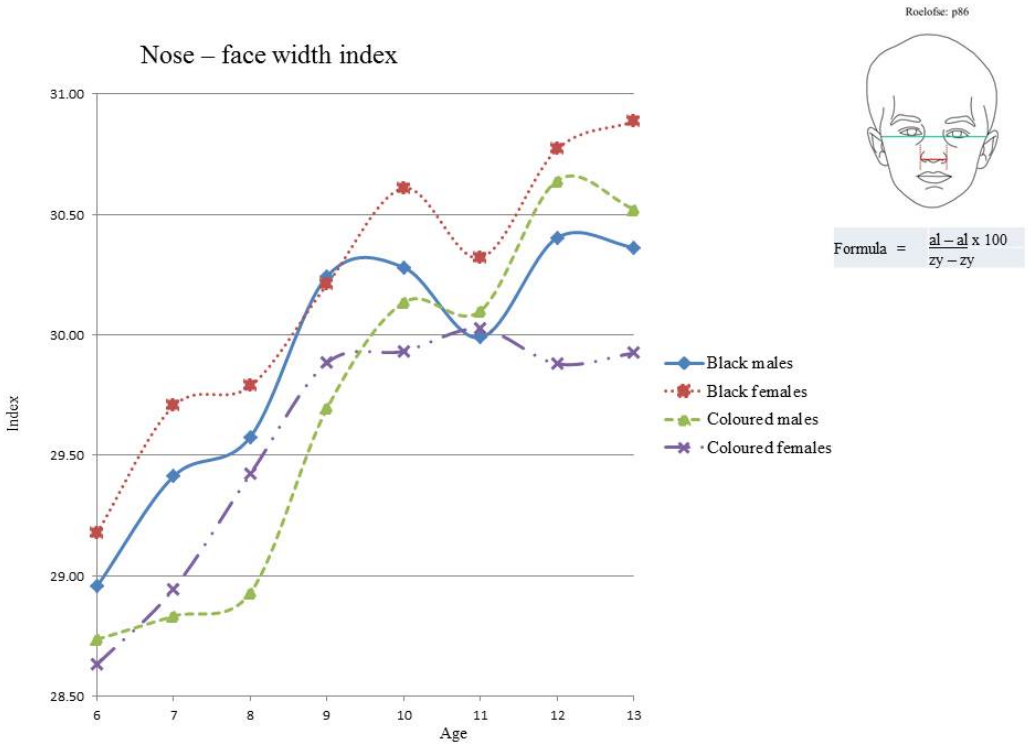

Figure 5.27: Progression of the nose – face width index from age 6 to age 13 per sex and ancestry.

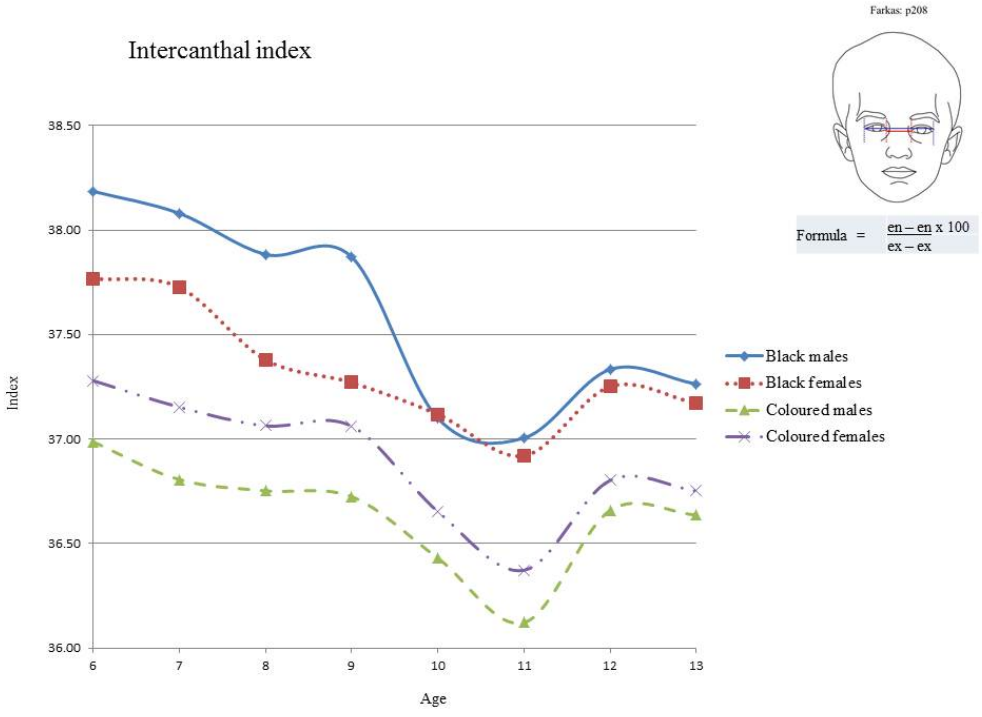

Figure 5.28: Progression of the intercanthal index from age 6 to age 13 per sex and ancestry.

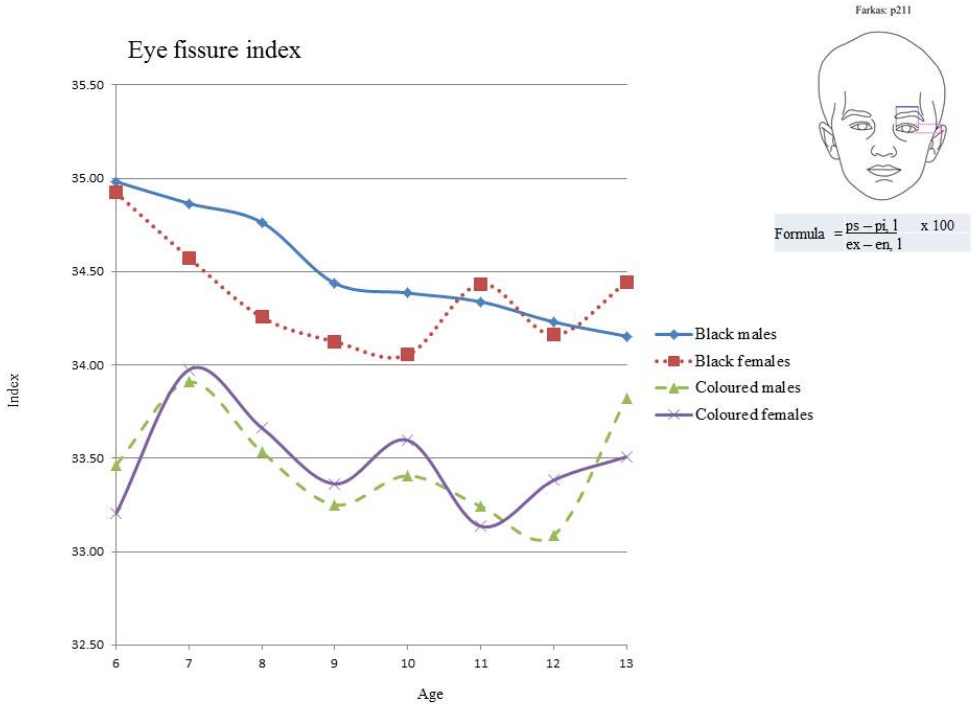

Figure 5.29: Progression of the eye fissure index from age 6 to age 13 per sex and ancestry.

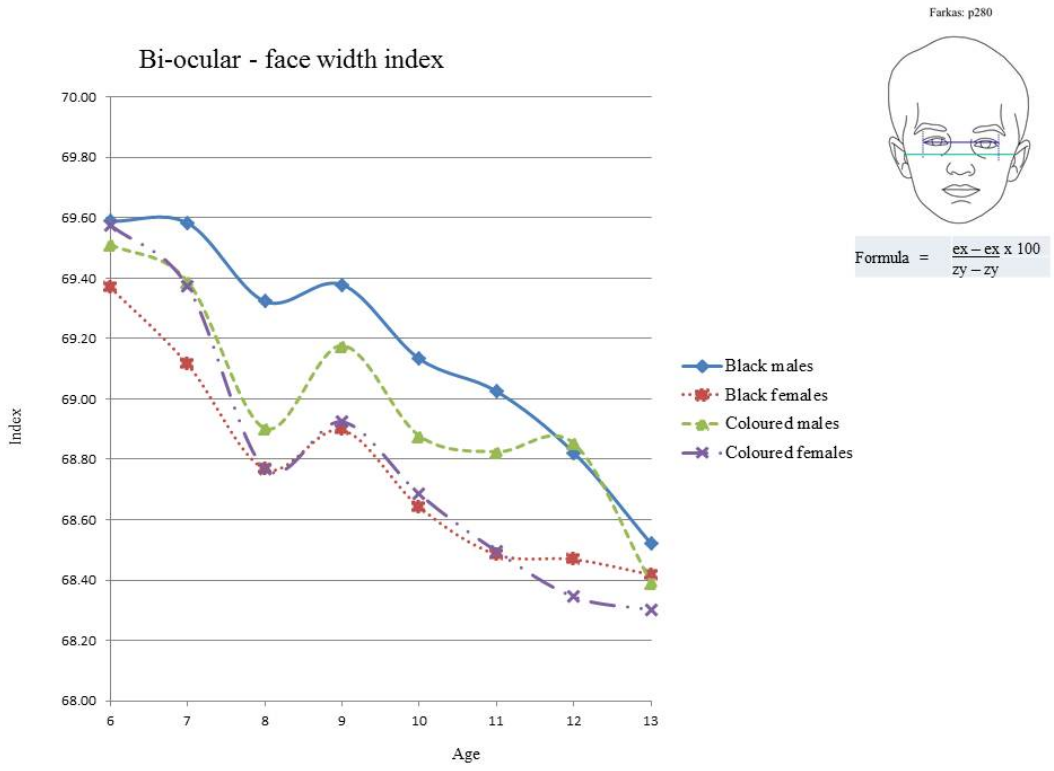

Figure 5.30: Progression of the bi-ocular – face width index from age 6 to age 13 per sex and ancestry.

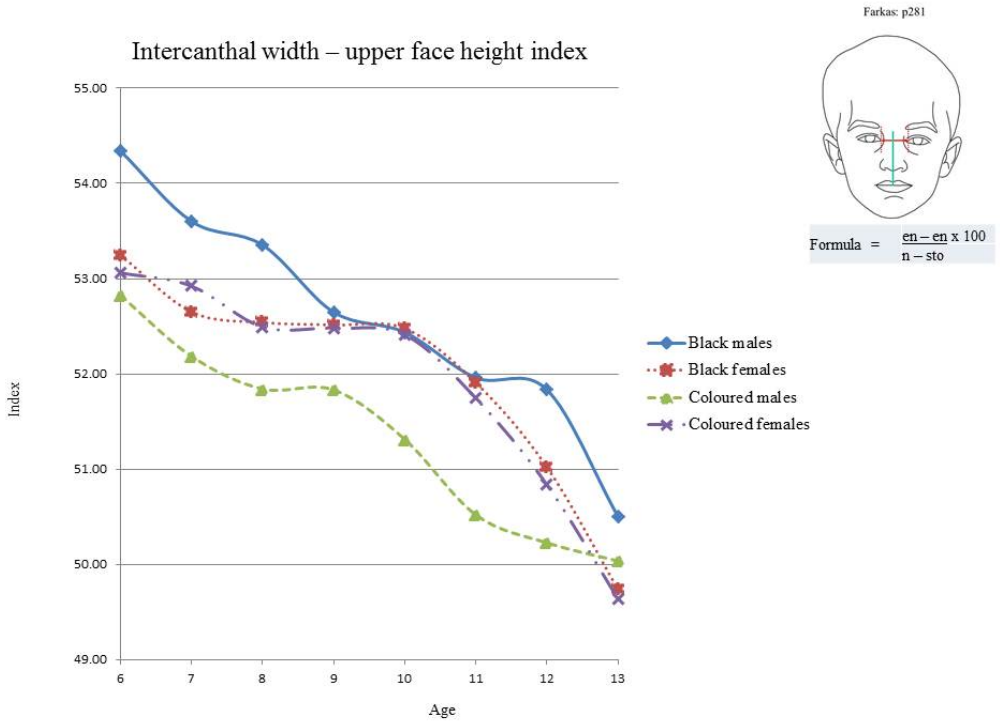

Figure 5.31: Progression of the intercanthal width upper face height index from age 6 to age 13 per sex and ancestry.

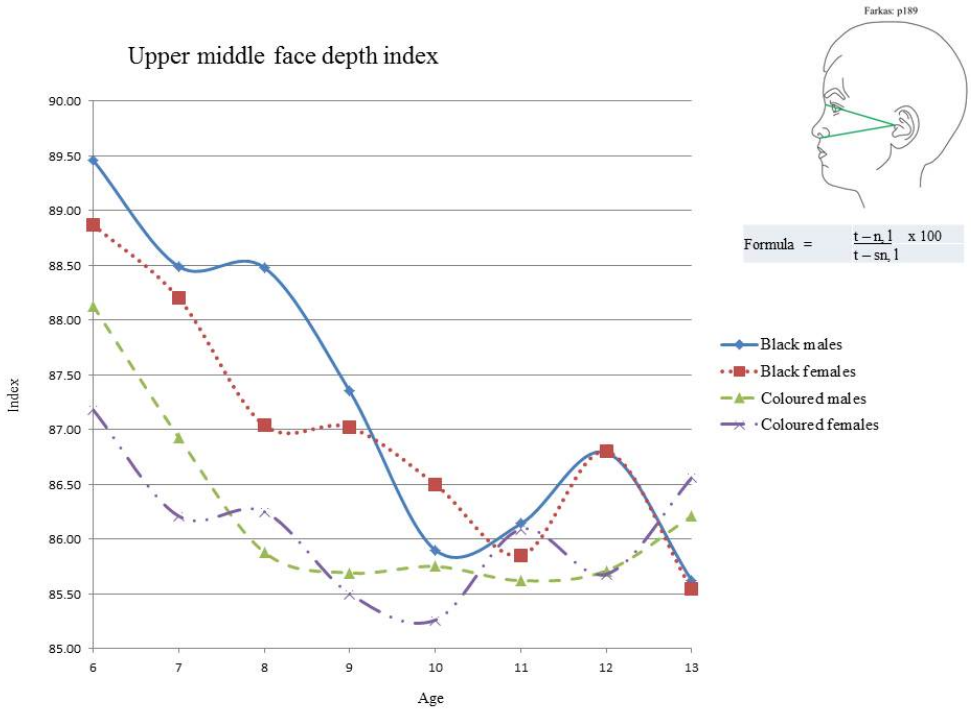

Figure 5.32: Progression of the upper middle face depth index from age 6 to age 13 per sex and ancestry.

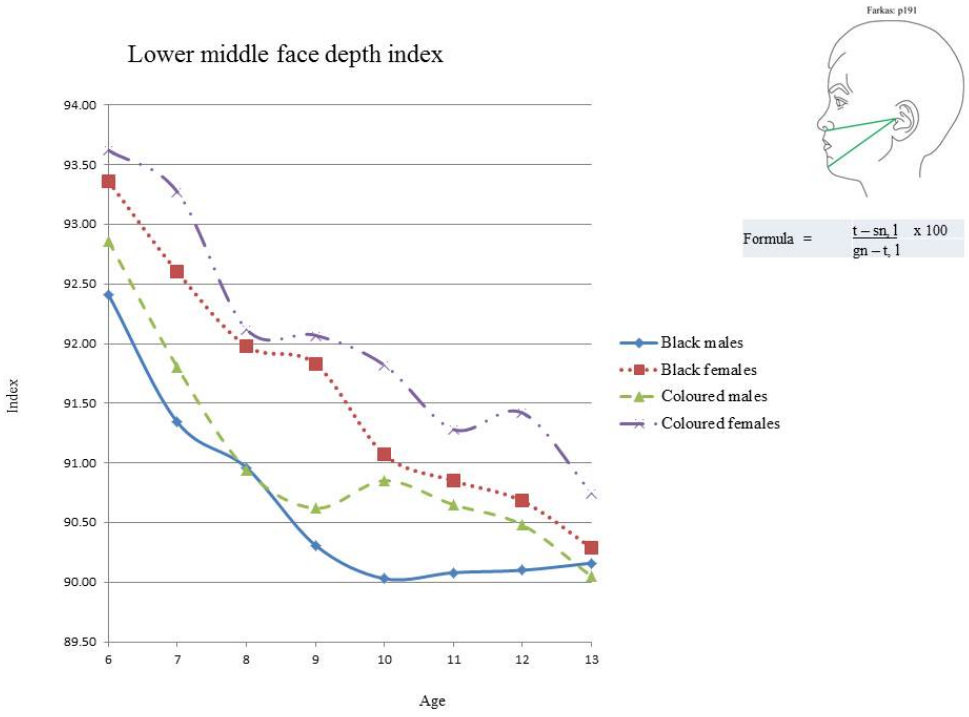

Figure 5.33: Progression of the lower middle face depth index from age 6 to age 13 per sex and ancestry.

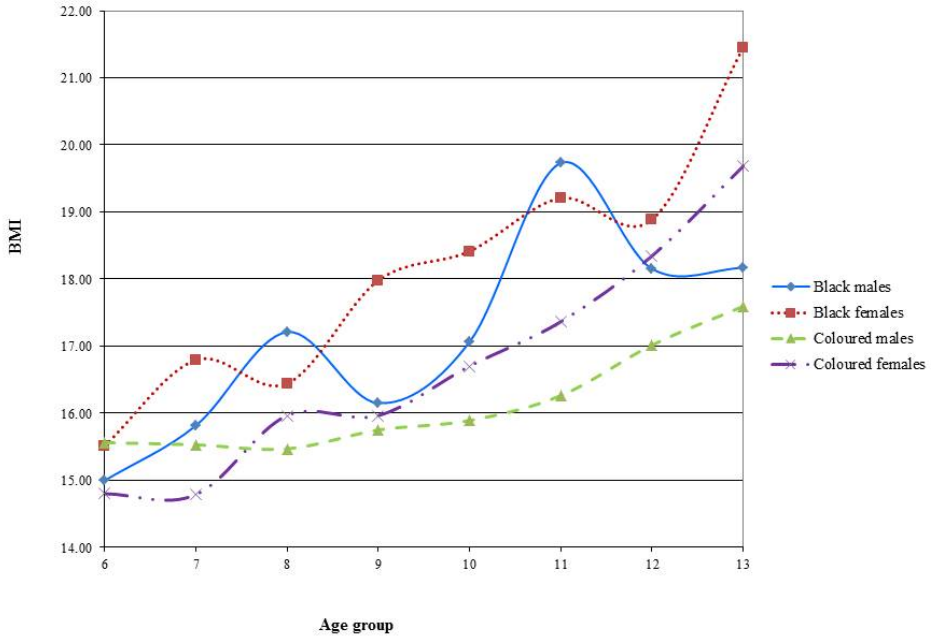

Figure 5.34: Mean BMI of Black male and Black female children and Coloured male and Coloured female children

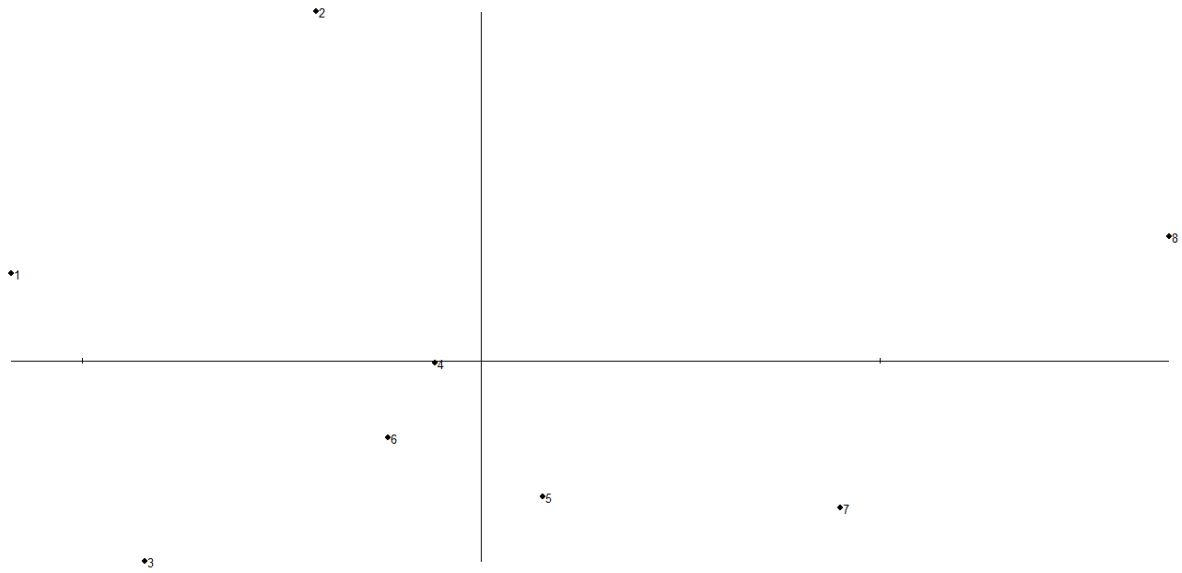

Figure 5.35: Relative warp analysis for all age groups.

Key:

1 = 6-year old group;

2 = 7-year old group;

3 = 8-year old group;

4 = 9-year old group;

5 = 10-year old group;

6 = 11-year old group;

7 = 12 year old group;

8 = 13-year old group.

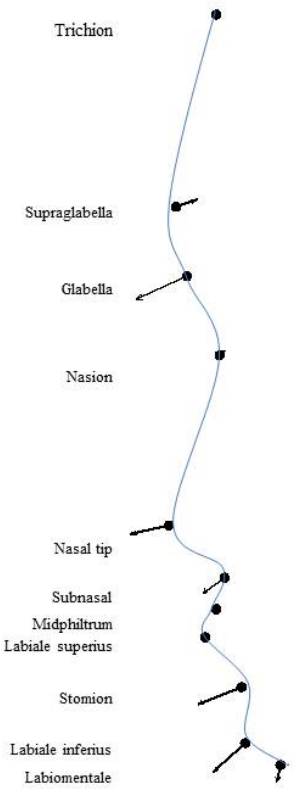

Figure 5.36: Vectors indicate the difference in lateral facial shape when pooling all age groups (6 – 13 years). The circles represent the landmarks of the 6 year old group and the end of the arrow the position of the same landmark in the13 year old group.

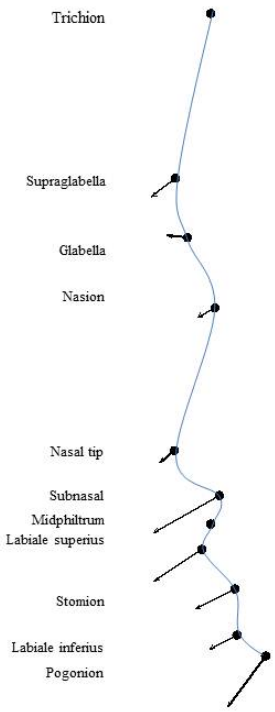

Figure 5.37: Vectors showing the difference in shape between 6 and 7 year old children. The circles represent the landmarks of the 6 year old group and the end of the arrow the position of the same landmark in the 7year old group.

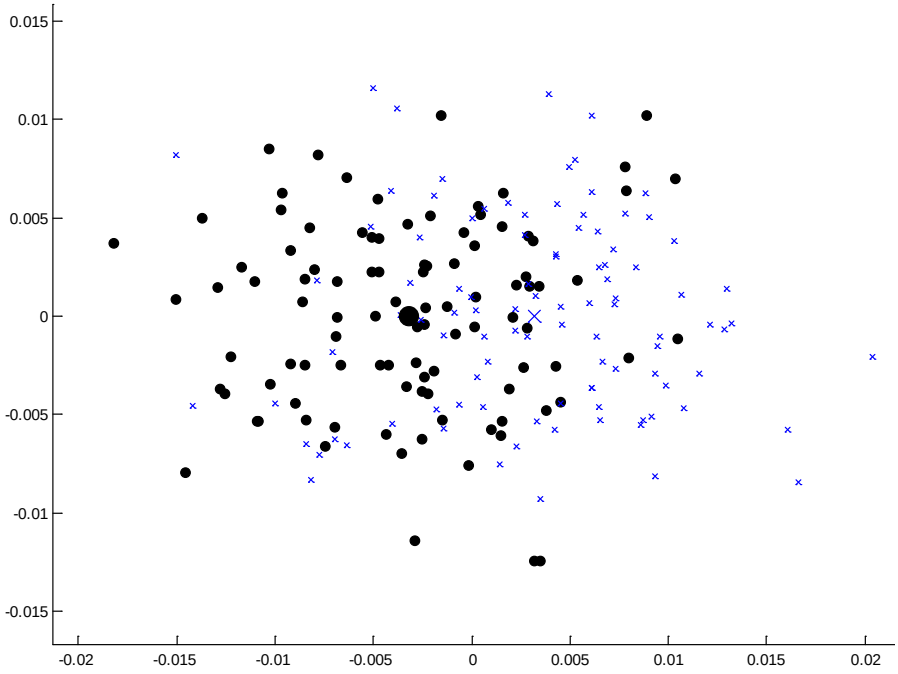

Figure 5.38: Mean CVA plot for the 6-year old (circles) and 7-year old (crosses) groups (sex and ancestry pooled). The mean shape for the 6-year old group is represented by the large circle and the mean shape for the 7-year old group is represented by the large cross.

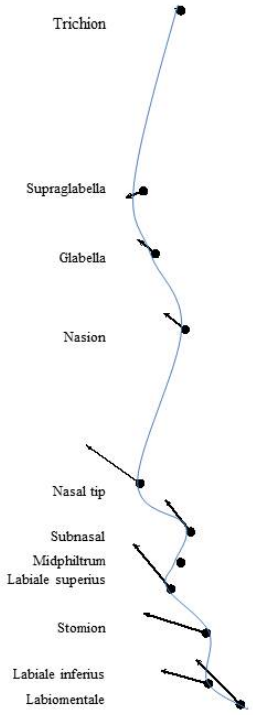

Figure 5.39: Vectors showing the difference in shape between 7 and 8 year old children. The circles represent the landmarks of the 7 year old group and the end of the arrow the position of the same landmark in the 8 year old group.

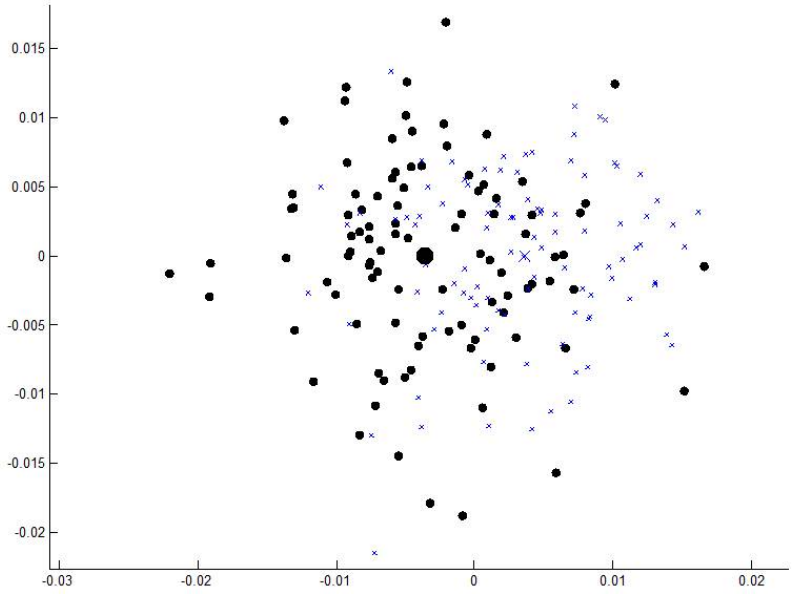

Figure 5.40: Mean CVA plot for the 7-year old (circles) and 8-year old (crosses) groups (sex and ancestry pooled). The mean shape for the 7-year old group is represented by the large circle and the mean shape for the 8-year old group is represented by the large cross.

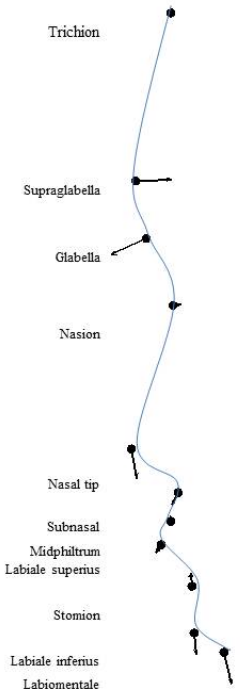

Figure 5.41: Vectors showing the difference in shape between 8 and 9 year old children. The circles represent the landmarks of the 8 year old group and the end of the arrow the position of the same landmark in the 9 year old group.

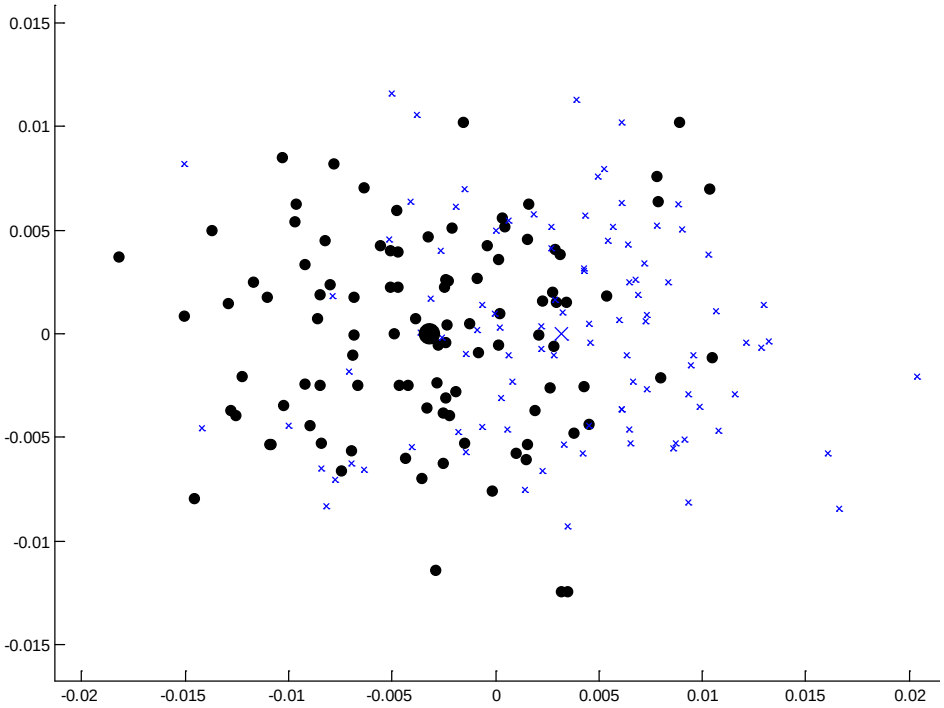

Figure 5.42: Mean CVA plot for the 8-year old (circles) and 9-year old (crosses) groups (sex and ancestry pooled). The mean shape for the 8-year old group is represented by the large circle and the mean shape for the 9-year old group is represented by the large cross.

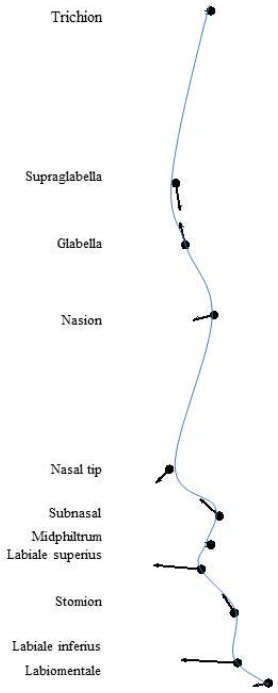

Figure 5.43: Vectors showing the difference in shape between 9 and 10 year old children. The circles represent the landmarks of the 9 year old group and the end of the arrow the position of the same landmark in the 10 year old group.

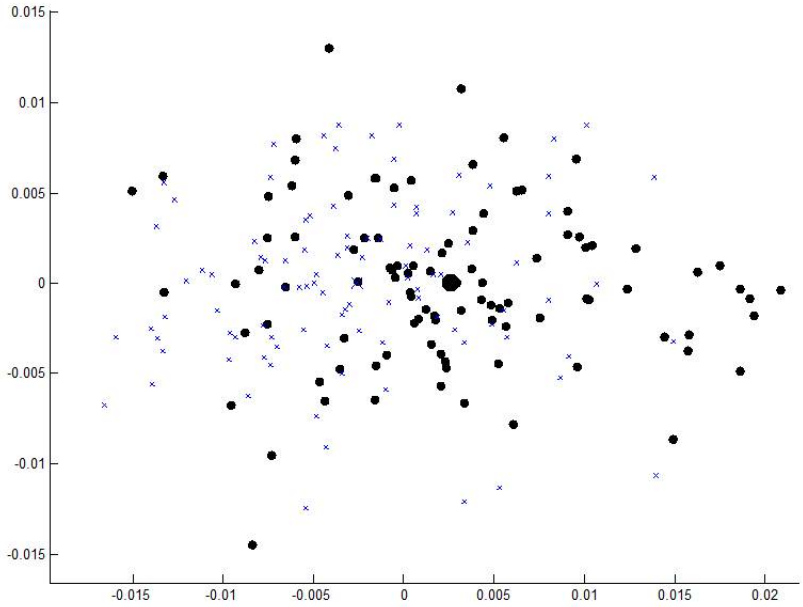

Figure 5.44: Mean CVA plot for the 9-year old (circles) and 10-year old (crosses) groups (sex and ancestry pooled). The mean shape for the 9-year old group is represented by the large circle and the mean shape for the 10-year old group is represented by the large cross.

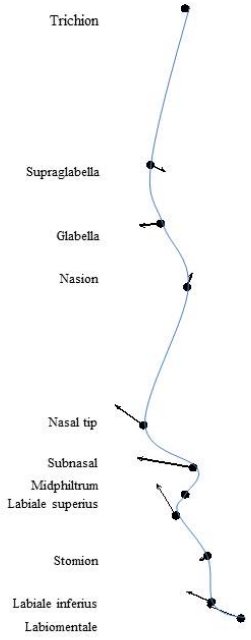

Figure 5.45: Vectors showing the difference in shape between 10 and 11 year old children. The circles represent the landmarks of the 10 year old group and the end of the arrow the position of the same landmark in the 11 year old group.

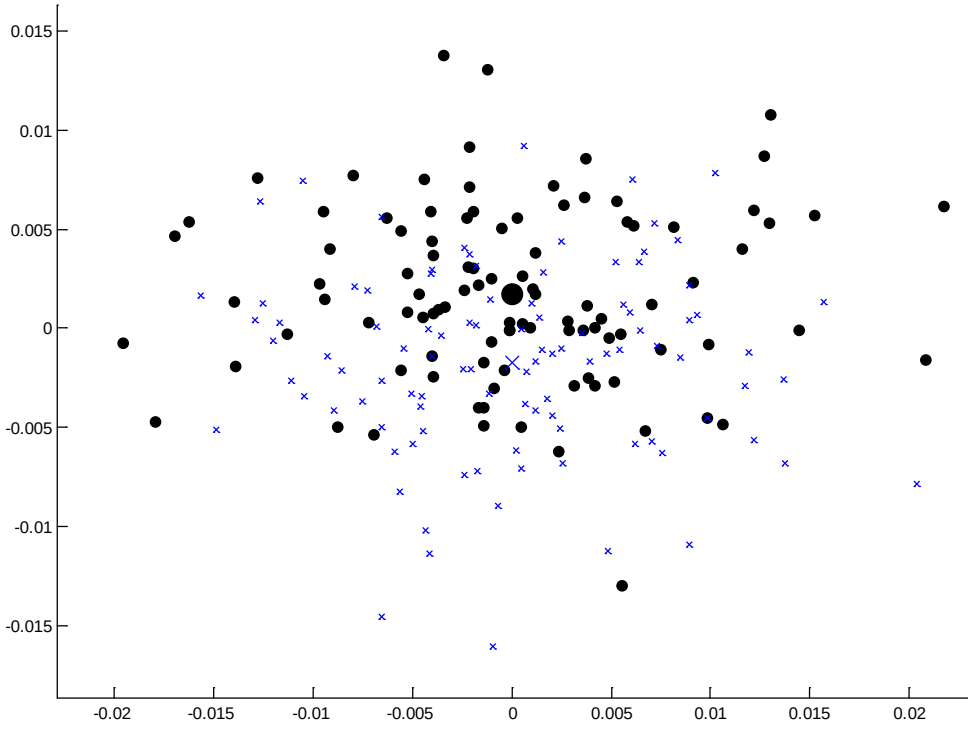

Figure 5.46: Mean CVA plot for the 10-year old (circles) and 11-year old (crosses) groups (sex and ancestry pooled). The mean shape for the 10-year old group is represented by the large circle and the mean shape for the 11-year old group is represented by the large cross.

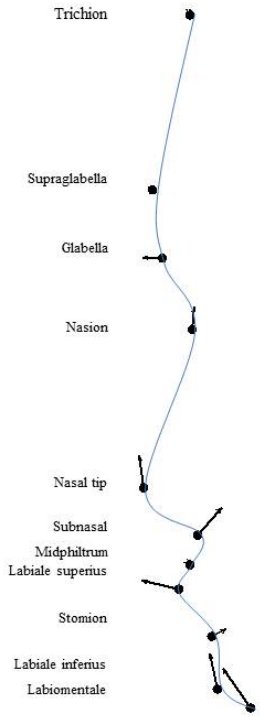

Figure 5.47: Vectors showing the difference in shape between 11 and 12 year old children. The circles represent the landmarks of the 11 year old group and the end of the arrow the position of the same landmark in the12 year old group.

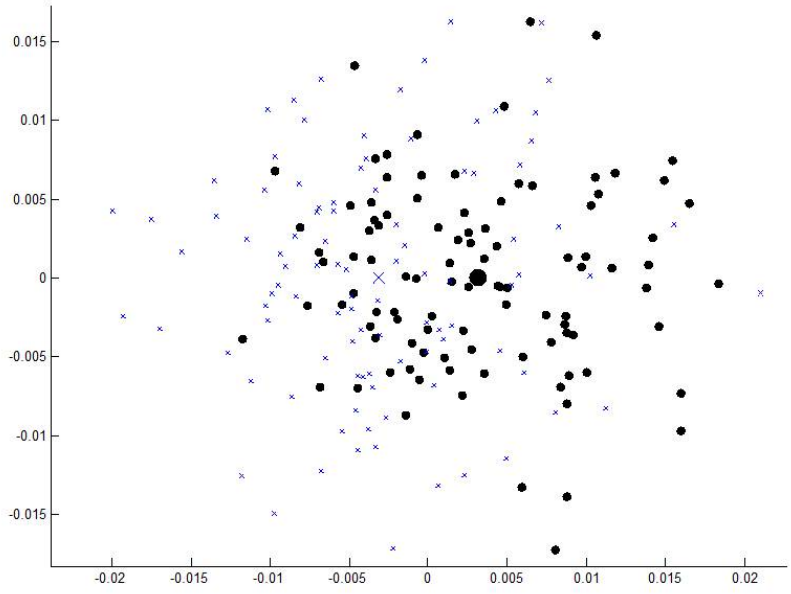

Figure 5.48: Mean CVA plot for the 11-year old (circles) and 12-year old (crosses) groups (sex and ancestry pooled). The mean shape for the 11-year old group is represented by the large circle and the mean shape for the 12-year old group is represented by the large cross.

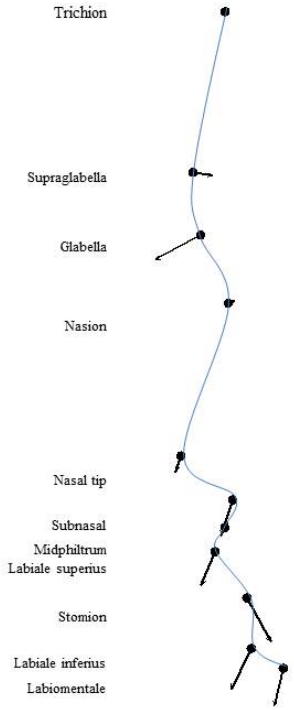

Figure 5.49: Vectors showing the difference in shape between 12 and 13 year old children. The circles represent the landmarks of the 12 year old group and the end of the arrow the position of the same landmark in the 13 year old group.

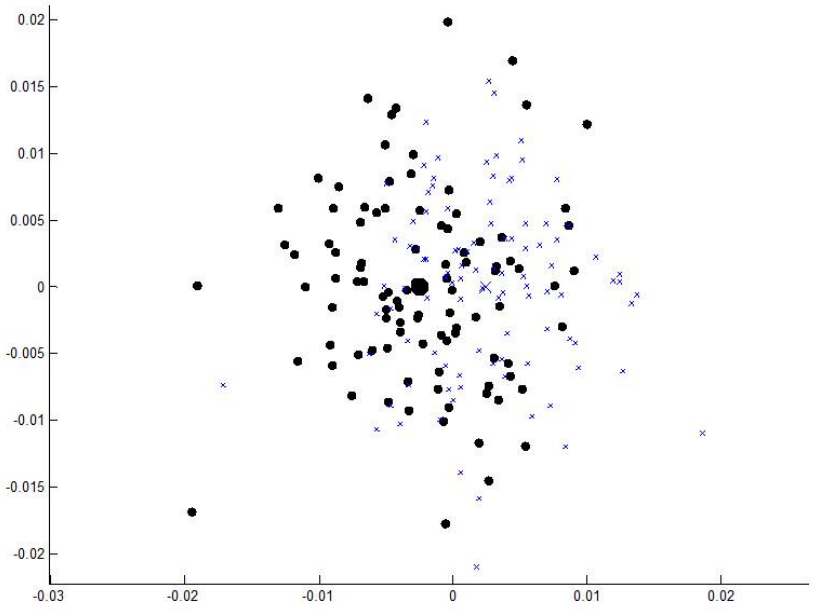

Figure 5.50: Mean CVA plot for the 12-year old (circles) and 13-year old (crosses) groups (sex and ancestry pooled). The mean shape for the 12-year old group is represented by the large circle and the mean shape for the 13-year old group is represented by the large cross.

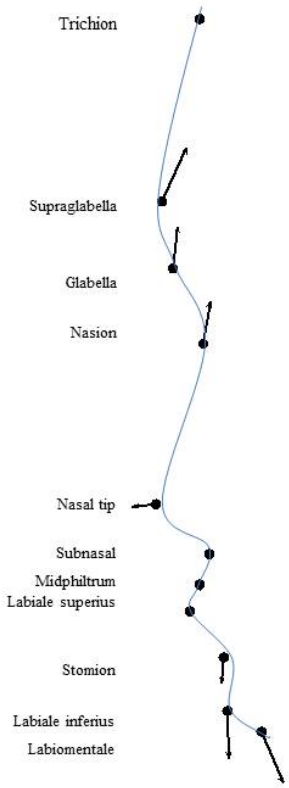

Figure 5.51: Vectors indicate the difference in lateral facial shape between males and females. The circles represent the landmarks of the females (n = 400) and the end of the arrow the position of the same landmark in the males (n = 400).

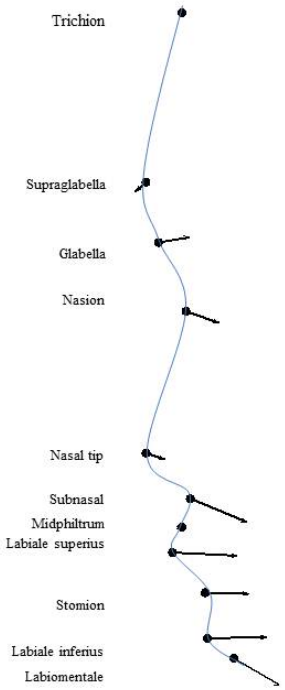

Figure 5.52: Vector plot for 6-year old males and 6-year old females (n=100). The circles represent the mean face shape of the 6-year old males and the arrows indicate the difference in face shape of 6-year old females from the males.

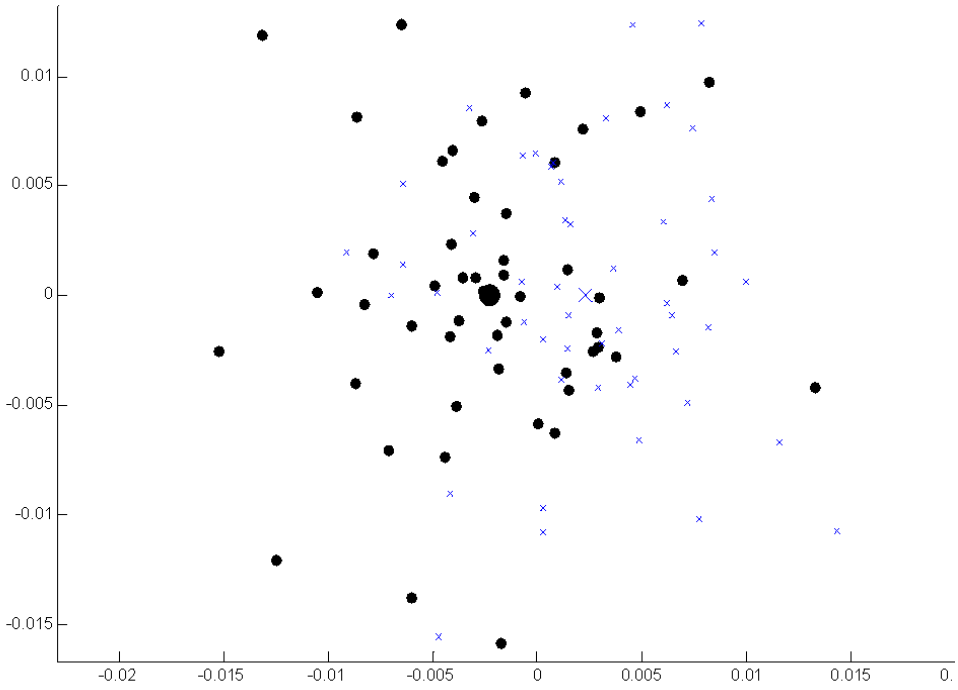

Figure 5.53: Mean CVA plot for the 6-year old males (circles) and females (crosses). The mean shape for males is represented by the large circle and the mean shape for females is represented by the large cross.

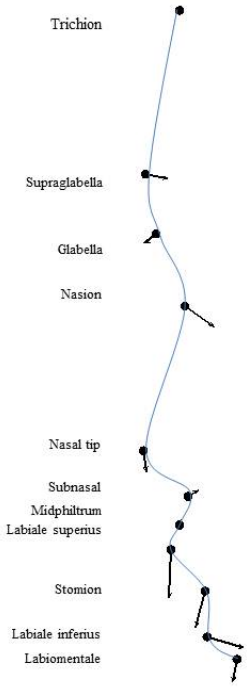

Figure 5.54: Vector plot for 7-year old males and 7-year old females (n=100). The circles represent the mean face shape of the 7-year old males and the arrows indicate the difference in face shape of 6-year old females from the males.

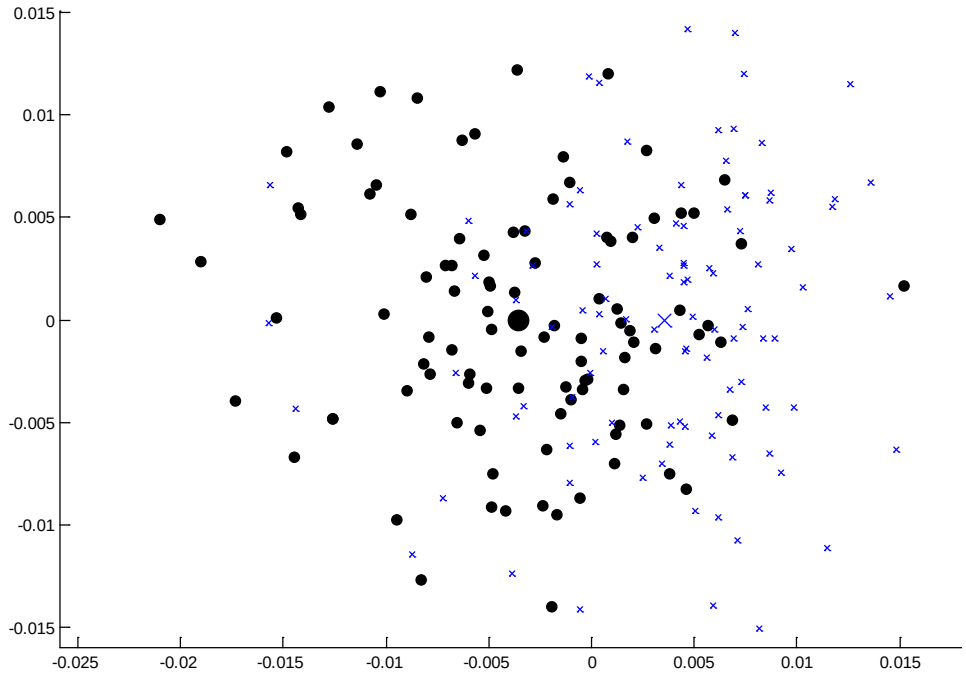

Figure 5.55 CVA plot for 7-year old males and 7-year old females (n=100). The mean shape for males is represented by the large circle and the mean shape for females is represented by the large cross.

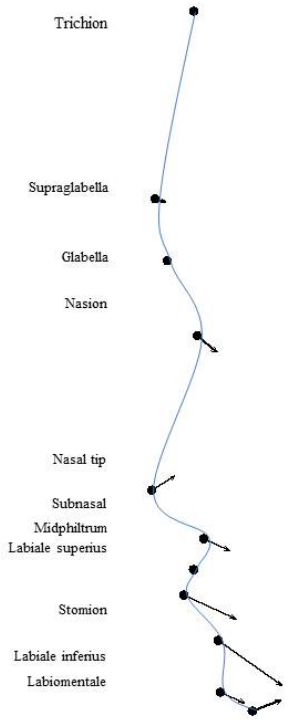

Figure 5.56: Vector plot for 8-year old males and 8-year old females (n=100). The circles represent the mean face shape of the 8-year old males and the arrows indicate the difference in face shape of 8-year old females from the males.

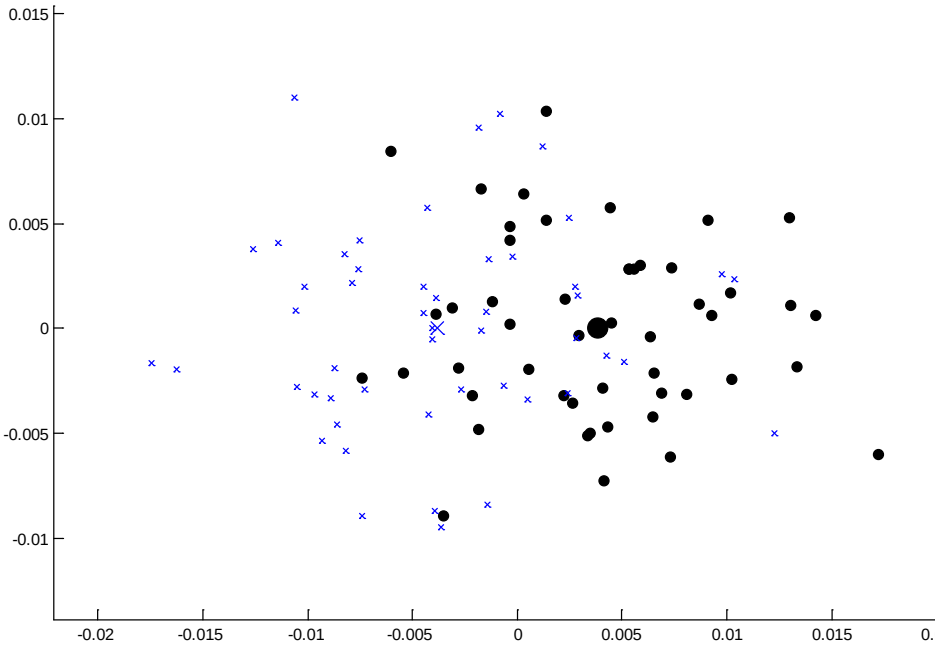

Figure 5.57: Mean CVA plot for the 8-year old males (circles) and females (crosses). The mean shape for males s represented by the large circle and the mean shape for females is represented by the large cross.

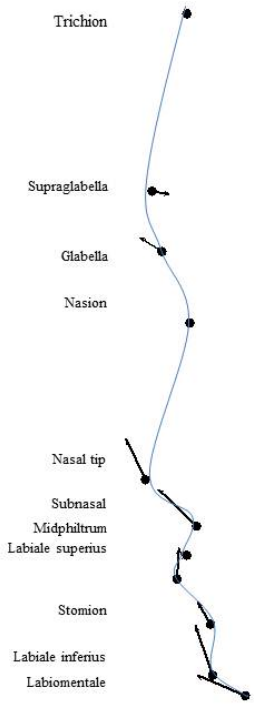

Figure 5.58: Vector plot for 9-year old males and 9-year old females (n=100). The circles represent the mean face shape of the 9-year old males and the arrows indicate the difference in face shape of 9-year old females from the males.

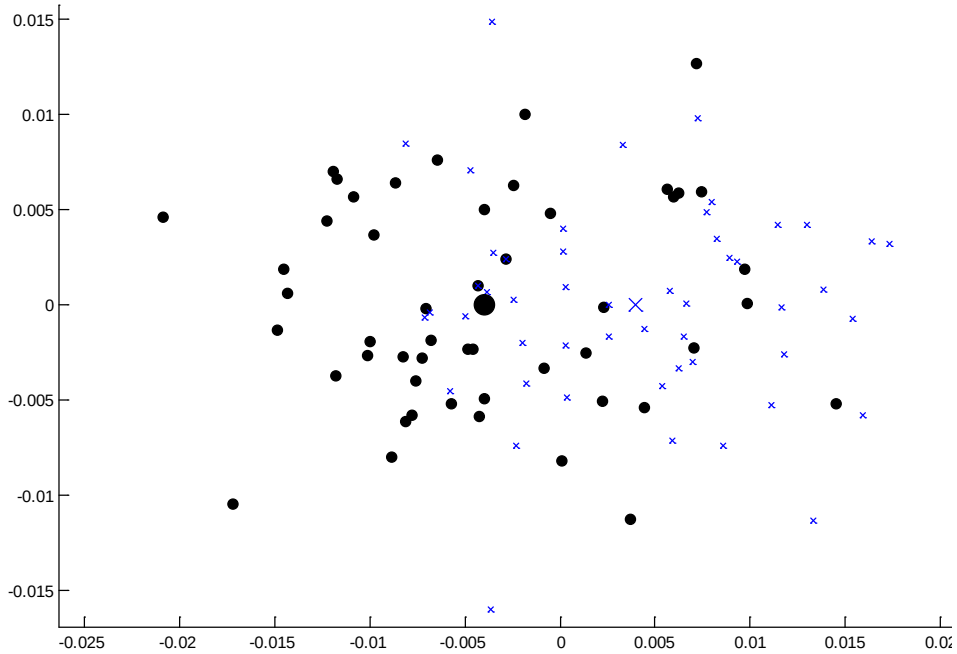

Figure 5.59: Mean CVA plot for the 9-year old males (circles) and females (crosses). The mean shape for males s represented by the large circle and the mean shape for females is represented by the large cross.

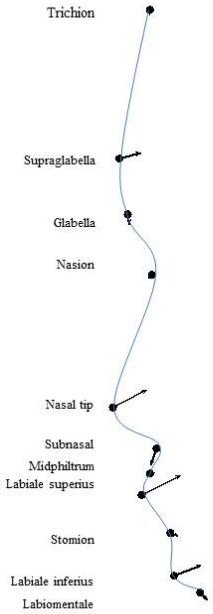

Figure 5.60: Vector plot for 10-year old males and 10-year old females (n=100). The circles represent the mean face shape of the 10-year old males and the arrows indicate the difference in face shape of 10-year old females from the males.

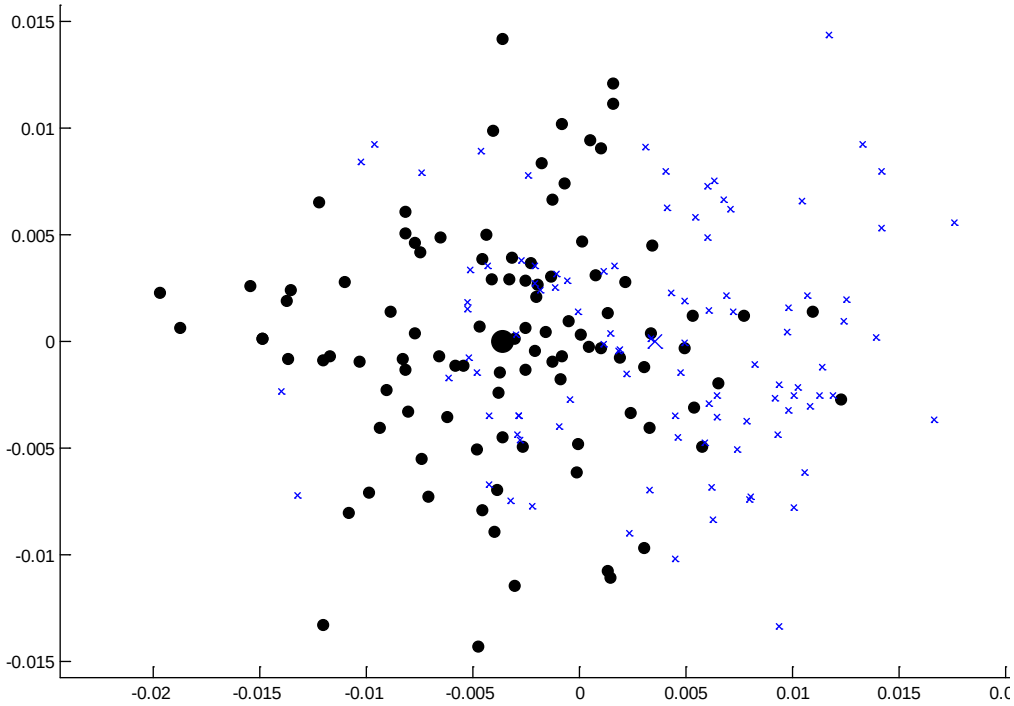

Figure 5.61: Mean CVA plot for the 10-year old males (circles) and females (crosses). The mean shape for males s represented by the large circle and the mean shape for females is represented by the large cross.

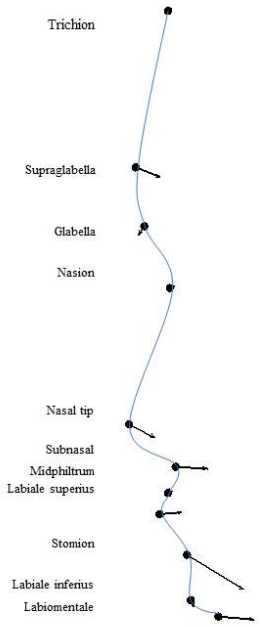

Figure 5.62: Vector plot for 11-year old males and 11-year old females (n=100). The circles represent the mean face shape of the 11-year old males and the arrows indicate the difference in face shape of 11-year old females from the males.

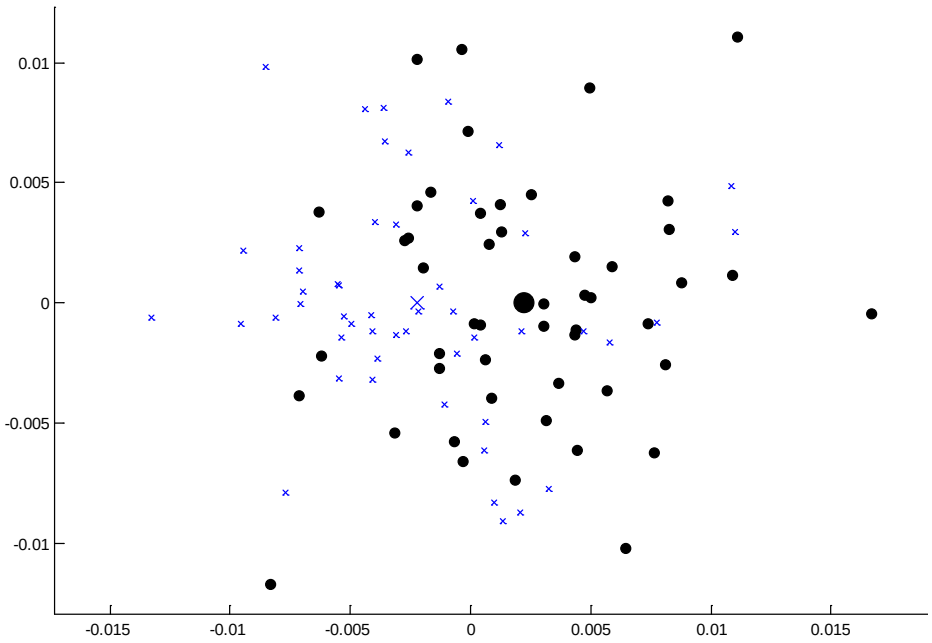

Figure 5.63: Mean CVA plot for the 11-year old males (circles) and females (crosses). The mean shape for males s represented by the large circle and the mean shape for females is represented by the large cross.

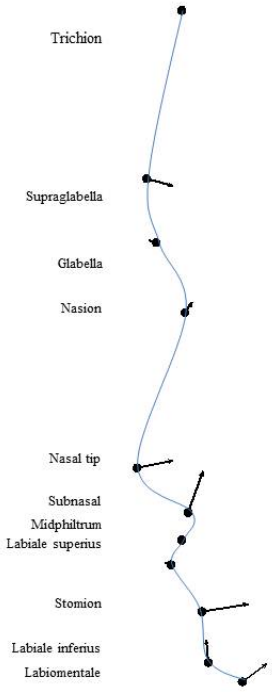

Figure 5.64: Vector plot for 12-year old males and 12-year old females (n=100). The circles represent the mean face shape of the 12-year old males and the arrows indicate the difference in face shape of 12-year old females from the males.

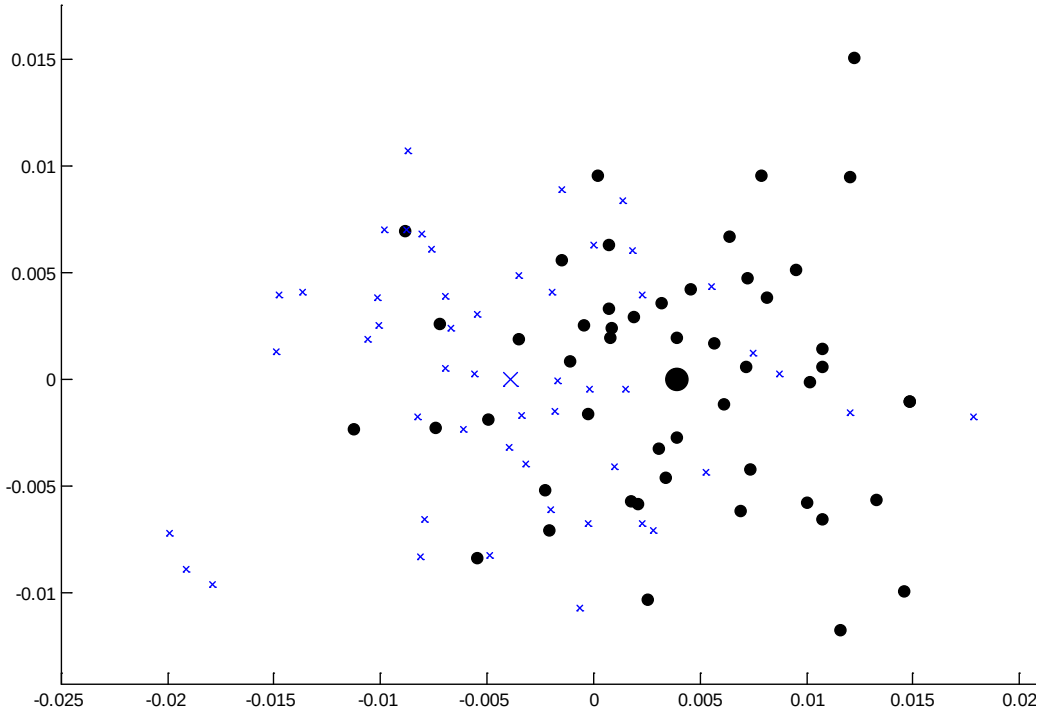

Figure 5.65: Mean CVA plot for the 12-year old males (circles) and females (crosses). The mean shape for males s represented by the large circle and the mean shape for females is represented by the large cross.

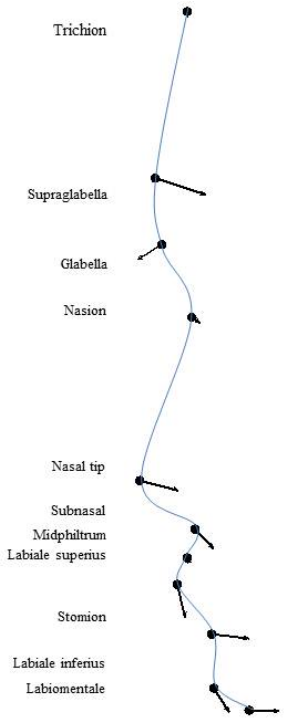

Figure 5.66: Vector plot for 13-year old males and 13-year old females (n=100). The circles represent the mean face shape of the 13-year old males and the arrows indicate the difference in face shape of 13-year old females from the males.

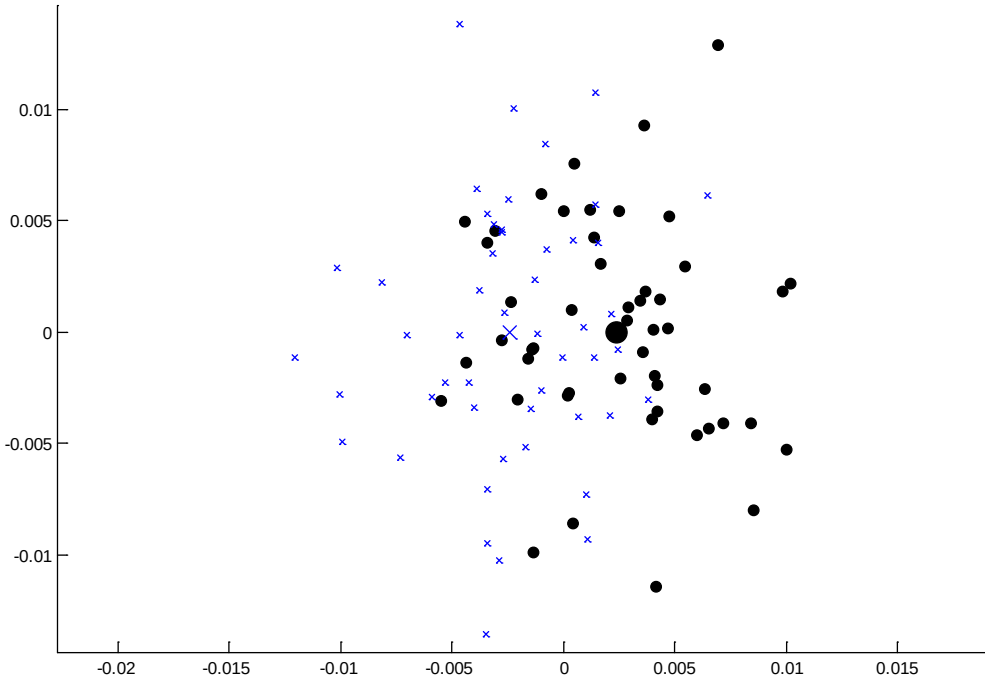

Figure 5.67: Mean CVA plot for the 13-year old males (circles) and females (crosses). The mean shape for males s represented by the large circle and the mean shape for females is represented by the large cross.

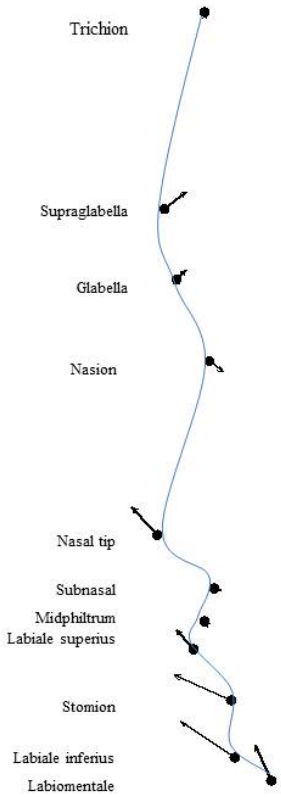

Figure 5.68: Vectors indicate the difference in lateral facial shape between Black and Coloured children. The circles represent the landmarks of the Coloured children (n = 400) and the end of the arrow the position of the same landmark in Black children (n = 400).

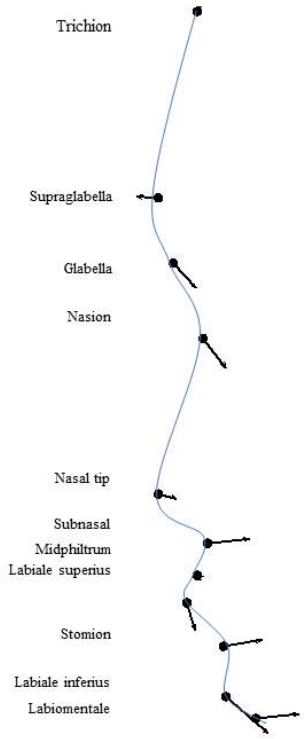

Figure 5.69: Vector plot for 6-year old Black children and 6-year old Coloured children (n=100). The circles represent the mean face shape of the 6-year old Black children and the arrows indicate the difference in face shape of 6-year old Coloured children from Black children.

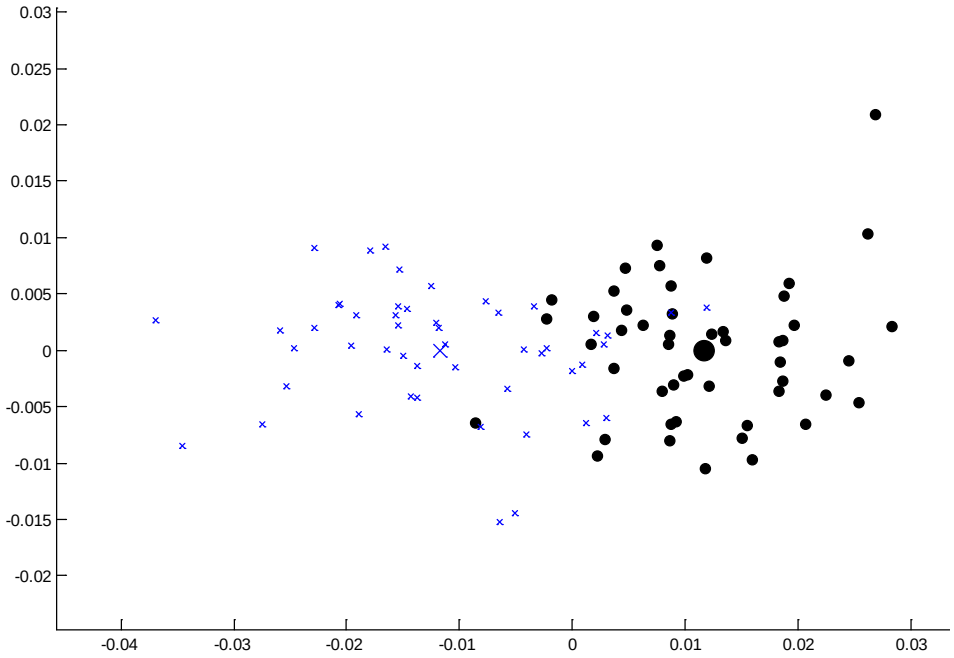

Figure 5.70: Mean CVA plot for the 6-year old Black children (circles) and 6-year old Coloured children (crosses). The mean shape for Black children is represented by the large circle and the mean shape for Coloured children is represented by the large cross.

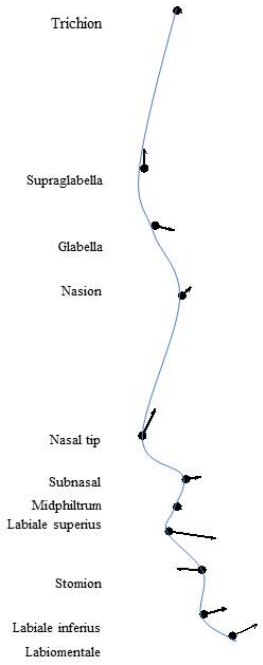

Figure 5.71: Vector plot for 7-year old Black children and 7-year old Coloured children (n=100). The circles represent the mean face shape of the 7-year old Black children and the arrows indicate the difference in face shape of 7-year old Coloured children from Black children.

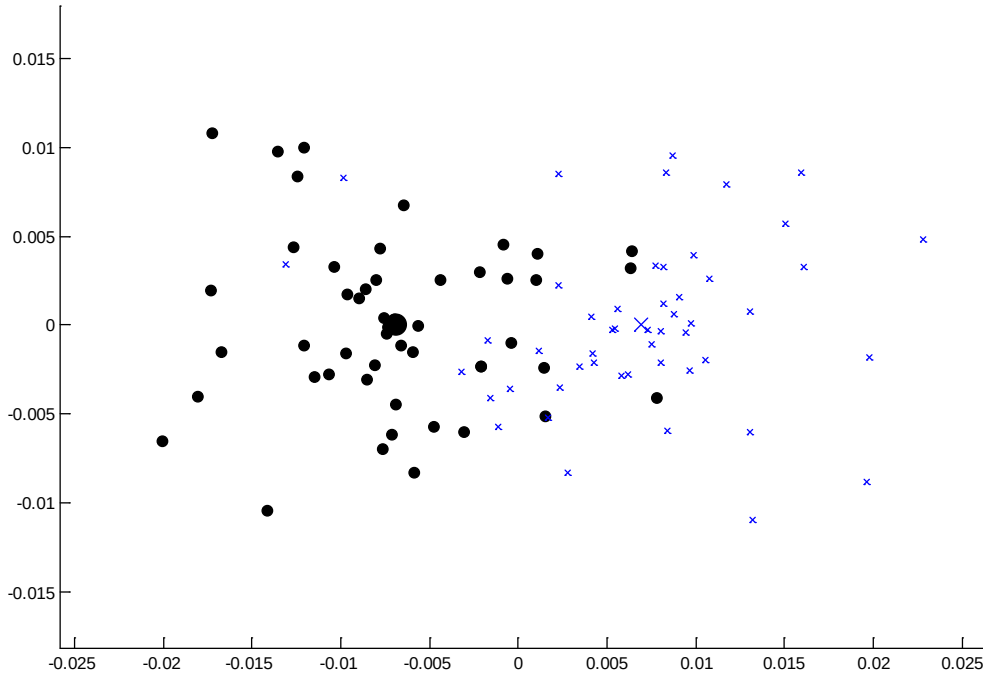

Figure 5.72: Mean CVA plot for the 7-year old Black children (circles) and 7-year old Coloured children (crosses). The mean shape for Black children is represented by the large circle and the mean shape for Coloured children is represented by the large cross.

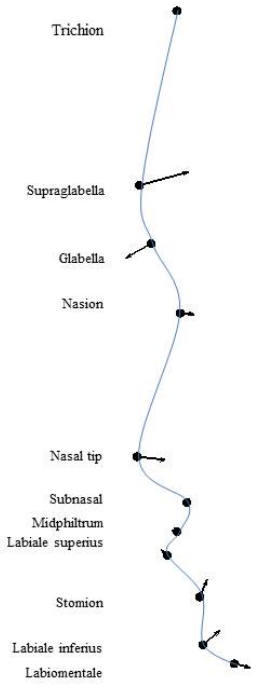

Figure 5.73: Vector plot for 8-year old Black children and 8-year old Coloured children (n=100). The circles represent the mean face shape of the 8-year old Black children and the arrows indicate the difference in face shape of 8-year old Coloured children from Black children.

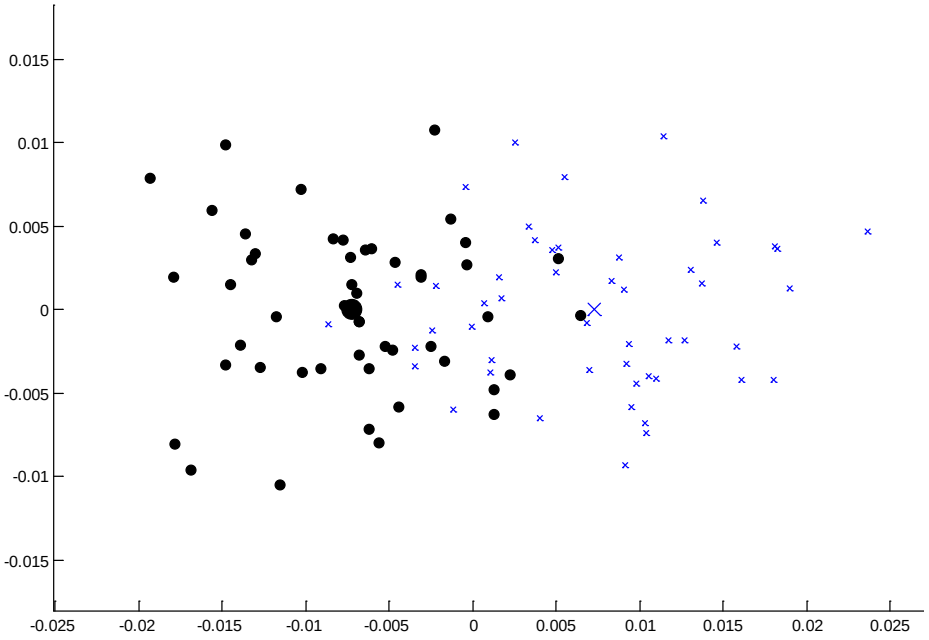

Figure 5.74: Mean CVA plot for the 8-year old Black children (circles) and 8-year old Coloured children (crosses). The mean shape for Black children is represented by the large circle and the mean shape for Coloured children is represented by the large cross.

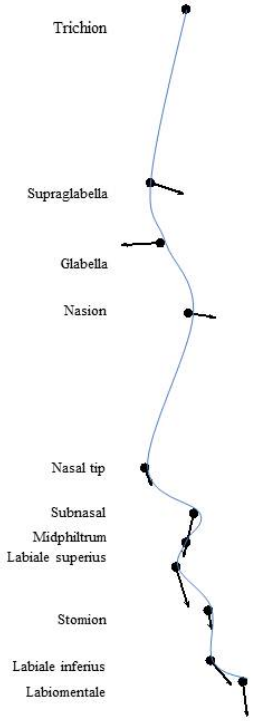

Figure 5.75: Vector plot for 9-year old Black children and 9-year old Coloured children (n=100). The circles represent the mean face shape of the 9-year old Black children and the arrows indicate the difference in face shape of 9-year old Coloured children from Black children.

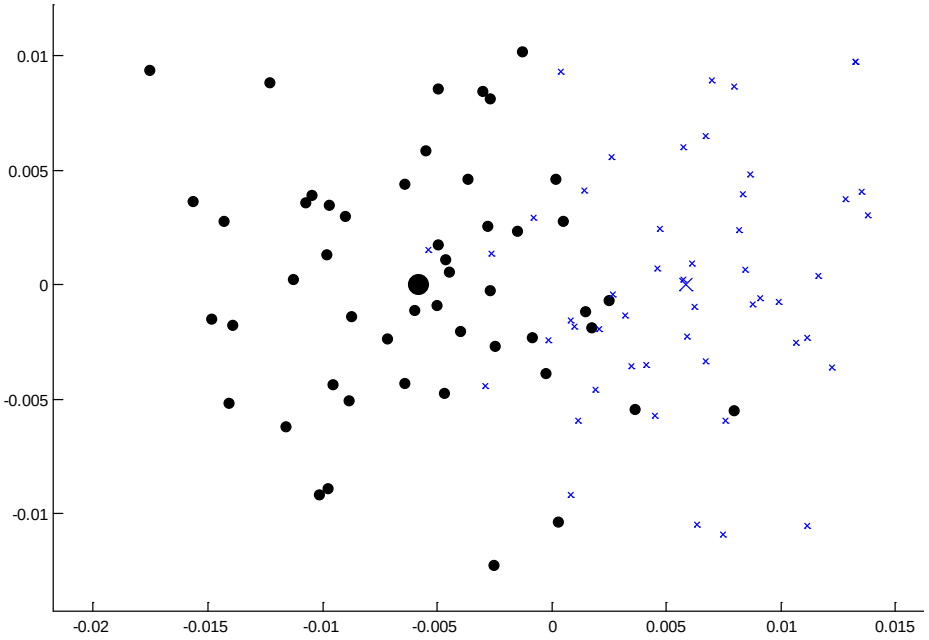

Figure 5.76: Mean CVA plot for the 9-year old Black children (circles) and 9-year old Coloured children (crosses). The mean shape for Black children is represented by the large circle and the mean shape for Coloured children is represented by the large cross.

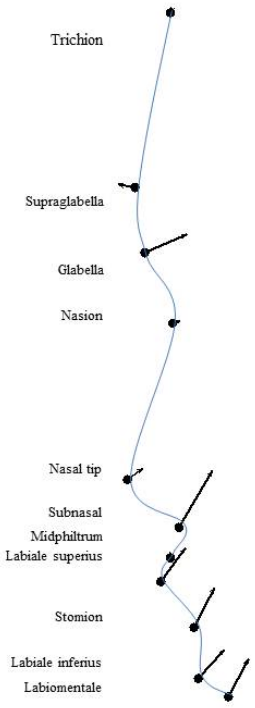

Figure 5.77: Vector plot for 10-year old Black children and 10-year old Coloured children (n=100). The circles represent the mean face shape of the 10-year old Black children and the arrows indicate the difference in face shape of 10-year old Coloured children from Black children.

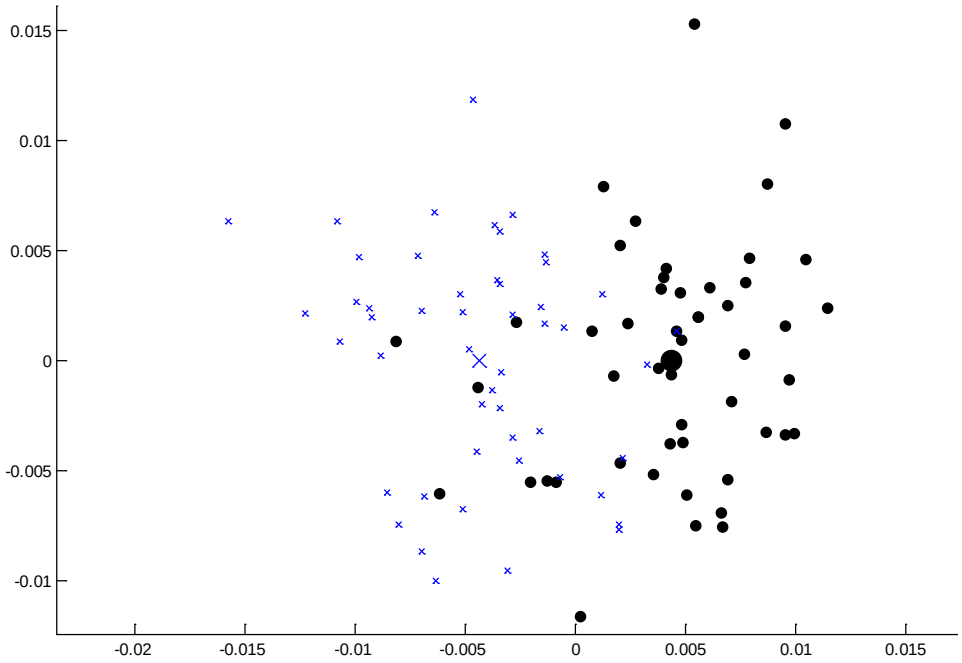

Figure 5.78: Mean CVA plot for the 10-year old Black children (circles) and 10-year old Coloured children (crosses). The mean shape for Black children is represented by the large circle and the mean shape for Coloured children is represented by the large cross.

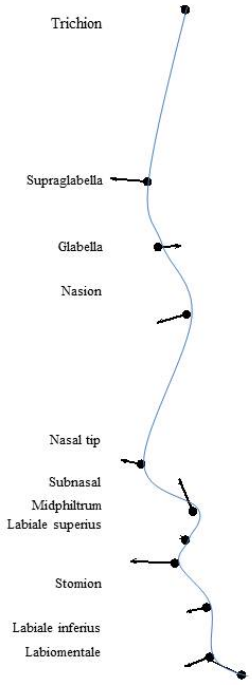

Figure 5.79: Vector plot for 11-year old Black children and 11-year old Coloured children (n=100). The circles represent the mean face shape of the 11-year old Black children and the arrows indicate the difference in face shape of 11-year old Coloured children from Black children.

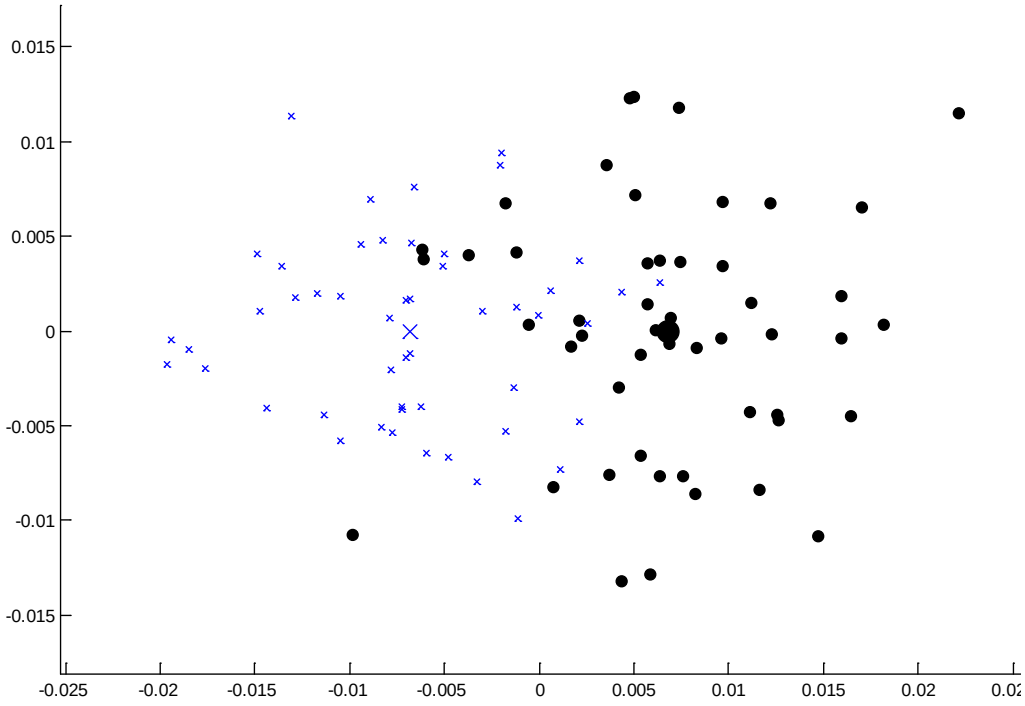

Figure 5.80: Mean CVA plot for the 11-year old Black children (circles) and 11-year old Coloured children (crosses). The mean shape for Black children is represented by the large circle and the mean shape for Coloured children is represented by the large cross.

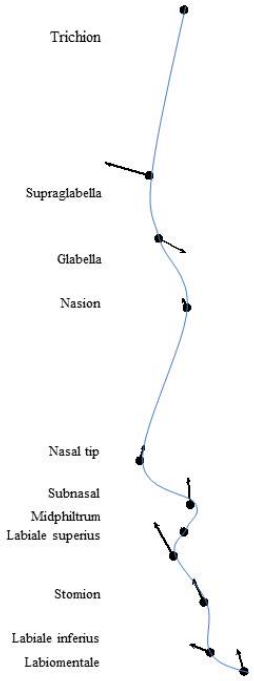

Figure 5.81: Vector plot for 12-year old Black children and 12-year old Coloured children (n=100). The circles represent the mean face shape of the 12-year old Black children and the arrows indicate the difference in face shape of 12-year old Coloured children from Black children.

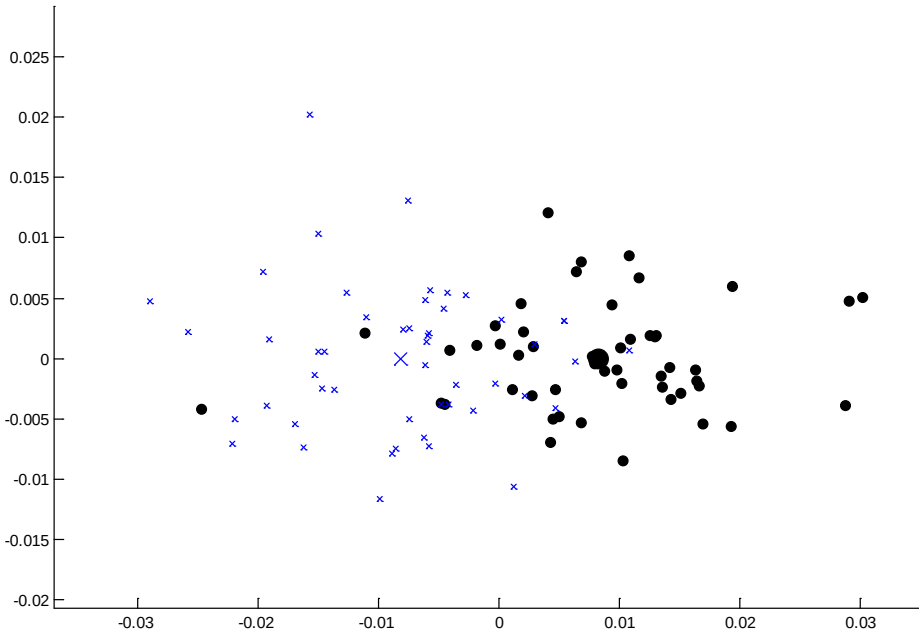

Figure 5.82: Mean CVA plot for the 12-year old Black children (circles) and 12-year old Coloured children (crosses). The mean shape for Black children is represented by the large circle and the mean shape for Coloured children is represented by the large cross.

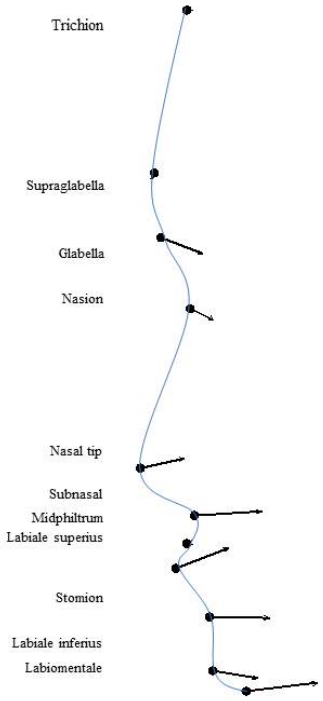

Figure 5.83: Vector plot for 13-year old Black children and 13-year old Coloured children (n=100). The circles represent the mean face shape of the 13-year old Black children and the arrows indicate the difference in face shape of 13-year old Coloured children from Black children.

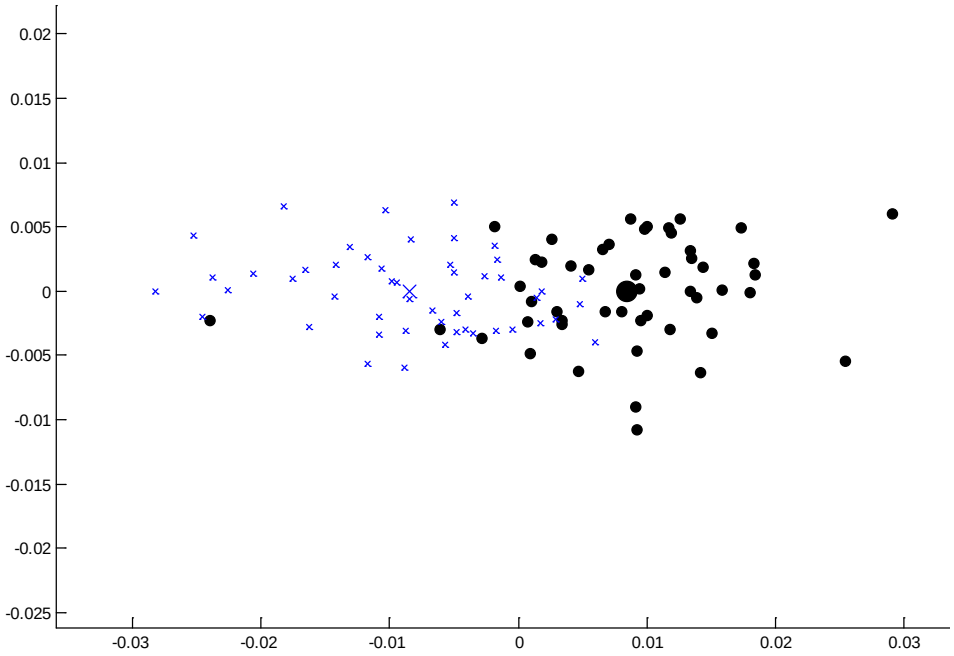

Figure 5.84: Mean CVA plot for the 13-year old Black children (circles) and 13-year old Coloured children (crosses). The mean shape for Black children is represented by the large circle and the mean shape for Coloured children is represented by the large cross.

Chapter 6: Discussion

6.1 Introduction

In this section the development of standards for soft tissue thickness and craniofacial indices for South African children aged 6 to 13 years will be discussed. The influence of age, sex and ancestry on tissue thickness and craniofacial indices as well as the validation of different data sets for each category will be reviewed. In addition, the possible effect of the facial profile (skeletal type) on tissue thickness values will be explored. Attention will be given to facial shape changes at different age levels as determined by geometric morphometrics. Differences between sexes at various age levels will be explored, as well as differences between ancestral groups. Finally, these findings will be integrated to provide an overall overview of the growth of indigenous South African children between the ages of 6 and 13 years.

6.2 Tissue thickness standards for South African children

Young children can become victims of crime as they are vulnerable. It is difficult to determine exactly how many children under the age of 18 fall victim to crime or missing due to the way in which the SAPS report crime statistics. The crime categories are also changed annually and therefore it becomes difficult to compare crime statistics involving children from one year to another. The increasing number of missing children in South Africa and unidentified skeletal remains (although not necessarily in the juvenile category) motivates the development of methods to legally deal with unclaimed remains and the social responsibilities that are associated with it. In this regard, facial reconstruction / approximation is one of the methods to be used when no other options such as fingerprinting or DNA analysis are available.

Facial reconstruction / approximation is based tissue thickness data and the debate in literature concerns the validity to use tissue thickness data specific to populations, sexes and age groups (Dumont, 1986; Aulsebrooke, 1996; Philips and Smuts, 1996; Tyrell, 1997; Manhein *et al*., 2000; Williamson *et al.* 2002; Wilkinson, 2002; Wilkinson, 2004; Utsuno, 2005; Utsuno, 2007; de Almeida *et al*., 2013; Peckman *et al*., 2013; Ruiz, 2013). Some authors argued that generalized pooled data can be used, ignoring these possible variants (Stephan, 2003; Stephan and Simpson, 2008a, Stephan and Simpson 2008b, Stephan, 2014). However, authors agree that adult and juvenile tissue thicknesses are different, but do not agree on how age categories should be divided.

Tissue thickness data of children are limited (Dumont, 1986; Manhein *et al*., 2000; Wilkinson, 2002; Utsuno, 2007; Codinha, 2010, Stephan and Simpson, 2008b, Stephan, 2014). One of the reasons for this is the difficulty in obtaining useful data from live children using ultrasound. Other reasons include the lack of information when performing a retrospective study on patient files with cephalogram or CT images. Therefore, pooling of tissue thickness data is common practice to enlarge the sample size in order to improve the reliability and validity of a dataset. Stephan and Simpson (2008b) suggested 0 – 11 and 12 - 18 years as categories for juvenile data to be pooled. While the division between 11 and 12 years of age is based on the onset of puberty coinciding with large physiological and physical changes in the body (Bogin 2009), the pooling of children aged 0 – 11 is questionable. The viscerocranium and overlying soft tissue undergoes extensive changes due to different growth rates in the childhood phase (age 3 - 7), juvenile phase (ages 7 – 10/12) and puberty (females: 10/11 and males 12/13) (Bogin, 1999; Black and Maat, 2010). Pooling tissue thickness data from all age groups will result in a too heterogeneous dataset. On the other hand, it is unlikely for a facial reconstruction / approximation to be required of a 1 year old individual. Williamson *et al.* (2002) and Utsuno (2005, 2007) pooled children of less than 9 years, from 10 – 12 years and age 13 and above together. This grouping coincides better with the childhood, juvenile and puberty phases. Manhein *et al*. (2000) and Wilkinson (2002) used 6 to 8 years and 9 to 13 years as categories which can be problematic as not all girls are in puberty at age 9. A South African study by Philips and Smuts (1996) did not take age into account as they included Coloured children and adults ranging from 12 to 71 years in their study, which also creates problems in terms of accuracy and validity.

Detailed tissue thickness standards for South African children per age, sex and ancestry are presented in Appendix I. Due to the lack of data for younger age groups, data of this study were also pooled as in the literature, before results were compared between groups and to other authors.

The tissue thickness part of the study has shown that cephalograms from patient files can be useful in obtaining midline facial tissue thickness measurements in order to establish a tissue thickness database for South African sub-adults. In this case, the patients were seated upright which minimized distortion of the soft tissue of face, an aspect that some researchers have argued causes tissue thickness measurement errors due to gravity with patients in supine position as in CT scans (Stephan and Simpson, 2008a).

Despite the sample size of 388 being the largest thus far in South Africa for children, the tissue thickness data had to be pooled in age groups in order to perform valid statistical tests, specifically at ages 6 to 9 years. Other reasons for this strategy were that 1) the exact age of juvenile remains presented for facial reconstruction / approximation is rarely known, only the possible age range is provided by the forensic anthropologist; and 2) in literature tissue thickness data are also reported in terms of age ranges, however the intervals of these ranges differ significantly. In this regard, the tissue thickness data of the current study were subdivided into 10 different pooled datasets (Chapter 4) in order to compare the results of South African children to White British children, African American children, Japanese children of different age, sex and facial profiles, as well as a pooled dataset, known as the T-Tables, by Stephan and Simpson (2008a) which only considers age and not ancestry or sex.

The T-Tables, or Tallied Facial Soft Tissue Depth Tables, were published by Stephan and Simpson (2008a, 2008b). These T-Tables are based on human tissue thickness data of adults and children (0 – 18 years) from different studies. Stephan and Simpson (2008a, 2008b) compiled the T-Tables to eliminate measurement errors and uncertainty created by different methodologies and to improve the practical implementation of tissue thickness data. Recently, Stephan (2014) included more adult data that have been published in the last five years. He revised the work from 2008 with the inclusion of the new data in order to compare the statistics from 2008 to 2013. He also further explored the use of the two new aspects, introduced by Stephan *et al*. (2013), namely the shorth and the 75-shormax. The shorth and the 75-shormax were introduced in 2013 to compensate for skewed data which are not normally distributed at some landmarks, measurement error and to provide central tendency statistics that would improve facial reconstruction / approximations (Stephan *et al*., 2013). Only minor differences were found when comparing the T-Tables from 2008 to the T-Tables generated in 2013 (Stephan *et al*., 2013; Stephan, 2014). He found that 23 of the 25 landmarks differed with less than 1 mm, while the gonion shows the maximum difference between the 2008 and 2013 Tables with 1.7 mm. The shorth is a non-parametric method used to visualize probability mass concentration. The shorth is based on the length of the shortest interval containing a certain fraction of the probability distribution and a point *x* (Einmahl *et al*. 2010). The 75-shormax is the 75th percentile between the shorth and the maximum value (Stephan, 2014). Stephan (2014) argues that the shorth and the 75-shormax describe central tendencies of skewed facial soft tissue thickness better compared to the “normal” (arithmetic) mean. However,

as these two descriptors need to be calculated from the raw data of 2000 to 3000 samples, which is not yet available, the T-Tables are currently of more practical use than the shorth and the 75-shormax. Only one new study regarding facial thickness data for children have since been published (Utsuno, 2010) and as a result, Stephan (2014) did not include a review of the subadult T-Tables or calculation of the subadult shorth statistics in his recent paper.

The arguments of Stephan and co-workers in their different papers on the subject (Stephan and Simpson, 2008a, 2008b; Stephan *et al*., 2013; Stephan, 2014) raise the question whether the data from the current study are similar to the T-Tables for sub-adults published by Stephan and Simpson (2008b).

A summary of the tissue thickness value comparison between Stephan and Simpson (2008b) and the current study at specific landmarks is provided in Table 4.79. Table 4.79 shows the difference in mm, at nine of the same landmarks that correspond between the current study and the results by Stephan and Simpson (2008b). Differences between 2.1 mm and 3.0 mm were seen at the other landmarks at the labiale inferius (2.1 mm), labiale superius (2.2 mm), nasion (2.9 mm) and midphiltrum (3.0 mm) when comparing tissue thicknesses of the current study to the generalized Tables of Stephan and Simpson (2008b) for children aged 12 to 17. Although these differences are 3 mm and less, the percentage difference was 56% at the nasion, 25% at the midphiltrum, 18% at the labiale superius and 16% at the labiale inferius. These differences are large and for these landmarks the data in the T-Tables are not considered as similar, necessitating consideration of ancestry in tissue thickness datasets.

Furthermore, the results from the current study indicated that when age groups (ancestry and sex pooled) were compared, statistical significant differences in tissue thickness were seen in 30% of landmarks, while tissue thickness comparison in terms of sex (ancestry and age pooled) only showed differences at 20% of landmarks. None of the differences were more than 1 mm. Comparison of tissue thickness between ancestry groups (age and sex pooled) showed significant differences at seven out of 10 landmarks with a maximum of 2.12 mm difference at the midphiltrum (Coloured children > Black children).

Tissue thickness differences were seen at three landmarks (nasion, midphiltrum and labiale superius) when facial profile per class (Utsuno, 2005; Utsuno, 2007: Utsuno, 2010; Utsuno, 2014) was considered. However, when ancestry was added as a subdivision of class, differences were seen at five landmarks in the upper and lower face regions (the

nasion, end nasal, midphiltrum, labiomentale and beneath the chin) with the tissue thickness differences between 2 and 4.5 mm. Subdividing classes by sex showed differences only at two landmarks (nasion and midphiltrum), with differences of less than 2 mm. These findings suggest that that facial profile per ancestry should be taken into account with facial reconstructions / approximations as it clearly impacts on several landmarks with large differences in actual mm.

Comparison of the different pooling methods show that the division of the tissue thickness data into two age groups rather than three (Dumont, 1986; Williamson *et al.*, 2002; Utsuno *et al.*, 2007; Utsuno *et al.*, 2010) rendered results that were less complex to interpret and trends could be better identified. When using age ranges from 6 - 8 year olds and 9 -13 year olds in terms of ancestry and sex (Manhein *et al*., 2000; Wilkinson, 2002**)**, significant differences were seen at 40% of landmarks. Actual significant differences in groups were between 1.25 mm and 1.96 mm. Specific trends were difficult to identify between groups even at landmarks where tissue thickness differed significantly. In terms of development, it makes sense to group 6 to 8 year old children together. However, pooling 9 year olds with ages up and including 13 is problematic as puberty plays a role from ages 10/11/12 and onwards. As a result, the 9 to 13 year old group is too heterogonous for comparison, obscuring trends in tissue thickness values. While the division between 11 and 12 years by Stephan and Simpson (2008b) was originally based the density of their data points, it also coincides with on the onset of puberty in females (Bogin, 2009). In the current study, tissue thickness data were pooled into age ranges 6 – 11 years and 12 & 13 years (ancestry and sex pooled) and significant differences were seen between the two age groups at 30% of landmarks; however none of these landmarks differed with more than 1 mm. Differences below 3 mm have been described as by Stephan *et al*. (2013) and Stephan (2014) as minimal with little practical value. From the findings of the current study and the small differences detected by Stephan and Simpson (2008b), the pooling of tissue thickness data of children 0 – 11 is not advised as children between these age groups are too heterogeneous for comparison.

Subdividing the ages at 10 to create age ranges 6 to 10 years and 11 to 13 years was added to this study for two reasons: 1) It divided the sample before the onset of puberty in either males or females (Bogin, 1999); and 2) data from craniofacial indices indicated pronounced differences in some indices around the age of 10. Indices include the upper lip thickness index, upper lip height mouth width index, mandibular index, mandible width face height index, upper face index, upper middle face depth index, nasofacial index

and nasal index. Comparison between age groups (sex and ancestry pooled) showed significant differences at 30% of landmarks with no difference of more than 1 mm found between groups that were significant. However, when the 6 to 10 year old and 11 to 13 year old groups were analyzed per ancestry, 70% of landmarks were significantly different. From these landmarks (with significant differences), at least half showed differences of more than 1.2 mm. At the labiale inferius the difference between groups was 1.9 mm and 1.6 mm at the pogonion (Coloured children > Black children). Analysis of 6 to 10 year old and 11 to 13 year old groups per sex and ancestry showed that tissue thickness were different at 50% of landmarks and the difference in millimeters at each were more than 1 mm. At the midphiltrum and labiale inferius the differences were 1.9 mm and 1.5 mm respectively.

From these findings it is recommend that in children, tissue thickness data should be pooled as two age groups subdivided at age 10 with ancestry taken into account. Sex should not be considered as it seems not to impact tissue thickness with more than 2 mm at any landmark.

In terms of tissue thickness, the current study therefore has shown that ancestry, and to a lesser extent age and facial profile, but not sex, impacts on tissue thickness of sub-adults. It has also showed that the division of samples in three or more age groups makes datasets too complex with little or no visible trends. Furthermore, when using two age groups, the division at age 8 and age 11 are not desirable as it creates heterogeneous subgroups that show little differences and obscures trends. The division at age 10 is based on growth and craniofacial indices.

The question remains, what is the actual difference in millimeters that will impact on the facial reconstructions / approximations of juveniles? Stephan and Simpson (2008b) imply that any difference below 3 mm is of no practical use. The answer may lie in the use of percentages rather than actual differences. A difference of 1.5 mm between groups at the end nasal landmark with a mean of 2.5 mm is a 75% difference; compared to a 13% difference at the labiomentale with a mean of 11.62 mm. In this example, the difference at the nasion is large and will have a greater impact of the facial appearance compared to the tissue thickness difference at the labiomentale.

Collaboration with forensic artists is necessary to determine when statistical differences are of practical value in terms of juvenile facial reconstructions / approximations. Although some past and current forensic cases in South Africa involve children, unfortunately no juvenile material is available to test the tissue thickness obtained

in the current study. The possibility of using three dimensional reconstructions / approximations of skulls from CT scans of living children is a possibility that could be investigated for future validation studies.

Based on the results of the current study, facial reconstructions / approximations should use datasets specific to age (6 - 10 and 11 - 13 years) and ancestry.

6.3 Facial growth

Craniofacial growth in children is seen in the changes in craniofacial proportions (indices) caused by increases in the width and length of both the face and cranium in the vertical-, transverse- and anterior-posterior planes, until adulthood (Bogin, 1999; Farkas *et al*., 1992). Facial shape changes caused by facial growth can be described by geometric morphometrics (O'Higgins and Jones, 1998; Hennessy and Moss, 2001; Buck and Vidarsdottir, 2004; Braga *et al*., 2007; Hutchinson *et al*., 2014). In the current study, facial growth will be described in terms of craniofacial indices and geometric morphometrics with the emphasis on changes seen in indigenous South African children.

According to Tanner (1962) and Veldhuis *et al*. (2005), craniofacial growth rate generally decreases during childhood, and is then followed by an increase during adolescence. The extent and influence of facial changes on facial appearance due to growth is often underestimated as facial growth generally is not constant. Furthermore, some areas within the craniofacial region grow faster than others e.g., the cranial dimensions of a child age 6 years have reached approximately 94% of the size it would become at age 18 (Farkas, 1981). In contrast, the facial dimensions of a child aged 6 are only 84% of the size that it would reach at age 18 (Farkas, 1981). Baughan *et al*. (1979) refer to "growth potential" to describe the different growth rates. In their view, the cranium has less growth potential compared to the face as the cranium is more "mature" because it has almost reached adult size at age 6. Buschang *et al.* (1983) and Buschang and Hinton (2005) describe a postnatal craniofacial maturity gradient in which the cranium is more mature than the cranial base, which is in turn more mature than the mid-facial region, while the mandible is the least mature. As a result, the mandible has the most growth potential followed by the mid-facial region, cranial base and cranium. In practical terms, most changes in face shape and dimensions in children are expected at the mandible and mid-facial region.

Following the potential growth rule for craniofacial dimensions, vertical height will change more than antero-posterior dimensions, which in turn will increase more than the

transverse dimensions (Meredith, 1971; Farkas, 1981; Snodell *et al.*, 1993; Gaži-Čoklica *et al.*, 1997).

Craniofacial measurements and indices were traditionally used by clinicians to compare the patient to normal reference groups in order determine the actual craniofacial and dentofacial proportions per sex, age and ancestry group (Stewart *et al*., 2008).

Broadbent and Golden (1975) and Farkas and Munro (1987) developed databases containing normative data. The Bolton standards of dentofacial developmental and growth are based mainly on dentofacial measurements and contain information on North American White males and females that was used for linear and angular comparative measurements and morphological assessment (Broadbent and Golden, 1975).

Farkas and Munro (1987) used anthropometric measurements between specific landmarks in White North American individuals (6 to 18 years). Due to the unique nature of the measurements at the time and the presentation of the results in the form of indices, the database appealed to more disciplines and became the standard used in orthodontics, plastic surgery, oral- and maxillofacial surgery and medical genetics (Deutsch *et al*., 2012).

Farkas *et al.* (2005) later elaborated on the first set of data by including population specific data as they argued that an update was necessary to include people from different geographic origin in order to assist clinicians and surgeons in the diagnosis of syndromes and rectification of deformities and trauma. Several studies by others followed to broaden the knowledge base of population-specific normative data. These included studies on children and adults from Turkey (Everekliogl*u et al*., 2002), children from Iceland (Thordarson *et al*., 2006), Finland, North America (Black and White children), South Africa (Coloured children) (Moore *et al*., 2007), Lithuania, Germany and Italy (Catteneo *et al*., 2012; Cummaudo *et al.*, 2014). However, comparison of the results of the current study to most of these studies proved difficult due to differences in methodology, landmarks, age and subjects used.

Everekliogl*u et al*. (2002) included both children and adults in their study on craniofacial anthropometry of a sample of the Turkish population. They pooled children aged 7 to 15, but separated them in terms of sex. Only one index, the intercanthal index, was the same and could be used for comparison to the current study.

Thordarson *et al.* (2006) conducted a longitudinal radiographic study and made use of actual measurements from cephalograms and not indices, which could not be compared to the detailed results from the current study. However, they noted that prognathism

increased from 6 to 16 years, with a larger increase in maxillary prognathism in male children. In South African children, a general decrease in the upper middle face index from age 6 to 13 suggests that the middle third of the face (t-sn) expands in an anterior posterior direction in relation to the upper third face depth (t-n). The similar trend was seen in the decrease of the lower middle third face index from age 6 to 13, which indicates that the lower third of the face (t-gn) increase with age relative to the middle third of the face (t-sn). These measurements were taken from the tragion to the subnasal and gnathion respectively, and therefore reflect changes in the anterior-posterior maxillary and mandibular length. These measurements do not reflect alveolar prognathism as the landmarks in living individuals for maxillary alveolar prognathism would be the labiale superius and for mandibular alveolar prognathism, labiale inferius.

The current study has shown, similar to that of Thordarson *et al.* (2006), that maxillary and mandibular prognathism increase with age. In addition, maxillary prognathism was more prominent in Black children, while mandibular prognathism were more pronounced in boys. The results are different from that of Thordarson *et al.* (2006) who found that maxillary prognathism is more pronounced in boys. A possible reason is that the difference between sexes is obscured by larger differences between ancestry groups and as a result, differences in sexes are less obvious.

Moore *et al*. (2007) used 3D laser scanning to acquire images of South African Coloured individuals between 2 and 21 years. Their study focused on the comparison of the facial features of children with Fetal Alcohol Syndrome (FAS) and normal children. They included a control group which could have been useful for comparative purposes, but there are several differences to the current study in terms of methodology and sample composition which makes comparison difficult. Firstly, the mean age of the South African Coloured children in their study is 5.4 years, and although not specified by the authors, they indicated that the age range for the South African children was narrow. They acquired images by three dimensional laser scanning and not by photo-anthropometry as in the current study. Measurements from different three dimensional imaging systems have not been shown to be fully comparable with traditional anthropometric methods, although several attempts have been made to improve reliability and validity of three dimensional methods (Weinberg *et al*., 2006; Wong *et al*., 2008). The current study included all Coloured children on the day of data collection with the necessary signed consent and assent forms. No distinction was made between normal children and the children with potential FAS or prenatal alcohol exposure, as these aspects were not within the scope of

the current study. Moore *et al.* (2007) included children without diagnosis of FAS in their control group, but could not ensure that the control comprised of children without pre-natal exposure to alcohol because that information was not known. Therefore, comparison of the results from the current study to that of Moore *et al*. (2007) should be regarded with caution. Despite these limitations, seven craniofacial indices could be calculated from the actual measurements provided by Moore *et al*. (2007). These included the forehead width-face width index, facial index, lower-face-face height index, intercanthal index, bi-ocular-face width index, upper middle third face depth index and the lower middle third face depth index. Comparison of these indices of the current study for 6 year old children (male and female pooled) to the values of Moore *et al*. (2007) (mean age 5.4 years; male and female pooled) showed no significant differences for most indices (Paired *t*-test, $p > 0.05$), except for the intercanthal index. The intercanthal index indicated a significant difference between the value of the current study (37.1) compared to the intercanthal index value of 40.5 obtained by Moore *et al*. (2007) (Paired *t*-test, $p = 0.002$). The forehead width-face width index and lower middle third face depth index in the current study is in agreement with the control group of Moore *et al.* (2007), which showed a larger index value compared to the FAS group. These indices are linked to the small head circumference and reduced mid facial depth reported for FAS children (Moore *et al*., 2001, 2007)

The larger intercanthal index of the control group children in the study by Moore *et al*. (2007) indicates that their eyes are slightly wider apart compared to the children of the current study. Using measurements obtained in the current study to supplement control group size in local FAS studies and to identify children, who suffer from prenatal alcohol exposure, but who do not meet FAS diagnostic criteria, is an exciting future possibility.

Cattaneo *et al*. (2012) included children aged 6 years and 10 year old children as separate groups in their pilot study. Comparison of the results to 6 and 10 year old children from the current study would have been ideal for comparison, however, closer examination of the methodology revealed that they used the selion (se) instead of the nasion when taking measurements. The selion is defined by Farkas (1994) as the midpoint of the nasal root at the level of the eye fissures. Catteneo *et al*. (2012) used the selion rather than the nasion as they argue that it may possibly be located with a higher level of precision on photographs. According to Farkas (1994), the selion is often mistaken for the nasion. Daniel and Farkas (1988) determined that the nasion was located 4.9 mm higher in young adults therefore the two landmarks cannot be viewed as the “same”. As a result, only one index (mouth width index [ch–ch/ex–ex] x 100) from the 20 indices calculated by Catteneo

et al. (2012) could be used for comparison to the current study. The comparison showed that the mouth width index for South African children is larger at age 6 and at age 10. Therefore, the mouth is larger in relation to the bi-ocular width in South African children compared the sample of Cattaneo *et al*. (2012) which comprised of Lithuanian, German and Italian children.

In a follow-up study by Cummaudo *et al.* (2014) on the same, but larger sample of Catteneo *et al*. (2012), the selion was again used instead of the nasion. More importantly, a correlation index which included age, instead of only indices was used. Direct comparisons of the results from the current study to the results of Cummaudo *et al.* (2014) could not be performed as they did not provide details on how the correlation index was calculated.

6.3.1 Facial growth in South African children

In this study, standard anterior and lateral craniofacial indices for Black and Coloured South African aged 6 to 13 years children were developed and are presented in Appendices II and III. The appendices include detailed information per age, sex and ancestry for each of the 21 anterior and 8 lateral craniofacial indices. The information is presented in similar format as Farkas and Munro (1987), in order to aid comparison of the datasets. Lateral face shape profiles presented in Chapter 5 are relevant to the discussion of these indices as these profiles provide graphic representations of how various landmarks are affected by facial growth. Vectors at landmarks can either show displacement superiorly or inferiorly indicating lateral facial shape changes in height e.g., face height, upper face height, lower face height, head height and mandibular height. In addition, vectors may also indicate anterior and posterior displacements at landmarks that show changes in facial depth indicative of brow bridge / frontal bone enlargement, maxillary and mandibular prognathism, e.g., upper middle third face depth and lower middle third face depth.

6.3.1.1 Black *vs* Coloured children

In Figure 6.1 generalized craniofacial growth patterns are shown. Overviews of facial growth patterns are inferred from the results of the craniofacial indices and geometric morphometrics to show differences between Black and Coloured children.

Black children have narrow heads (dolicephalic) in relation to head and face height, while Coloured children have wider heads in relation to height. In comparison to all

groups, the foreheads of the Coloured females are wider in relation to head width. The neurocranium (v-po) is lower relative to the skull base (t-t) in Coloured children. The upper face index (relationship between the length of the upper face and face width) showed separation in terms of ancestry before, but not after the age of 10. This means that before the age of the 10, Black children have wider faces.

The growth rate of the face height in Coloured children is faster and marked growth in this region starts earlier (age 7) than in Black children (age 10). However, indices related to head height (head-face height index and upper face-face height index), indicated that despite the faster growth rate, at age 13, Coloured children have shorter face height in relation to forehead and head height.

In older anthropology texts, the term “paedomorphism” is used as reference to the retention of infantile proportions in later phases of development which usually lasts into adulthood (de Villiers, 1968; Singer, 1975). Results of the geometric morphometric study by Sardi and Rozzi (2012) on sub-adult and adult European and Black South African skulls, suggested that indigenous sub-Saharan populations reach adulthood earlier than Europeans and that Southern Africans generally appear to retain young features in adulthood.

Paedomorphism is a term that also has been used to describe facial features of the Khoesan (Tobias, 1959; de Villiers, 1968; Singer, 1978). In addition, Bogin (1999) refers to the infantile appearance in children, specifically a small face in relation to a large cranium, which provokes care-giving and nurturing behavior in older individuals. The infantile appearance of the Coloured children (short, wide face and less prominent chin) is reminiscent of the appearance of the Khoesan as described by Singer (1978). Therefore, it seems that the paedomorphic appearance of the Khoesan is to some degree still present in their modern day descendants in the current study.

Vector plots showed general anterior and inferior displacement of landmarks related to the upper face region from age 6 to 13. Only at age 6 inferior displacements of the glabella and nasion were present, showing lengthening of the forehead region. At all other ages the displacement of the supraglabella posteriorly, and glabella anteriorly, are overshadowed by lengthwise displacement. Vector plots showed very little displacement of the nasal tip between Black and Coloured children regardless of age, suggesting that their noses are very similar.

The indices also showed that lower face height in Coloured children is shorter in relation to total face height. Vector plots showed inferior and slightly anterior

displacement of the landmarks of the lower face region in Coloured children at ages 7 and 8. However, at ages 10 and 12, landmarks from the nasal tip to the labiomentale showed superior and posterior displacement, indicating a shortening of the lower face, including the nose. The net effect of these landmark displacements once again result in retaining the infantile appearance of Coloured children.

The lip index shows that Black children have thicker lips at all ages, but in Coloured children the lower lip is relatively larger and in Black females the mouth is larger in width. Displacement of the landmarks of the lips with age (labiale superius and labiale inferius) does not necessarily indicate enlargement of the lips as the surrounding landmarks (subnasal, midphiltrum, stomion and labiomentale) also show displacement. This may be the combined effect of maxillary and mandibular enlargement rather than just the lips alone. Therefore, no specific comment on the landmark displacement regarding the lips will be made.

Indices have shown that at age 6, the mandible height (sto-gn) is short in relation to its width for Black children, but these differences becomes less from age 8 onwards.

Black children have wider noses than Coloured children at all ages, while Coloured children have longer noses in relation to their face height. Vector plots showed displacement of the subnasal to inferior and slightly anterior between the age of 7 and 9 in Coloured children. Although the landmark was displaced superiorly and posteriorly from age 10 to 13, the initial landmark displacement was seemingly enough to create a longer nose in relation to face height as suggested by the indices.

The intercanthal index shows differences between groups, but the differences are small. These small differences correlate with results from Burke and Hughes-Lawson (1988) who found minimal growth of the intercanthal width and size of the eye when comparing twins at age 9 and again at age 16 year old in a longitudinal study. Everekliogl*u et al.* (2002) determined the intercanthal index for Turkish male children as 34.7 and for females as 35.0 in the age group 7 to 15 years. When pooling the age and ancestry groups in the South African sample, the intercanthal index value for males and females aged 6 to 13 years is 37.1. According to Farkas and Munro (1987), the intercanthal index values for Turkish children fall into the subnormal range indicating orbital hypotelorism. The eyes of South African children are thus wider apart compared to Turkish children. Later it will be seen that the eyes of Turkish children are also closer together than that of North American children.

Facial depth indices and lateral face profiles provide quantitative and visual information on the degree of prognathism. In the field of orthodontics, prognathism is seen as a developmental disorder of the craniofacial region. Mandibular prognathism is the result of excessive mandibular growth in relation to the maxilla, or hindered growth of the maxilla which can be the result of environmental or genetic factors (Jacobson *et al*., 1974; Tomaszewska *et al.*, 2013). The positional difference between the mandible and maxilla then leads to occlusion disorders. Alveolar prognathism specifically refers to the misalignment of the maxillary or mandibular teeth or both. This condition has been attributed to habitual thumb-sucking and tongue thrusting as well as genetic factors. In their geometric morphometric study on variation of the facial skeleton in sub-adult and adult skulls, Viarsdóttir *et al*. (2002) describes an increase in alveolar prognathism in some ancestry groups (Australians, Alaskans, African Americans, Arikara and Caucasians). They link the phenomenon to variations in the development of these groups which ultimately produced different adult facial features.

In anthropology, the term “alveolar prognathism” is used as a non-metric trait in dry skulls which describes the degree of maxillary projection beyond the anterior portion of the nasal bones (Bass, 1995; La Abbé *et al*., 2011). In a longitudinal cephalometric study of craniofacial changes in Icelandic children, Thordarson *et al*. (2006) refer to mandibular and maxillary prognathism to describe the relative positions of the maxilla and the mandible in children with normal occlusion. For the purpose of the current study, facial depth indices were used to describe the relationship of the upper third of the face (t-n) to the middle third of the face (t-sn), and the middle third of the face (t-n) to the lower third of the face (t-sn) in an anterior – posterior dimension as viewed from lateral. As such, these relationships provide information on maxillary and mandibular prognathism and are not limited to alveolar prognathism.

In terms of facial depth, indices showed that Black children display a greater anterior-posterior expansion (as seen on lateral view) of the middle third of the face in relation to the upper third face depth. A vector plot confirmed this observation as anterior displacement of the subnasal, stomion, labiale inferius and labiomentale, thereby indicating that Black children already displayed maxillary and mandibular enlargements at age 6. These enlargements are related to increasing prognathism seen with age progression.

The indices showed that the mandible expands in an anterior-posterior direction with age (as seen on lateral view), but differences in terms of ancestry become obvious

only after age 10. From ages 7 and 8, vectors showed inferior and anterior displacement of the subnasal, stomion, labiale inferius and labiomentale in Coloured children, indicating that more growth is taking place in the maxilla and mandible of Coloured children. At age 9, the displacement of the landmarks in Coloured children is inferior and slightly posterior, showing some lengthening of the mandible at this age. These landmark displacements cancelled the differences seen at age 6, therefore the indices did not demonstrate changes until age 10. In Black children, superior and posterior displacement of the nasal tip, subnasal, labiale superius, stomion, labiale inferius and labiomentale were seen at ages 10 and 13. Landmark displacements indicates that Black children display maxillary and mandibular enlargement at age 10 and 13, despite some anterior displacement at age 11 and superior displacement at age 12 in Coloured children at various landmarks. Therefore, the lower middle face index is influenced by ancestry after the age of 10 in such a way that the mandible is more prognathic in Black males than in other groups at age 13.

6.3.1.2 Male *vs* Female children

In Figure 6.2 generalized craniofacial growth patterns are demonstrated from the results of the craniofacial indices and geometric morphometrics to show differences between male and female children.

Posterior displacement of the supraglabella and anterior displacement of the glabella were seen at ages 6, 7, 9 and 13 years. Posterior displacement of the supraglabella was seen at ages 10 to 12 years. The displacement is pronounced at age 13. This displacement coincides with the development of the frontal paranasal sinuses from age 12 (Som and Curtin, 2003). Almost no displacement of the supraglabella and glabella were seen at the age of 8 years.

Male and female children follow a similar trend in terms of the elongation of the face due to growth in the mid-facial region after the age of 10. This trend is also seen on vector plots when comparing male and female children of the same age group. Inferior displacement of landmarks of the nasal tip, stomion and labiomentale was seen when comparing 11 year old males and females. The pattern was again seen specifically when comparing landmark displacement between 13 year old males and females. At age 13, more landmarks were involved (glabella, nasal tip, subnasal, labiale superius, stomion and labiale inferius) which may point toward growth acceleration and as a result, differences between sexes becoming more obvious at this age.

Phases of faster growth is seen in 9 to 11 year old males where the mandible expands more in height than the lower face height, thereby contributing more to the growth in facial height. Between ages 12 and 13 another period of mandibular height increase is seen in both males in females. According to the vector plots, landmarks of the lower face region shows inferior displacement indicative of increase in mandibular height in males at age 9. At ages 10 and 11, there is firstly an inferior and anterior displacement followed by an anterior displacement. In addition, specific inferior displacement of the lower face landmarks were seen at age 7 when males and females. Although the increase in mandibular height was not clearly visible at age 7 by means of the indices, vector plots were able to determine landmark displacement. Eruption of the mandibular central and lateral incisors, as well as the first molar takes place between 6 and 8 years, which could be correlated to landmark displacement. The lengthening of the mandible correlates with the eruption of the canines and pre-molars between ages 9 and 11 as well as the second permanent molar around the age of 12 (Işcan and Steyn, 2013). From age 6 to 9 (in males) and 6 to 10/11 (in females) the mandible expands in width (go-go), followed by a period where the face width (zy-zy) becomes larger. All males have longer noses in relation to their face height before the age of 13 compared to the females. This tendency is confirmed by vectors indicating the nasal tip and subnasale in males moving inferiorly in males specifically at ages 8 to 10 and at age 12. The lower middle face depth index separates groups in terms of sex until the age of 10. The mandible expands more in an anterior-posterior direction (as seen on lateral view) in males than in females. This trend is similar to that observed by Thordarson *et al.* (2006) in Icelandic children. In the current study it is confirmed by vector plots. At ages 6, 8 and 10, landmarks in the lower face region in males were displaced anteriorly and superiorly indicating forward displacement of the lower face region. At ages 7 and 9, inferior displacement of the same landmarks is seen indicating lengthening of the lower face region that includes the mandible. At age 11, the displacement is superior and anterior, but less lower region landmarks are involved and most the vectors are smaller, the exception being the stomion. At age 13, the vectors again indicate a superior displacement of the lower region landmarks in males. The vectors are however, smaller compared to males in younger age groups.

Taken together, the results of the vector plots confirm the results of the indices that show the differences between males and females are mostly located in the lower face region and at the forehead.

6.3.1.3 Facial growth trends ages 6 to 13 years

Enlargement of forehead width relative to head width is seen between 6 and 13 years. A sharp increase is seen between ages 6 and 7, which coincides with the expansion of the neurocranium specifically frontal lobe enlargement (Bogin, 1999). Between the age 12 and 13, the forehead suddenly becomes much wider in relation to head width. This enlargement matches the development of the frontal paranasal sinuses which shows a dramatic increase in size after age 12 until adulthood (Som and Curtin, 2003).

In addition, the forehead becomes rounder and smoother due to the loss of "bossing" of of the neurocranium. Bossing describes the protuberance of bones that form part of the cranial vault (frontal-, parietal- and, occipital bones). Bossing is more pronounced in the cranium of infants. Frontal and parietal bossing creates a pentagonoid appearance when the infant cranium is viewed from superior. On anterior view, only frontal bossing is visible. Bossing gradually disappears as the child becomes older and the skull becomes less angulated and more rounded to fit into the general curvature of the cranium (de Villiers, 1968).

On the lateral facial profile, the combination of the posterior displacement of the supraglabella and the anterior displacement at glabella relates to the enlargement of the brow bridge and the rounded appearance of the forehead. The enlargement of the brow bridge is supported by the findings of the indices, specifically between the 12 and 13 year old groups.

Progressive elongation of the face is seen from ages 6 to 13 which are mainly attributed to growth in the mid-facial region. Two stages of intense increase in the upper face index is seen respectively between 6 and 8 years and again between age 12 and 13, signaling that during these phases, elongation of the mid-face region relative to face width happens faster compared to other ages. Between the ages of 6 and 7, vectors showed an anterior displacement of the landmarks related to the mid-facial (nasion, nasal tip, subnasal) and lower face (labiale superius to labiomentale) regions. Between the ages 7 and 8, the vectors of the same landmarks in the lower face region showed less superior displacement. Between the ages of 12 and 13 the vectors showed a combined anterior and inferior displacement. The net effect of the vector displacement supports the notion of elongation of the face as shown by the indices at these ages.

These observations are supported by a recent bone modeling study by Martinez-Maza *et al*. (2013). Bone remodeling has shown that not all age-related changes are expansive in nature. Martinez-Maza *et al*. (2013) determined patterns of bone formation and resorption

in the facial skeletal of 6 children between the ages of 7 and 17. Five of these individuals are same age range as children from the current study. They found that the viscerocranium follows a predominantly downward and forward growth pattern. More specifically, they established that that bone formation occurred mainly in the following upper and mid-facial regions: Glabella, supercillary arch, nasal bones and frontal process of the maxilla. In contrast, areas of bone resorption were found in the lower face region, specifically the region involving the maxilla and frontal process of the zygomatic bone. The mandible also showed bone formation.

Eruption of maxillary molars between ages 6 and 7, eruption of the second maxillary molar between 12 and 13 and the enlargement of the maxillary paranasal sinuses contribute to the enlargement of the maxilla at these ages. Other indices showing the same tendency in the young age groups due to maxillary and mandibular tooth eruption, are the upper face-face height and mandibulo-lower face height index. Tooth eruption also influences indices related to the mouth and mandible. From age 6 to 13 the mouth (ch-ch) becomes wider in relation to the distance between bi-ocular width (ex-ex), but it seems to slow down at age 12 due to head width enlargement. Upper lip height is higher in relation to mouth width in the younger children, but in the older group mouth width increases. Cattaneo *et al*. (2012) reported the mouth width index for 6 year old children as 47.3 and for 10 year old children as 49.1 (sex pooled) for a sample consisting of Lithuanian, German and Italian children. The mouth width index for South African children is larger at age 6 (48.7) and at age 10 (51.5) (sex and ancestry pooled). In practical terms, it means that in South African children, the mouth is larger in relation to the bi-ocular width.

In general, the mandible expands in width from age 6 to 11, probably due to eruption of mandibular teeth. This expansion is followed by a period where the face width (zy-zy) becomes larger which also coincides with the lateral expansion of the maxillary sinus around the age of 12 which will reach full size by age 15 (Sergueef, 2007). The process is more pronounced in males with (larger paranasal sinuses) and starts at an earlier age compared to the females. Despite these dramatic changes related to tooth eruption and development of the anterior paranasal sinuses, the elongation of the face around age 9, dwarfs the events taking place around the mouth. The nose – face width index shows that nose width (al-al) becomes progressively wider in relation to face width (zy-zy) with age. Indices related to the eyes and face depth showed almost no differences. However, landmark displacements in the middle and lower face region were visible on a vector plot of the lateral facial profile, indicating shape changes in this region. Specifically, the

forward and downward displacement of the subnasal, stomion, labiale inferius and labiomentale indicate an increase in the anterior-posterior direction of the maxilla and the mandible, indicative of an increase in facial depth. Landmark displacement may be more easily detected as size is not considered in shape analysis, therefore little change in middle- and lower third face depth indices were seen as opposed to landmark displacement. Eye indices varied with 1 or 2 index points which is small in comparison to other indices. Differences between ancestries in terms of facial depth were more evident, and these were discussed above.

6.3.2 Facial growth in South African children *vs* North American children

Figure 6.3 demonstrates the generalized craniofacial growth difference according to craniofacial indices when comparing a sample of indigenous South African children (age, sex and ancestry combined) to the North American sample of Farkas and Munro (1987).

The faces of South African children are wider (zy-zy) with prominent cheek bones in relation to head width (eu-eu) compared to the North American children. In addition, the foreheads of South African children are also wider in relation to face width. The dome of the skull is not as high compared to the American children. South African children, aged 6 to 13, have shorter faces in relation to face width. In the South African sample, the upper face height is longer than in North American children. South Africans generally have shorter lower face regions and as a result, their chins are smaller in height, but more prominent in an anterior – posterior direction on lateral view.

The mandible height of the South African sample is smaller in relation to the face height compared to North American children. The mandibulo-lower face height index for South African children are also smaller compared to the North American sample, indicating that the mandible height is lower in relation to the upper face. South African children undergo phases where the mandible expands in height more than the lower face height thereby contributing more to the growth in facial height. This lengthening of the mandible correlates with the eruption of first permanent teeth around the age of 6 and the eruption of the second permanent molar around the age of 12 (Işcan and Steyn, 2013). The upper lip height is longer in relation to mouth width in South African children compared to North American children. South African children have a short mandible in relation to its width and in South African children, the mandible reaches adult size earlier compared to North American children. South African children have wider mandibles in relation to face

width. In the South African sample, the nose is wide in relation to its height and short in relation to face height and face width.

In terms of indices related to the eyes, only the intercanthal width in relation to face width was slightly larger in South African children, indicating that the eye in the South Africans are set apart wider compared to North American children, although it falls within the normal range described by Farkas and Munro (1987). In South African children, the middle third of the face (t-sn) increased relative more to the upper third of the face (t-n) from age 6 to 13, compared to North American children. In addition, the lower third of the face is larger in the South African sample indicating a more prognathic facial profile.

6.3.3 Facial growth summary of indigenous South African children between the ages 6 and 13 years

Craniofacial growth in children is a constant, dynamic process until adulthood is reached. Changes were observed in all indices although some showed very little change with age progression even between sex and ancestry groups. In terms of geometric morphometrics, almost no change in displacement was seen at the midphiltrum regardless of age, sex and ancestry. Indices related to the eye fell into this category as the eye is almost fully developed by age 7/8 (Vaughan *et al*., 1999). The surrounding orbits may change as head or face width changes as seen in the bi-ocular-face width index, but not the eye itself (Burke and Hughes-Lawson, 1988).

Most significant changes in craniofacial indices were seen around the age of 10. The mandible expanded in width before 10, while the face width expanded more after 10. Eruption of canines and pre-molars between ages 9 and 11 affected mandibular width. In males, indices show that the mandible grows faster around age 10 and as a result their facial profile is more prognathic than in females. This trend was confirmed by landmark displacement in the lower face region that indicated an increase in mandibular height at age 9 followed by forward displacement in combination to the inferior displacement at ages 10 and 11. In addition, specific inferior displacement of the lower face landmarks were seen at age 7, although the increase in mandibular height was not clearly visible in indices at age 7. This result supports the work by Braga and Treil (2007) who were able to more accurately determine age from geometric morphometric facial wire frames and centroid size as opposed to a basi-cranial wireframes and centroid size after the age of 10. Although they cite sample size as a possible reason, they also state that more changes in the facial skeleton takes place after age 10.

After age of 10, mandibular growth is influence by ancestry rather than of sex. This tendency was substantiated by vector plots which showed anterior displacement of lower face landmarks at ages 10 and 13 specifically, indicating that Black children display more maxillary and mandibular enlargement at these ages compared to Coloured children.

Between ages 6 and 7 a sharp increase in forehead width relative to head width is seen which coincides with the expansion of the neurocranium specifically frontal lobe expansion. From ages 6 to 8, an increase in the upper face index and elongation of the mid-face region relative to face width happens faster compared to other ages, due to eruption of maxillary molars between ages 6 and 7 and the enlargement of the maxillary paranasal sinuses. Also, an increase in upper face-face height and mandibulo-lower face height is seen due to maxillary and mandibular tooth eruption. The net effect of the vector displacement at the nasion, nasal tip and subnasal supports the elongation of the mid-facial region as shown by the indices from age 6 to 8. The landmark displacement from the labiale superius to labiomentale in the lower face is also indicative of lengthening of the lower face region in the younger age groups.

From age 11 to 12 the face width increases which coincides with the lateral expansion of the maxillary sinus around the age of 12. Between ages 12 to 13 an increase in forehead width to head width is seen which can be related to development of the frontal paranasal sinuses. An elongation of the mid-face region relative to face width is also apparent. This elongation happens faster compared to other ages, due to eruption of the second maxillary molar between 12 and 13 and the enlargement of the maxillary paranasal sinuses. Between the ages of 12 and 13, vectors showed a combined anterior and inferior displacement in the lower face region which support the finding of the indices related to the maxilla and mandible.

Geometric morphometrics showed that the net effect of the opposite displacements of the supraglabella and glabella created enlargement of the brow bridge and a rounded forehead in Coloured children. This effect is difficult to see in terms of indices as indices are measured in straight lines and do not follow the contour of the face shape. It was not possible to use geometric morphometrics to comment on changes in width, e.g., mouth width, bi-ocular width, face width, etc., as only the lateral face shape was analyzed. However, the intention of using geometric morphometrics on the lateral face shape was to comment on prognathic differences between groups in support of facial depth indices.

In comparison to North American children, the faces, foreheads, noses and mandibles of South African children are wider. South Africans generally also have more

prominent cheek bones and shorter faces.Viewed from laterally, the facial profile (from the orbital region to the mandible) of South African children are more concave in shape due to the maxillary and mandibular regions being more prognathic.

6.3.4 Face shape and mechanical stress

The influence of mechanical stress on bone is well known. Diets of predominantly hard or soft foods are said to change the masticatory apparatus in modern populations (Little *et al*., 2006). Several studies have shown that masticatory stress influences head and face morphology and as a result, face shape (Little *et al*., 2006; Patriquin, 2013). Some of the differences seen between South African and North American children may be accounted for by mechanical stress of the masticatory apparatus.

Patriquin (2013) demonstrated that South African Black adult males have more bite force at the incisors and first molars which causes more stress on the zygomatic arch, lateral margins of the orbit and mandible. The increased stress is associated with wider faces, wider mandibles and prognathism. These trends were also seen in the current study, where the South African children have wider faces and mandibles than their North American counterparts. They also displayed more prognathism compared to the North American children.

In addition, Patriquin (2006) determined that the upper facial index showed positive correlation with the degree of prognathism in adult Black South African males. This was also case in South African children. All groups showed a sharp increase in the upper facial index and upper face-head height indices between 6 and 8 and again between 12 and 13. The lower middle face depth, a measure of prognathism, shows a downward tendency indicating mandibular anterior-posterior expansion, confirming the results by Patriquin (2013) in adult Black males.

Glanville (1969) found that short, wide noses are correlated to prognathism, while Patriquin (2006; 2013) determined that mechanical stress due to bite force did not influence the nasal region. From these two studies it is clear that the wider nose of the South African children is associated with prognathism, genetics and environmental adaptions.

Prognathic individuals have to accommodate more mechanical stress in the frontal region during incisor and molar bite, however the degree of prognathism does not affect the appearance of features of the frontal region (brow ridge and glabella) (Patriquin, 2013). Therefore, the prominent foreheads seen in Coloured children with their wide, short,

paedomorphic faces may be the result of genetic and environmental control rather than prognathism, a feature that is less evident in this group compared to Black children.

6.3.5 Practical applications

Datasets for tissue thickness and craniofacial indices created by the current study serve as reference for South African children of Black and Coloured ancestry aged 6 to 13 years.

The findings of the current study have shown that tissue thickness cannot be pooled without taking age and ancestry into account. In practice, the tissue thickness data can be used to produce a facial reconstruction / approximation that are realistic and closely resemble a missing South African child of Black or Coloured ancestry. Craniofacial index data from this study can be used by the forensic artist to two dimensionally age a child who has been missing for some time. For example, if a Black child was 6 years old when he disappeared in 2010, his facial index was 75.97. In 2014, the child would be 10 years old and his facial index 80.89 (Appendix II). The calculation is as follows: [{(80.89 - 75.97) / 80.89} x 100] = 6.1%. As a result, from age 6 to age 10, the child's face became 6% longer since age 6. Furthermore, the craniofacial indices can be used by clinicians as a normative dataset to determine facial dysmorphology in their patients in order to diagnose syndromes such as FAS which has a high prevalence in South Africa. The dataset will also be of use in planning reconstructive maxilla-facial surgery and orthodontic treatment as it provides the normal ranges for maxillary and mandibular prognathism for Black and Coloured children.

Facial growth, inferred from craniofacial indices and lateral face shape profiles of Black and Coloured children, as well male and female South African children, are presented in Figures 6.1 and 6.2. These growth patterns summarize the main findings and differences between the different groups. The visual presentation of the growth patterns is aimed at promoting the understanding the facial growth of a sample of South African children.

6.4 BMI of South African children

The descriptive analysis of BMI is supplementary to the current study because the schools requested this information as part of the conditions under which anthropometric assessment of the children was allowed to be conducted. In this section, comments

regarding the overall health / nutrition of the group and how this may have influenced their overall growth will be made.

In South Africa, research regarding BMI has been conducted in various areas either as cross-sectional (Armstrong *et al*., 2006; Kimani-Murage *et al*., 2010; Tathiah *et al.*, 2013) or as longitudinal cohort studies (Henneberg and Louw, 1998; Richter *et al*., 2007; Monyeki *et al*., 2008). The study by Armstrong *et al.* (2006) is known as the "Health of the Nation" paper and included several South African groups of different ancestry. Tathiah *et al.* (2013) conducted a secondary analysis on anthropometric data of Black female children aged 9 to 13 years which were collected during the 2011 Human Papilloma Virus (HPV) Vaccination Demonstration Project.

The current study showed a significant increase in the percentage in overweight and obese children compared to Armstrong *et al*. (2006) and Tathiah *et al.* (2013). In effect, there was an 8% increase of obesity under Black children compared to a decrease of 4% in Coloured children. The data used in the study by Tathiah *et al.* (2013) were collected in 2011 and should show more correlation to the current study than with Armstrong *et al.* (2006). However, this is not the case. A possible reason for this may be that the current study included both rural and urban children in contrast to Tathiah *et al.* (2013) who only analyzed data from rural female children.

The current study determined that 8.4% of Black children and 12.7% of Coloured children were underweight with children aged 6 to 9 years being most affected. Armstrong *et al.* (2006) did not report on the underweight children, but Tathiah *et al.* (2013) found that 4% of children were underweight with the highest prevalence in the 10 year old group.

Good nutrition is important to maintain good health. Malnutrition includes both undernutrition and overnurtrition. Undernutrition is usually seen as an individual being underweight with or without muscle wasting and stunted growth, and overnurtrition is seen in individuals being overweight or obese, with or without a history of stunted growth (Reddy *et al*., 2009; Tathiah *et al.* 2013). Malnutrition creates a variety of health problems. These health problems are aggravated by continued malnutrition as malnourished individuals are more prone to disease described as the "malnutrition-infection complex" (FOA, n.d.). In this regard, the increase of obesity under Black children is as problematic as the large number of underweight Coloured children and should be pertinently addressed. The situation is worsening as the current study has shown that there seems to be a shift from normal weight to overweight in Black children of whom 10.9% are already

overweight, and thus at risk of becoming obese. Coloured children are mostly of normal weight, but are more at risk of being underweight rather than overweight.

Sedlmeyer and Palmert (2002) and Kimani-Murgae *et al*. (2010) determined that South African girls tend to be overweight / obese, which is also confirmed by the present study. Obese children are more at risk becoming obese adults creating problems regarding health, social interaction, and on economic and psychosocial level (Kimani-Murage *et al*., 2010; WHO, 2012). Undernutrition is more prevalent in South African boys which is said to delay the pubertal growth spurt (Sedlmeyer and Palmert, 2002; Jinabhai et al., 2007). The current study also found boys; specifically Coloured boys, have a tendency to be underweight as a result of undernutrition. Children who are underweight do not reach developmental stages on time, have low energy levels, poor self-image and show signs of stunted growth (Reddy *et al*., 2009).

The consequences of stunted growth in childhood are far reaching as it increases the child's vulnerability to infections, delay the onset of puberty, reduce adult height, diminish cognitive ability and result in behavioral problems. The combined effect of stunted growth and obesity between the ages of 10 to 13 years, in addition to SES and delayed pubertal development, are significant predictors of the risk of cardio- and metabolic disease in adulthood (Reilly *et al*., 2003; Kimani-Murage (2013).

The results of the BMI part of the study will be conveyed to the schools as per agreement. It is suggested that in addition to increased levels of activity and physical education, region specific intervention strategies at schools and parental guidance should be developed to promote normal growth and overall health status of South African children.

6.5 Limitations of the study

Due to the cross-sectional nature of the study, the data cannot be used to comment on real growth of the sample *per se*, but this problem is not new to index studies using a cross-sectional design (Farkas, 1987; Farkas *et al*., 1992, Farkas *et al*., 1994; Sforza *et al*., 2012, Torres-Restrepo *et al*., 2014). However, the combination of indices and face shape analysis in the study provided an approximation of facial development in South African children.

Despite the large number of children included in the tissue thickness part of the study (n = 388), the younger age groups are underrepresented. The underrepresentation of young children is also seen in other studies where pooled data are used to circumnavigate

the problem, (Dumont, 1986; Manhein et al., 2000; Wilkinson, 2002; Williamson *et al.*, 2002; Utsuno *et al.*, 2007; 2010; Stephan and Simpson, 2008b; Stephan, 2014). Future studies should aim specifically to increase sample sizes in these groups.

In the current study, only midline tissue thickness were measured in cephalograms as not enough CT scans of children were available at the local academic hospital to meet the sample size criteria. A variety of methods have been used in order to obtain tissue thickness data. Stephan and Simpson (2008a), obtained tissue thickness data from different authors using different methodologies (needle puncture, ultrasound, cephalograms, CT scans and MRI). They showed that tissue thickness data did not differ significantly regardless of which method was used and that no method was superior to the other. Recent studies favoured either ultrasound (Peckman *et al.*, 2013) or CT (Ruiz, 2013; Parks *et al.*, 2014).

The use of photoanthropometry for measuring facial dimensions have been criticized due to potential measurement errors which may occur due to magnification, varying subject to camera distance, variation of head position between subjects, the angle of the camera and incorrect landmark identification (Farkas, 1980; Wong *et al.*, 2008; Moreton and Morley, 2011; FISWG guidelines v1.0, 2012). Although every precaution in the current study was taken to control conditions in order to minimize these problems, the issue remains contentious. Davies *et al.* (2010) pointed out that facial expressions may differ even in the neutral position.

Landmark identification further contributes to potential measurement errors. Although repeatability was tested and care was taken to ensure proper visualization of landmarks, it remains a problem regardless of which method is used to obtain anthropometric measurements (direct anthropometry, photo-anthropomtery or three dimensional laser scanning) (Farkas, 1980; Weinberg *et al.*, 2006; Wong *et al.*, 2008; Wei *et al.*, 2011; Moreton and Morley, 2011; Medonca *et al.*, 2013). The calculation of indices from measurements rather than using actual measurements to some extent reduce measurement error due to landmarks misidentification.

In the present study, only the shape of the lateral facial profile was analyzed by means if geometric morphometrics. Lateral profiles enable visualization of shape changes regarding the forehead, nose, mouth as well as the degree of prognathism. Vectors were used as indicators of landmark displacement and the similarities/dissimilarities between groups were determined by means of Goodall's F test and Hotteling's T^2-test. The current study did not include aspects related to size e.g., centroid size. As a result, no comment

regarding age related changes in size derived from geometric morphometric analysis can be made.

The impact of BMI on tissue thickness in adults has been described (De Greef *et al*., 2006; Starbuck and Ward, 2007; Codinha, 2010; Tedeschi-Oliveira, 2010), but the effect of BMI on tissue thickness in South African children could not be assessed due to the lack of information in patient files. This is likely to remain a difficult problem in future studies for several reasons: First, the weight and height of children are not routinely collected when patient present for orthodontic evaluation. Special permission has to be sought from an ethics committee to actively recruit patients on site in order to obtain the necessary consent and assent. Second, a dedicated trained person and equipment is needed to perform the measurements as the patients arrive to ensure reliability and validity. Third, girls from the age of 11 typically present for orthodontic evaluation. Unless such a study includes more research sites e.g., dental practices, the younger age groups and boys will remain underrepresented. However, besides the increase in sample sizes, another potential benefit of including more sites would be to conduct the study as a longitudinal investigation rather than a cross-sectional study. However, problems such as sample attrition, collection of data over several years and cost are challenges associated with longitudinal studies which would have to be addressed.

The sample comprised of children from two different geographical origins: Gauteng and Western Cape. Therefore, the results of the current study of relate to Black children in Gauteng and Coloured children from the Western Cape and not necessarily to all Black and Coloured children in the remaining parts of South Africa.

Also, the sample comprised of children from predominantly low SES communities and children from high and middle SES may present differently in terms of tissue thickness, facial dimensions, facial growth and BMI.

Regardless of these limitations, the data collected in the current study provide a quantitative description of the facial features from three different perspectives (tissue thickness, craniofacial indices and lateral face shape analysis) of Black and Coloured South African children.

6.6 Future research

The current study points the way toward a number of research opportunities that will have practical applications in the forensic and clinical fields. These include:

- The South African tissue thickness data from this study should be applied to reconstruction / approximation of juvenile remains between the ages of 6 and 13 and compared to reconstruction / approximation of the same individual using tissue thickness data from other authors, so that the practical value of population and sex specific data can be assessed in terms of best resemblance testing;
- Tissue thickness data from the current study can be validated by means of three dimensional reconstructions / approximations of skulls from CT scans of living children. For this reason it is suggested that CT scans of children between age 6 and 13 should be obtained and the midline tissue thicknesses re-measured and correlated to the tissue thicknesses from the midline as measured on cephalograms of the current study. In addition, lateral facial tissue thickness landmarks such as the frontal eminence, fronto-temporale, supra-orbital, sub-orbital, zygomaxillare, midmassetric etc. should also be included. A large enough sample size would be possible if more research sites are included. It would also be advisable to conduct the investigation as a prospective study where weight and height of children can be noted, instead of a retrospective study were only patient files are accessed which do not contain this information. This approach will enable the researcher to determine whether BMI should be considered as a co-variant for tissue thickness.
- The statistical significant differences in tissue thickness of less than 3 mm should be assessed in order to determine whether sex and ancestry differences are of practical value in facial reconstructions /approximations. In this regard, local forensic artists should be approached and asked to reconstruct / approximate the face of a Black or Coloured South African child between 6 and 13 (with known identity), based the tissue thickness dataset from the current study. They will be provided with two thickness datasets which have shown differences between 1 mm and 3 mm in the current study: one that has been generalized (6 to 10 years and 11 to 13 years with sex and ancestry pooled) and one per age and ancestry (sex pooled). The reconstruction / approximation should be assessed in terms of best resemblance testing by independent volunteers.
- In order to track facial growth and associated facial changes, a longitudinal cohort study would be more suitable for both tissue thickness and craniofacial indices. This longitudinal study should take a multi-centre approach in order to obtain an adequate sample size despite anticipated sample attrition. In the interest of inclusiveness it would be beneficent to include not only Black and Coloured children, but also children

from Indian and European descent so that a comprehensive database for South African children can be established;

- Age estimation by means of geometric morphometrics and craniofacial indices can be tested on the images from the current study as the age (sex and self-reported ancestry) of the children were documented. In terms of geometric morphometrics, the wire frame and resultant centroid size of facial landmarks involving the ectocanthion, endocanthion, alare, chelion, stomion etc. can be used to correlate size with age. Images and craniofacial indices obtained from the current study can also be used to verify the age range of children shown in two dimensional pornographic material, to assist in ageing a child who has been missing for several months / years and to provide a normative database specific to age, sex and ancestry against which South African children with undiagnosed FAS can be assessed.
- A follow-up BMI study in the same schools where data were originally gathered for craniofacial indices should be conducted to assess the health status of the children against previously collect BMI information. A multi-disciplinary team consisting of physical anthropologists, dieticians and public health professionals should be included. Both physical measurements and health / nutrition questionnaires should form part of the investigation.

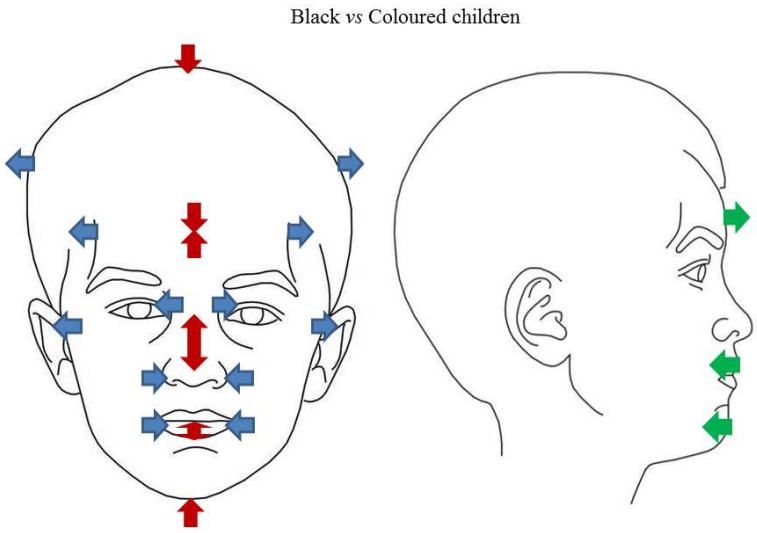

Figure 6.1: Vectors inferred from craniofacial indices and lateral face shape profiles as determined by geometric morphometrics to show the generalized craniofacial growth patterns for Black and Coloured South African children. The arrows indicate the changes in indices and direction of landmark displacement in Coloured children relative to that of Black children.

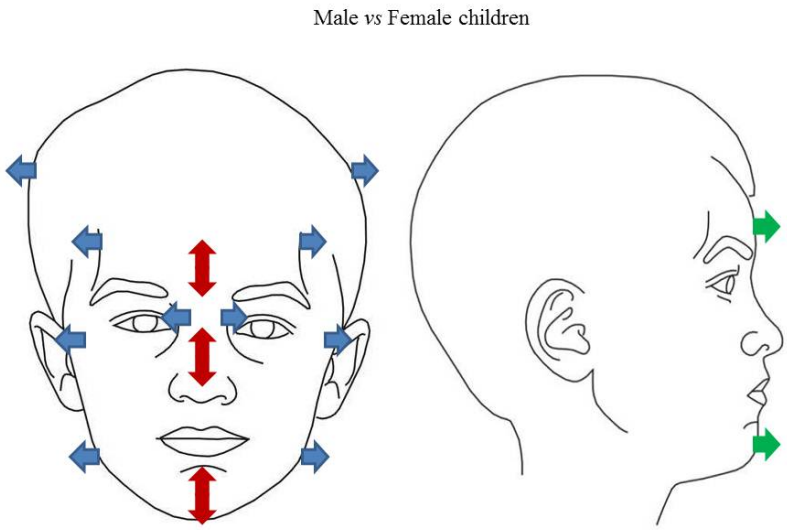

Figure 6.2: Vectors inferred from craniofacial indices and lateral face shape profiles as determined by geometric morphometrics to show the generalized craniofacial growth patterns for male and female South African children. The arrows indicate the changes in indices and direction of landmark displacement in male children relative to that of female children.

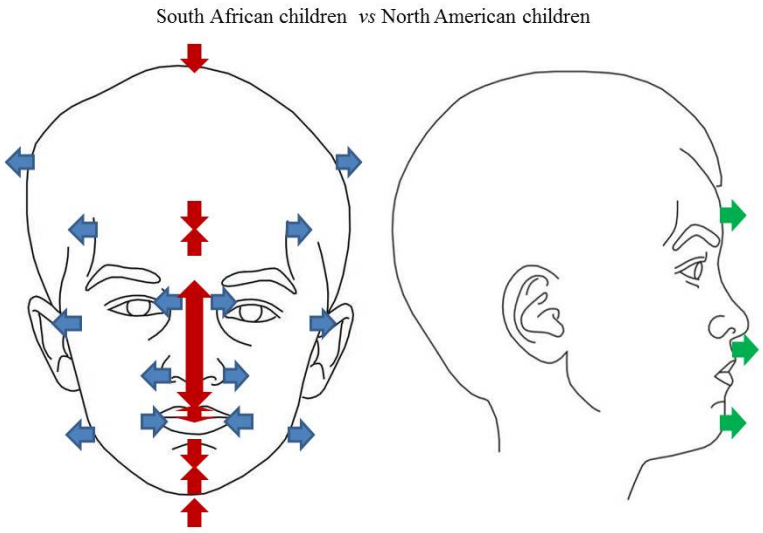

Figure 6.3: Changes in craniofacial indices to show the generalized craniofacial growth patterns for indigenous South African children in comparison to North American children. The arrows indicate the changes in indices in South African children relative to North American children.

Chapter 7: Conclusions

The primary aims of this study were to develop standards for soft tissue thickness and craniofacial indices for South African children aged 6 to 13 years and to describe changes in craniofacial morphology at different ages. In this regard, the current study is the first to provide complete datasets of tissue thickness and craniofacial indices of South African children that are age, sex and ancestry specific. In addition, the combination of craniofacial indices and geometric morphometrics used to determine generalized facial growth patterns in South African children is new and as far as could be determined, has not been reported in literature to date. The following can be concluded from the study:

1. Tissue thickness data are important in order to produce facial reconstructions / approximations that will portray a realistic image of a child. For this purpose, tissue thickness data for South African children that are age, sex and ancestry specific have been developed. Based on the findings, it is best to set up tables for soft tissue thickness in two age groups, namely 6 – 10 years and 11 to 13. Tissue thickness data should be appropriate in terms of ancestry, but it is not necessary to use different tables for different sexes.
2. Craniofacial indices provide information on facial proportions and growth at various ages. The craniofacial indices developed by this study provide a normative dataset for South African children aged 6 to 13 years per age, sex and ancestry.
3. The tissue thickness and craniofacial index sections of the study demonstrated that most of the changes in the face occur around age 10.
4. Differences between ancestry groups are especially linked to differences in the forehead shape and maxillary- and mandibular projection and size.
5. The short, wide faces and small chins of Coloured children resemble, to some extent, the descriptions found in older anthropology texts of the infantile appearance of the Khoesan.
6. The degree of prognathism is dictated by ancestry and to a lesser extent, by age and sex as findings showed that maxillary prognathism was more prominent in Black children, while mandibular prognathism was more pronounced in male children. Tooth eruption is probably the major reason for differences seen between age groups and to a lesser extent, the increased size of the frontal lobes of the brain as well as the development frontal and maxillary paranasal sinuses. In terms of sex, differences between males and females in the upper face region relate to the development of the

frontal paranasal sinus, and in the lower face region to mandibular prognathism. Enlargement of the frontal sinuses with age progression was responsible for age related changes from 6 to 13 years in the upper region of the lateral face profile where the supraglabella and glabella were displaced in opposite directions. The larger, sloping brow bridge in males was demonstrated by the inferior displacement of landmarks of the forehead (supraglabella, glabella, and nasion).

7. Forehead differences between Black and Coloured children are less prominent as only minor inferior and anterior displacements were seen of the supraglabella and glabella. The mandible lengthens in an anterior posterior direction as children become older as the lower face landmarks (labiale superior, stomion, labiale inferius and labiomentale) were inferiorly and anteriorly displaced with age.
8. The longer faces of males in comparison to females relates mainly to the inferior displacement of the landmarks of the mandible (stomion, labiale inferius and labiomentale) in males.
9. Prognathism in Black children is seen by the anterior and superior landmark displacement in the lower face (labiale superius, stomion, labiale inferius and labiomentale).
10. Craniofacial index data from living South African children were developed to add to knowledge of the normal range of facial proportions. This knowledge can be used to adjust and to some degree calculate / project changes in children's faces due to facial growth, specifically in cases where children have been missing for an extended period of time and where comparable photographs are limited. Furthermore, the South African indices will enable clinicians to diagnose and provide proper treatment for local juvenile patients with syndromes that presents with facial dysmorphology. Craniofacial indices and face shape data presented here will hopefully in future also assist in the identification of children as well as the verification of the ages of children involved in pedo-pornographic material.

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Appendix I: Tissue thickness for Black and Coloured South African children aged 6 to 13 years (mean ± 1 SD)

Supraglabella									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	0.96	3.24	5.53	2.28	7.81	10.09
Black	Male	7	5	2.94	3.74	4.54	0.80	5.33	6.13
Black	Male	8	2	4.20	4.82	5.44	0.62	6.06	6.68
Black	Male	9	4	2.70	3.51	4.32	0.81	5.13	5.94
Black	Male	10	11	3.25	3.87	4.49	0.62	5.10	5.72
Black	Male	11	7	4.05	4.51	4.98	0.47	5.44	5.91
Black	Male	12	5	2.50	3.62	4.73	1.12	5.85	6.97
Black	Male	13	7	2.29	3.42	4.54	1.13	5.67	6.80
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	3.99	4.49	5.00	0.50	5.50	6.00
Black	Female	8	6	3.45	4.27	5.09	0.82	5.90	6.72
Black	Female	9	6	2.48	3.66	4.84	1.18	6.01	7.19
Black	Female	10	6	2.93	3.73	4.54	0.80	5.34	6.14
Black	Female	11	9	3.19	4.12	5.06	0.94	6.00	6.93
Black	Female	12	11	2.48	3.88	5.28	1.40	6.68	8.08
Black	Female	13	5	4.05	4.74	5.44	0.70	6.14	6.83
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	3.75	4.32	4.88	0.57	5.45	6.01
Coloured	Male	8	8	2.01	3.25	4.48	1.24	5.72	6.96
Coloured	Male	9	21	1.37	3.17	4.97	1.80	6.77	8.57
Coloured	Male	10	10	2.91	3.67	4.42	0.76	5.18	5.93
Coloured	Male	11	21	2.08	3.20	4.31	1.11	5.42	6.53
Coloured	Male	12	22	3.07	4.13	5.20	1.06	6.26	7.32
Coloured	Male	13	23	3.14	4.19	5.23	1.05	6.28	7.33
Coloured	Female	6	0	N/A	-	-	-	-	-
Coloured	Female	7	5	2.29	3.83	5.38	1.55	6.93	8.47
Coloured	Female	8	6	3.16	3.99	4.82	0.83	5.64	6.47
Coloured	Female	9	24	1.57	3.53	5.49	1.96	7.44	9.40
Coloured	Female	10	26	2.77	3.59	4.41	0.82	5.23	6.05
Coloured	Female	11	37	2.14	3.48	4.82	1.34	6.15	7.49
Coloured	Female	12	52	2.79	3.84	4.88	1.04	5.93	6.97
Coloured	Female	13	38	2.82	3.77	4.72	0.95	5.67	6.62

Glabella									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	3.03	4.72	6.42	1.70	8.12	9.81
Black	Male	7	5	2.49	4.15	5.81	1.66	7.47	9.13
Black	Male	8	2	3.80	5.08	6.35	1.27	7.62	8.90
Black	Male	9	4	3.07	4.10	5.13	1.03	6.15	7.18
Black	Male	10	11	3.95	4.55	5.14	0.59	5.73	6.33
Black	Male	11	7	3.99	4.80	5.60	0.81	6.41	7.21
Black	Male	12	5	3.57	4.48	5.39	0.91	6.29	7.20
Black	Male	13	7	3.52	4.69	5.86	1.17	7.02	8.19
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	4.63	5.05	5.47	0.42	5.88	6.30
Black	Female	8	6	3.74	4.91	6.08	1.17	7.25	8.42
Black	Female	9	6	2.65	3.98	5.31	1.33	6.64	7.97
Black	Female	10	6	3.53	4.53	5.54	1.01	6.55	7.56
Black	Female	11	9	4.08	5.16	6.24	1.08	7.32	8.40
Black	Female	12	11	3.57	4.81	6.06	1.25	7.30	8.55
Black	Female	13	5	5.46	5.88	6.30	0.42	6.72	7.14
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	2.88	4.47	6.06	1.59	7.65	9.24
Coloured	Male	8	8	1.33	3.84	6.34	2.50	8.84	11.35
Coloured	Male	9	21	3.58	5.09	6.60	1.51	8.11	9.62
Coloured	Male	10	10	3.70	4.84	5.98	1.14	7.12	8.26
Coloured	Male	11	21	3.79	4.74	5.69	0.95	6.64	7.59
Coloured	Male	12	22	4.02	5.00	5.98	0.98	6.97	7.95
Coloured	Male	13	23	4.42	5.40	6.39	0.98	7.37	8.35
Coloured	Female	6	0	N/A	-	-	-	-	-
Coloured	Female	7	5	3.18	4.85	6.52	1.67	8.19	9.86
Coloured	Female	8	6	4.14	5.14	6.14	1.00	7.14	8.14
Coloured	Female	9	24	2.13	4.45	6.77	2.32	9.10	11.42
Coloured	Female	10	26	3.46	4.58	5.69	1.11	6.81	7.92
Coloured	Female	11	37	3.71	4.87	6.03	1.16	7.19	8.35
Coloured	Female	12	52	2.62	4.20	5.77	1.58	7.35	8.93
Coloured	Female	13	38	3.68	4.90	6.11	1.21	7.33	8.54

Nasion									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	4.50	4.52	4.53	0.01	4.54	4.56
Black	Male	7	5	3.76	4.33	4.90	0.57	5.47	6.04
Black	Male	8	2	4.78	5.03	5.28	0.25	5.52	5.77
Black	Male	9	4	3.99	4.39	4.79	0.40	5.18	5.58
Black	Male	10	11	3.43	4.31	5.19	0.88	6.07	6.95
Black	Male	11	7	2.24	3.62	5.00	1.38	6.39	7.77
Black	Male	12	5	3.25	4.07	4.89	0.82	5.71	6.53
Black	Male	13	7	2.49	3.42	4.36	0.94	5.30	6.24
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	0.18	2.35	4.53	2.17	6.70	8.87
Black	Female	8	6	3.93	4.58	5.23	0.65	5.88	6.53
Black	Female	9	6	2.23	3.38	4.53	1.15	5.68	6.83
Black	Female	10	6	3.03	4.24	5.44	1.20	6.64	7.85
Black	Female	11	9	1.95	3.54	5.13	1.59	6.71	8.30
Black	Female	12	11	2.94	4.13	5.33	1.19	6.52	7.71
Black	Female	13	5	0.45	2.44	4.44	1.99	6.43	8.42
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	1.30	2.99	4.69	1.69	6.38	8.07
Coloured	Male	8	8	3.03	3.90	4.78	0.88	5.65	6.53
Coloured	Male	9	21	2.69	4.24	5.78	1.54	7.32	8.86
Coloured	Male	10	10	1.14	3.05	4.96	1.91	6.87	8.78
Coloured	Male	11	21	2.06	3.50	4.94	1.44	6.39	7.83
Coloured	Male	12	22	2.23	3.92	5.60	1.68	7.28	8.97
Coloured	Male	13	23	3.06	4.36	5.66	1.30	6.96	8.26
Coloured	Female	6	0	N/A	-	-	-	-	-
Coloured	Female	7	5	4.71	5.13	5.55	0.42	5.97	6.40
Coloured	Female	8	6	2.36	3.99	5.63	1.63	7.26	8.89
Coloured	Female	9	24	2.76	4.25	5.73	1.49	7.22	8.70
Coloured	Female	10	26	3.21	4.33	5.46	1.12	6.58	7.70
Coloured	Female	11	37	1.95	3.52	5.09	1.57	6.66	8.22
Coloured	Female	12	52	2.11	3.67	5.23	1.56	6.80	8.36
Coloured	Female	13	38	2.87	4.19	5.51	1.32	6.83	8.15

End nasal									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	1.60	2.12	2.65	0.52	3.17	3.69
Black	Male	7	5	1.25	1.83	2.42	0.58	3.00	3.59
Black	Male	8	2	1.04	1.64	2.23	0.59	2.82	3.42
Black	Male	9	4	0.47	1.29	2.11	0.82	2.92	3.74
Black	Male	10	11	1.58	2.05	2.52	0.47	3.00	3.47
Black	Male	11	7	1.67	2.24	2.80	0.56	3.37	3.93
Black	Male	12	5	1.58	2.11	2.64	0.53	3.17	3.70
Black	Male	13	7	2.06	2.30	2.54	0.24	2.78	3.02
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	1.57	1.97	2.37	0.40	2.77	3.17
Black	Female	8	6	1.36	1.95	2.53	0.59	3.12	3.70
Black	Female	9	6	1.97	2.21	2.45	0.24	2.69	2.93
Black	Female	10	6	1.62	2.04	2.46	0.42	2.89	3.31
Black	Female	11	9	0.38	1.68	2.98	1.30	4.28	5.58
Black	Female	12	11	1.37	1.96	2.55	0.59	3.14	3.73
Black	Female	13	5	1.86	2.07	2.28	0.21	2.49	2.70
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	0.50	1.18	1.87	0.69	2.56	3.24
Coloured	Male	8	8	1.13	1.66	2.18	0.52	2.70	3.22
Coloured	Male	9	21	0.40	1.35	2.30	0.95	3.25	4.20
Coloured	Male	10	10	0.86	1.38	1.90	0.52	2.42	2.93
Coloured	Male	11	21	0.95	1.52	2.09	0.57	2.65	3.22
Coloured	Male	12	22	0.96	1.62	2.28	0.66	2.93	3.59
Coloured	Male	13	23	0.83	1.49	2.14	0.66	2.80	3.46
Coloured	Female	6	0	N/A	-	-	-	-	-
Coloured	Female	7	5	0.72	1.33	1.94	0.61	2.54	3.15
Coloured	Female	8	6	0.14	1.45	2.76	1.31	4.07	5.38
Coloured	Female	9	24	0.59	1.44	2.29	0.85	3.14	3.98
Coloured	Female	10	26	0.80	1.50	2.19	0.70	2.89	3.58
Coloured	Female	11	37	1.03	1.68	2.33	0.65	2.98	3.62
Coloured	Female	12	52	0.84	1.49	2.14	0.65	2.79	3.44
Coloured	Female	13	38	0.96	1.60	2.24	0.64	2.88	3.51

Midphiltrum									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	4.22	7.23	10.24	3.01	13.25	16.26
Black	Male	7	5	5.90	8.71	11.52	2.81	14.32	17.13
Black	Male	8	2	1.65	6.84	12.03	5.19	17.22	22.41
Black	Male	9	4	6.74	8.85	10.96	2.11	13.06	15.17
Black	Male	10	11	5.20	7.96	10.72	2.76	13.48	16.24
Black	Male	11	7	8.29	9.47	10.65	1.18	11.83	13.02
Black	Male	12	5	7.39	10.16	12.92	2.77	15.69	18.45
Black	Male	13	7	5.83	8.93	12.04	3.11	15.15	18.25
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	3.39	6.43	9.47	3.04	12.51	15.55
Black	Female	8	6	5.73	7.79	9.85	2.06	11.91	13.97
Black	Female	9	6	4.90	7.22	9.54	2.32	11.86	14.18
Black	Female	10	6	3.88	6.51	9.15	2.64	11.79	14.42
Black	Female	11	9	4.51	6.90	9.30	2.40	11.70	14.09
Black	Female	12	11	6.77	8.79	10.81	2.02	12.84	14.86
Black	Female	13	5	8.98	10.23	11.48	1.25	12.74	13.99
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	5.35	8.30	11.26	2.96	14.22	17.18
Coloured	Male	8	8	9.03	11.68	14.33	2.65	16.97	19.62
Coloured	Male	9	21	5.45	8.65	11.86	3.21	15.07	18.27
Coloured	Male	10	10	7.51	9.80	12.09	2.29	14.37	16.66
Coloured	Male	11	21	7.64	10.51	13.38	2.87	16.25	19.12
Coloured	Male	12	22	6.90	10.12	13.34	3.22	16.56	19.78
Coloured	Male	13	23	3.76	8.35	12.95	4.59	17.54	22.14
Coloured	Female	6	0	-	-	-	-	-	-
Coloured	Female	7	5	7.21	9.68	12.15	2.47	14.63	17.10
Coloured	Female	8	6	6.62	9.71	12.80	3.09	15.88	18.97
Coloured	Female	9	24	9.17	10.97	12.78	1.81	14.59	16.39
Coloured	Female	10	26	4.91	8.44	11.98	3.54	15.51	19.05
Coloured	Female	11	37	8.38	11.02	13.67	2.65	16.31	18.96
Coloured	Female	12	52	5.80	9.16	12.52	3.36	15.87	19.23
Coloured	Female	13	38	5.93	9.19	12.44	3.25	15.69	18.94

Labiale superius									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	8.39	11.31	14.24	2.92	17.16	20.08
Black	Male	7	5	8.13	10.33	12.54	2.21	14.74	16.95
Black	Male	8	2	8.36	10.38	12.40	2.02	14.41	16.43
Black	Male	9	4	5.16	8.21	11.25	3.04	14.29	17.34
Black	Male	10	11	8.74	10.52	12.30	1.78	14.07	15.85
Black	Male	11	7	10.15	11.14	12.14	1.00	13.13	14.13
Black	Male	12	5	7.48	8.92	10.37	1.44	11.81	13.26
Black	Male	13	7	4.97	8.70	12.43	3.73	16.15	19.88
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	10.83	11.79	12.75	0.96	13.71	14.66
Black	Female	8	6	11.85	12.47	13.10	0.62	13.72	14.34
Black	Female	9	6	8.18	10.33	12.48	2.15	14.63	16.79
Black	Female	10	6	8.96	10.52	12.07	1.56	13.63	15.19
Black	Female	11	9	10.39	11.40	12.41	1.01	13.42	14.43
Black	Female	12	11	9.17	11.14	13.10	1.97	15.07	17.04
Black	Female	13	5	9.67	11.79	13.91	2.12	16.02	18.14
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	8.17	10.13	12.09	1.96	14.05	16.01
Coloured	Male	8	8	6.43	9.37	12.31	2.94	15.25	18.19
Coloured	Male	9	21	9.10	11.00	12.90	1.90	14.81	16.71
Coloured	Male	10	10	6.32	8.99	11.66	2.67	14.33	17.00
Coloured	Male	11	21	7.47	9.78	12.08	2.31	14.39	16.70
Coloured	Male	12	22	7.74	10.32	12.90	2.58	15.48	18.06
Coloured	Male	13	23	9.87	11.58	13.28	1.71	14.99	16.70
Coloured	Female	6	0	-	-	-	-	-	-
Coloured	Female	7	5	8.52	10.70	12.88	2.18	15.06	17.24
Coloured	Female	8	6	5.39	8.72	12.06	3.33	15.39	18.72
Coloured	Female	9	24	6.90	9.57	12.24	2.67	14.91	17.58
Coloured	Female	10	26	6.70	9.27	11.83	2.56	14.39	16.96
Coloured	Female	11	37	8.39	10.48	12.58	2.09	14.67	16.77
Coloured	Female	12	52	8.56	10.47	12.37	1.91	14.28	16.19
Coloured	Female	13	38	7.03	9.52	12.01	2.49	14.50	16.99

Labiale inferius									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	2.93	7.10	11.27	4.17	15.44	19.61
Black	Male	7	5	10.12	12.23	14.34	2.11	16.45	18.56
Black	Male	8	2	9.57	10.07	10.56	0.49	11.05	11.55
Black	Male	9	4	7.63	9.63	11.62	1.99	13.61	15.60
Black	Male	10	11	8.57	10.44	12.31	1.87	14.18	16.05
Black	Male	11	7	9.55	11.31	13.08	1.77	14.85	16.62
Black	Male	12	5	9.87	11.14	12.41	1.27	13.68	14.95
Black	Male	13	7	8.43	11.01	13.59	2.58	16.17	18.75
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	5.34	8.38	11.43	3.04	14.47	17.51
Black	Female	8	6	6.88	9.32	11.77	2.45	14.22	16.66
Black	Female	9	6	8.63	10.47	12.30	1.83	14.13	15.96
Black	Female	10	6	9.02	10.45	11.88	1.43	13.31	14.74
Black	Female	11	9	11.24	12.36	13.47	1.12	14.59	15.71
Black	Female	12	11	9.80	11.91	14.02	2.11	16.13	18.25
Black	Female	13	5	11.00	12.69	14.38	1.69	16.06	17.75
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	4.03	8.91	13.78	4.87	18.65	23.52
Coloured	Male	8	8	8.46	10.91	13.37	2.46	15.82	18.28
Coloured	Male	9	21	8.16	10.71	13.26	2.55	15.82	18.37
Coloured	Male	10	10	7.36	9.75	12.15	2.40	14.55	16.94
Coloured	Male	11	21	7.99	10.84	13.68	2.84	16.53	19.37
Coloured	Male	12	22	10.72	12.11	13.50	1.39	14.88	16.27
Coloured	Male	13	23	9.97	12.04	14.11	2.07	16.18	18.25
Coloured	Female	6	0	-	-	-	-	-	-
Coloured	Female	7	5	10.40	12.02	13.63	1.62	15.25	16.87
Coloured	Female	8	6	9.84	11.46	13.07	1.61	14.68	16.29
Coloured	Female	9	24	8.31	10.77	13.23	2.46	15.69	18.15
Coloured	Female	10	26	7.25	10.03	12.81	2.78	15.59	18.37
Coloured	Female	11	37	9.28	11.41	13.55	2.13	15.68	17.82
Coloured	Female	12	52	9.90	11.63	13.36	1.73	15.10	16.83
Coloured	Female	13	38	8.86	11.15	13.44	2.29	15.72	18.01

Labiomentale									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	5.98	7.79	9.60	1.81	11.41	13.22
Black	Male	7	5	6.29	8.34	10.39	2.05	12.43	14.48
Black	Male	8	2	9.52	10.49	11.47	0.98	12.45	13.42
Black	Male	9	4	5.59	7.77	9.95	2.18	12.13	14.31
Black	Male	10	11	6.33	8.13	9.93	1.80	11.74	13.54
Black	Male	11	7	7.89	9.57	11.25	1.68	12.93	14.62
Black	Male	12	5	8.48	9.18	9.87	0.69	10.56	11.26
Black	Male	13	7	10.20	11.24	12.27	1.03	13.31	14.34
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	6.29	8.60	10.91	2.31	13.22	15.52
Black	Female	8	6	7.48	9.07	10.66	1.59	12.26	13.85
Black	Female	9	6	8.33	9.48	10.63	1.15	11.77	12.92
Black	Female	10	6	8.77	9.59	10.42	0.82	11.24	12.06
Black	Female	11	9	8.95	10.01	11.07	1.06	12.13	13.18
Black	Female	12	11	8.16	9.51	10.85	1.35	12.20	13.55
Black	Female	13	5	7.67	10.33	12.99	2.66	15.65	18.31
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	6.96	8.65	10.33	1.68	12.01	13.69
Coloured	Male	8	8	7.14	9.26	11.38	2.12	13.49	15.61
Coloured	Male	9	21	7.74	10.21	12.68	2.47	15.15	17.63
Coloured	Male	10	10	8.24	10.17	12.09	1.93	14.02	15.95
Coloured	Male	11	21	7.84	9.55	11.27	1.72	12.98	14.70
Coloured	Male	12	22	7.80	10.07	12.35	2.27	14.62	16.89
Coloured	Male	13	23	8.06	10.18	12.29	2.12	14.41	16.52
Coloured	Female	6	0	-	-	-	-	-	-
Coloured	Female	7	5	9.01	9.79	10.56	0.77	11.33	12.11
Coloured	Female	8	6	7.72	9.32	10.92	1.60	12.52	14.11
Coloured	Female	9	24	7.95	10.18	12.41	2.23	14.64	16.88
Coloured	Female	10	26	7.11	8.95	10.80	1.85	12.64	14.49
Coloured	Female	11	37	6.67	9.27	11.86	2.59	14.45	17.05
Coloured	Female	12	52	8.47	10.15	11.84	1.68	13.52	15.20
Coloured	Female	13	38	8.11	10.15	12.20	2.04	14.24	16.28

Pogonion									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	5.45	7.66	9.88	2.21	12.09	14.30
Black	Male	7	5	7.93	9.23	10.53	1.30	11.84	13.14
Black	Male	8	2	8.90	9.31	9.72	0.41	10.13	10.54
Black	Male	9	4	6.25	8.65	11.05	2.40	13.45	15.85
Black	Male	10	11	7.91	8.95	9.99	1.04	11.03	12.07
Black	Male	11	7	6.09	8.30	10.52	2.21	12.73	14.94
Black	Male	12	5	7.61	9.20	10.79	1.59	12.38	13.97
Black	Male	13	7	3.47	6.57	9.68	3.11	12.79	15.90
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	7.27	8.41	9.55	1.14	10.70	11.84
Black	Female	8	6	8.26	9.40	10.54	1.14	11.68	12.82
Black	Female	9	6	6.85	8.89	10.93	2.04	12.96	15.00
Black	Female	10	6	7.96	9.70	11.44	1.74	13.18	14.92
Black	Female	11	9	7.10	9.96	12.82	2.86	15.67	18.53
Black	Female	12	11	8.93	10.29	11.64	1.35	12.99	14.35
Black	Female	13	5	6.60	9.50	12.40	2.90	15.30	18.20
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	6.41	8.56	10.72	2.15	12.87	15.02
Coloured	Male	8	8	4.90	7.51	10.12	2.61	12.72	15.33
Coloured	Male	9	21	5.40	8.06	10.72	2.66	13.39	16.05
Coloured	Male	10	10	5.10	7.53	9.97	2.43	12.40	14.83
Coloured	Male	11	21	4.95	7.64	10.33	2.69	13.02	15.71
Coloured	Male	12	22	5.95	8.56	11.16	2.61	13.77	16.38
Coloured	Male	13	23	6.35	8.29	10.23	1.94	12.16	14.10
Coloured	Female	6	0	-	-	-	-	-	-
Coloured	Female	7	5	7.32	8.77	10.22	1.45	11.67	13.12
Coloured	Female	8	6	6.65	8.28	9.91	1.63	11.54	13.17
Coloured	Female	9	24	4.22	7.32	10.42	3.10	13.52	16.62
Coloured	Female	10	26	4.52	7.35	10.18	2.83	13.01	15.84
Coloured	Female	11	37	6.44	9.07	11.70	2.63	14.32	16.95
Coloured	Female	12	52	5.42	8.32	11.22	2.90	14.12	17.03
Coloured	Female	13	38	6.06	8.53	11.01	2.48	13.49	15.96

Beneath chin									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	2	1.51	2.36	3.21	0.85	4.06	4.91
Black	Male	7	5	3.96	4.44	4.91	0.47	5.38	5.86
Black	Male	8	2	5.89	6.61	7.33	0.72	8.05	8.77
Black	Male	9	4	1.99	3.38	4.76	1.39	6.15	7.54
Black	Male	10	11	3.53	4.32	5.11	0.79	5.90	6.69
Black	Male	11	7	3.80	4.82	5.84	1.02	6.87	7.89
Black	Male	12	5	4.54	5.19	5.84	0.65	6.49	7.15
Black	Male	13	7	2.87	3.78	4.69	0.91	5.61	6.52
Black	Female	6	0	-	-	-	-	-	-
Black	Female	7	4	2.12	3.85	5.59	1.73	7.32	9.05
Black	Female	8	6	3.15	4.31	5.47	1.16	6.62	7.78
Black	Female	9	6	3.66	4.72	5.77	1.06	6.83	7.88
Black	Female	10	6	2.63	4.05	5.46	1.42	6.88	8.29
Black	Female	11	9	2.55	4.57	6.60	2.02	8.62	10.65
Black	Female	12	11	4.20	5.18	6.17	0.98	7.15	8.13
Black	Female	13	5	3.89	4.63	5.38	0.75	6.13	6.87
Coloured	Male	6	0	-	-	-	-	-	-
Coloured	Male	7	5	0.26	2.56	4.85	2.30	7.15	9.45
Coloured	Male	8	8	2.23	4.17	6.10	1.94	8.04	9.98
Coloured	Male	9	21	2.03	3.91	5.79	1.88	7.67	9.55
Coloured	Male	10	10	3.39	4.51	5.63	1.12	6.74	7.86
Coloured	Male	11	21	2.33	4.15	5.97	1.82	7.79	9.61
Coloured	Male	12	22	3.10	4.53	5.96	1.43	7.38	8.81
Coloured	Male	13	23	3.06	4.74	6.42	1.68	8.11	9.79
Coloured	Female	6	0	-	-	-	-	-	-
Coloured	Female	7	5	2.94	4.42	5.89	1.47	7.36	8.83
Coloured	Female	8	6	3.96	4.80	5.64	0.84	6.48	7.33
Coloured	Female	9	24	2.85	4.27	5.69	1.42	7.12	8.54
Coloured	Female	10	26	2.97	4.33	5.70	1.36	7.06	8.42
Coloured	Female	11	37	3.40	5.07	6.74	1.67	8.41	10.08
Coloured	Female	12	52	2.73	4.53	6.34	1.81	8.14	9.95
Coloured	Female	13	38	3.07	4.77	6.46	1.69	8.16	9.85

Appendix II: Complete anterior craniofacial indices for Black and Coloured South African children aged 6 to 13 years (mean ± 1 SD and ± 2SD)

Head width - craniofacial height									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	59.33	63.53	67.73	4.20	71.93	76.13
Black	Male	7	42	57.87	62.28	66.69	4.41	71.11	75.52
Black	Male	8	38	57.57	61.79	66.00	4.22	70.22	74.44
Black	Male	9	44	56.09	60.50	64.90	4.41	69.31	73.71
Black	Male	10	47	56.97	60.67	64.37	3.70	68.06	71.76
Black	Male	11	36	55.85	60.07	64.29	4.22	68.50	72.72
Black	Male	12	43	55.92	60.43	64.94	4.51	69.45	73.96
Black	Male	13	37	57.95	62.04	66.14	4.09	70.23	74.32
Black	Female	6	57	57.08	61.01	64.94	3.93	68.87	72.80
Black	Female	7	49	57.09	60.63	64.17	3.54	67.71	71.25
Black	Female	8	46	56.43	59.82	63.21	3.39	66.60	69.99
Black	Female	9	56	55.72	59.21	62.69	3.48	66.17	69.65
Black	Female	10	36	53.22	58.22	63.22	5.00	68.23	73.23
Black	Female	11	50	55.16	59.41	63.66	4.25	67.90	72.15
Black	Female	12	44	58.07	61.32	64.57	3.25	67.81	71.06
Black	Female	13	38	59.86	62.78	65.71	2.93	68.64	71.56
Coloured	Male	6	44	67.54	70.52	73.50	2.98	76.48	79.46
Coloured	Male	7	54	59.82	64.92	70.03	5.11	75.13	80.24
Coloured	Male	8	59	59.10	63.82	68.54	4.72	73.26	77.98
Coloured	Male	9	58	57.22	62.17	67.12	4.95	72.08	77.03
Coloured	Male	10	54	58.06	62.75	67.45	4.70	72.14	76.84
Coloured	Male	11	56	54.83	60.33	65.82	5.49	71.31	76.80
Coloured	Male	12	48	57.71	61.97	66.24	4.26	70.50	74.76
Coloured	Male	13	80	58.74	62.78	66.82	4.04	70.86	74.90
Coloured	Female	6	35	58.33	64.02	69.71	5.69	75.41	81.10
Coloured	Female	7	57	58.27	63.24	68.22	4.97	73.19	78.17
Coloured	Female	8	86	55.88	61.39	66.91	5.52	72.43	77.94
Coloured	Female	9	75	57.69	62.67	67.64	4.97	72.61	77.58
Coloured	Female	10	71	55.80	61.37	66.94	5.57	72.51	78.08
Coloured	Female	11	87	55.40	60.83	66.25	5.42	71.67	77.10
Coloured	Female	12	81	56.11	60.75	65.40	4.64	70.04	74.68
Coloured	Female	13	88	60.58	63.46	66.34	2.88	69.22	72.10

Forehead-head width									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	58.52	63.99	69.45	5.47	74.92	80.39
Black	Male	7	42	63.02	68.30	73.58	5.28	78.86	84.15
Black	Male	8	38	62.06	67.40	72.73	5.34	78.07	83.41
Black	Male	9	44	64.44	69.39	74.34	4.95	79.29	84.23
Black	Male	10	47	65.30	70.26	75.22	4.96	80.18	85.15
Black	Male	11	36	62.09	67.45	72.82	5.36	78.18	83.54
Black	Male	12	43	60.97	66.80	72.62	5.82	78.44	84.27
Black	Male	13	37	61.41	66.99	72.56	5.57	78.13	83.71
Black	Female	6	57	60.57	66.04	71.51	5.47	76.97	82.44
Black	Female	7	49	65.78	70.44	75.10	4.66	79.76	84.42
Black	Female	8	46	67.49	71.38	75.26	3.88	79.14	83.03
Black	Female	9	56	64.90	70.19	75.48	5.29	80.77	86.06
Black	Female	10	36	63.41	69.39	75.38	5.98	81.36	87.34
Black	Female	11	50	65.15	70.61	76.06	5.45	81.51	86.97
Black	Female	12	44	68.72	72.53	76.34	3.81	80.15	83.96
Black	Female	13	38	68.94	73.10	77.26	4.16	81.42	85.58
Coloured	Male	6	44	61.87	67.35	72.82	5.47	78.30	83.77
Coloured	Male	7	54	63.42	68.79	74.16	5.37	79.53	84.89
Coloured	Male	8	59	62.27	68.25	74.22	5.97	80.19	86.16
Coloured	Male	9	58	64.60	70.53	76.45	5.92	82.38	88.30
Coloured	Male	10	54	65.00	70.03	75.07	5.03	80.10	85.13
Coloured	Male	11	56	64.43	70.44	76.45	6.01	82.45	88.46
Coloured	Male	12	48	65.70	71.24	76.78	5.54	82.31	87.85
Coloured	Male	13	80	66.07	71.03	75.99	4.96	80.95	85.91
Coloured	Female	6	35	63.50	68.66	73.83	5.16	78.99	84.15
Coloured	Female	7	57	64.54	69.60	74.65	5.05	79.71	84.76
Coloured	Female	8	86	64.22	70.15	76.09	5.94	82.03	87.96
Coloured	Female	9	75	67.04	71.43	75.82	4.39	80.21	84.61
Coloured	Female	10	71	65.06	70.91	76.77	5.85	82.62	88.47
Coloured	Female	11	87	66.07	72.03	77.99	5.96	83.95	89.91
Coloured	Female	12	81	68.43	73.98	79.52	5.55	85.07	90.62
Coloured	Female	13	88	69.78	74.95	80.11	5.16	85.27	90.44

Skull base-head width									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	86.35	90.06	93.78	3.72	97.50	101.21
Black	Male	7	42	85.86	90.41	94.97	4.56	99.53	104.08
Black	Male	8	38	87.22	91.19	95.16	3.97	99.13	103.10
Black	Male	9	44	85.09	90.46	95.83	5.37	101.20	106.57
Black	Male	10	47	87.44	91.80	96.16	4.36	100.52	104.88
Black	Male	11	36	86.35	91.46	96.57	5.11	101.68	106.79
Black	Male	12	43	86.76	91.67	96.58	4.91	101.49	106.40
Black	Male	13	37	90.09	93.91	97.73	3.82	101.55	105.37
Black	Female	6	57	85.17	89.29	93.41	4.12	97.53	101.65
Black	Female	7	49	85.57	89.66	93.74	4.08	97.82	101.91
Black	Female	8	46	86.14	89.89	93.63	3.74	97.37	101.12
Black	Female	9	56	86.50	90.24	93.98	3.74	97.72	101.46
Black	Female	10	36	84.90	89.77	94.63	4.86	99.49	104.36
Black	Female	11	50	85.69	90.28	94.88	4.60	99.48	104.07
Black	Female	12	44	86.90	91.13	95.36	4.23	99.59	103.82
Black	Female	13	38	90.78	93.52	96.26	2.74	99.00	101.74
Coloured	Male	6	44	84.30	89.03	93.77	4.74	98.51	103.24
Coloured	Male	7	54	85.37	89.87	94.37	4.50	98.87	103.37
Coloured	Male	8	59	81.66	88.02	94.37	6.35	100.72	107.08
Coloured	Male	9	58	83.08	89.10	95.12	6.02	101.14	107.16
Coloured	Male	10	54	83.79	89.62	95.45	5.83	101.28	107.11
Coloured	Male	11	56	80.85	88.34	95.84	7.50	103.34	110.83
Coloured	Male	12	48	84.27	90.32	96.37	6.05	102.42	108.47
Coloured	Male	13	80	88.25	92.87	97.5	4.63	102.13	106.75
Coloured	Female	6	35	83.83	88.97	94.1	5.13	99.23	104.37
Coloured	Female	7	57	82.86	88.57	94.29	5.72	100.01	105.72
Coloured	Female	8	86	81.95	88.15	94.36	6.21	100.57	106.77
Coloured	Female	9	75	83.07	88.73	94.4	5.67	100.07	105.73
Coloured	Female	10	71	82.42	88.70	94.97	6.27	101.24	107.52
Coloured	Female	11	87	82.82	89.17	95.51	6.34	101.85	108.20
Coloured	Female	12	81	84.53	90.38	96.23	5.85	102.08	107.93
Coloured	Female	13	88	85.47	91.33	97.19	5.86	103.05	108.91

Forehead width-face width									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	71.84	76.73	81.63	4.90	86.53	91.42
Black	Male	7	42	72.40	76.87	81.35	4.48	85.83	90.30
Black	Male	8	38	72.41	77.08	81.76	4.68	86.44	91.11
Black	Male	9	44	73.70	77.42	81.14	3.72	84.86	88.58
Black	Male	10	47	71.80	77.01	82.22	5.21	87.43	92.64
Black	Male	11	36	75.14	78.74	82.35	3.61	85.96	89.56
Black	Male	12	43	74.49	78.16	81.83	3.67	85.50	89.17
Black	Male	13	37	70.97	76.84	82.7	5.86	88.56	94.43
Black	Female	6	57	71.34	76.40	81.47	5.07	86.54	91.60
Black	Female	7	49	73.91	77.58	81.26	3.68	84.94	88.61
Black	Female	8	46	75.01	78.25	81.48	3.23	84.71	87.95
Black	Female	9	56	69.82	75.52	81.22	5.70	86.92	92.62
Black	Female	10	36	73.48	77.69	81.9	4.21	86.11	90.32
Black	Female	11	50	71.01	76.11	81.2	5.09	86.29	91.39
Black	Female	12	44	74.38	77.94	81.49	3.55	85.04	88.60
Black	Female	13	38	74.77	78.63	82.48	3.85	86.33	90.19
Coloured	Male	6	44	73.66	78.10	82.54	4.44	86.98	91.42
Coloured	Male	7	54	70.01	76.25	82.49	6.24	88.73	94.97
Coloured	Male	8	59	75.18	78.84	82.49	3.65	86.14	89.80
Coloured	Male	9	58	75.33	78.84	82.35	3.51	85.86	89.37
Coloured	Male	10	54	76.66	79.55	82.44	2.89	85.33	88.22
Coloured	Male	11	56	74.73	78.68	82.63	3.95	86.58	90.53
Coloured	Male	12	48	73.59	77.97	82.35	4.38	86.73	91.11
Coloured	Male	13	80	77.34	80.34	83.34	3.00	86.34	89.34
Coloured	Female	6	35	75.25	78.99	82.72	3.73	86.45	90.19
Coloured	Female	7	57	75.87	79.07	82.28	3.21	85.49	88.69
Coloured	Female	8	86	76.52	79.51	82.5	2.99	85.49	88.48
Coloured	Female	9	75	75.67	79.00	82.32	3.32	85.64	88.97
Coloured	Female	10	71	75.68	79.05	82.42	3.37	85.79	89.16
Coloured	Female	11	87	75.67	79.24	82.8	3.56	86.36	89.93
Coloured	Female	12	81	75.60	78.91	82.23	3.32	85.55	88.86
Coloured	Female	13	88	76.59	79.91	83.23	3.32	86.55	89.87

Auricular head height-skull-base width									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	80.25	86.12	91.98	5.86	97.84	103.70
Black	Male	7	42	82.16	87.02	91.87	4.85	96.73	101.58
Black	Male	8	38	81.25	86.32	91.38	5.07	96.45	101.52
Black	Male	9	44	81.17	86.23	91.29	5.06	96.35	101.41
Black	Male	10	47	81.08	85.63	90.17	4.54	94.71	99.25
Black	Male	11	36	81.66	86.02	90.37	4.35	94.72	99.07
Black	Male	12	43	81.55	86.21	90.87	4.66	95.53	100.19
Black	Male	13	37	76.46	82.65	88.85	6.19	95.04	101.24
Black	Female	6	57	82.67	87.80	92.93	5.13	98.06	103.20
Black	Female	7	49	83.78	88.56	93.35	4.79	98.14	102.93
Black	Female	8	46	80.04	86.65	93.26	6.61	99.86	106.47
Black	Female	9	56	79.44	85.40	91.35	5.96	97.31	103.27
Black	Female	10	36	79.72	85.58	91.43	5.85	97.28	103.13
Black	Female	11	50	80.83	86.05	91.28	5.22	96.50	101.72
Black	Female	12	44	81.82	86.36	90.90	4.54	95.44	99.98
Black	Female	13	38	82.07	86.51	90.94	4.44	95.38	99.82
Coloured	Male	6	44	83.38	87.50	91.62	4.12	95.74	99.86
Coloured	Male	7	54	79.22	85.09	90.97	5.88	96.85	102.73
Coloured	Male	8	59	78.69	84.69	90.68	5.99	96.68	102.67
Coloured	Male	9	58	78.54	84.29	90.04	5.75	95.80	101.55
Coloured	Male	10	54	80.80	85.35	89.91	4.56	94.47	99.03
Coloured	Male	11	56	79.25	84.50	89.76	5.25	95.01	100.26
Coloured	Male	12	48	77.84	83.50	89.17	5.66	94.83	100.50
Coloured	Male	13	80	78.19	83.59	89.00	5.41	94.41	99.82
Coloured	Female	6	35	79.96	85.45	90.93	5.49	96.42	101.91
Coloured	Female	7	57	81.41	86.17	90.93	4.76	95.70	100.46
Coloured	Female	8	86	79.19	84.45	89.70	5.25	94.95	100.20
Coloured	Female	9	75	78.52	84.03	89.54	5.51	95.04	100.55
Coloured	Female	10	71	80.14	84.82	89.49	4.68	94.17	98.84
Coloured	Female	11	87	77.10	82.96	88.82	5.86	94.67	100.53
Coloured	Female	12	81	79.08	83.92	88.75	4.83	93.59	98.42
Coloured	Female	13	88	80.15	84.25	88.35	4.10	92.45	96.55

Facial index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	69.36	72.66	75.97	3.30	79.27	82.57
Black	Male	7	42	72.12	75.76	79.40	3.64	83.04	86.68
Black	Male	8	38	72.26	76.34	80.43	4.08	84.51	88.60
Black	Male	9	44	72.23	76.58	80.93	4.35	85.28	89.63
Black	Male	10	47	72.59	76.74	80.89	4.15	85.04	89.19
Black	Male	11	36	72.45	76.51	80.57	4.06	84.63	88.69
Black	Male	12	43	73.74	77.85	81.96	4.11	86.07	90.18
Black	Male	13	37	75.23	79.17	83.11	3.94	87.04	90.98
Black	Female	6	57	68.24	72.69	77.14	4.45	81.59	86.04
Black	Female	7	49	70.47	74.77	79.08	4.31	83.38	87.69
Black	Female	8	46	72.48	76.37	80.25	3.89	84.14	88.03
Black	Female	9	56	72.33	76.35	80.37	4.02	84.39	88.41
Black	Female	10	36	72.27	77.19	82.11	4.92	87.04	91.96
Black	Female	11	50	73.52	78.03	82.54	4.51	87.05	91.56
Black	Female	12	44	75.49	78.92	82.36	3.43	85.79	89.22
Black	Female	13	38	75.76	79.92	84.07	4.15	88.22	92.37
Coloured	Male	6	44	66.92	71.50	76.09	4.59	80.68	85.26
Coloured	Male	7	54	67.88	73.48	79.08	5.60	84.68	90.28
Coloured	Male	8	59	70.94	74.88	78.82	3.94	82.76	86.70
Coloured	Male	9	58	73.34	76.70	80.05	3.35	83.40	86.76
Coloured	Male	10	54	72.68	77.10	81.52	4.42	85.94	90.35
Coloured	Male	11	56	75.98	79.30	82.62	3.32	85.94	89.26
Coloured	Male	12	48	74.45	78.60	82.74	4.15	86.89	91.03
Coloured	Male	13	80	74.45	78.75	83.05	4.30	87.35	91.65
Coloured	Female	6	35	69.80	74.45	79.11	4.66	83.77	88.42
Coloured	Female	7	57	72.27	75.73	79.19	3.46	82.65	86.11
Coloured	Female	8	86	71.13	75.32	79.51	4.19	83.70	87.88
Coloured	Female	9	75	71.77	76.08	80.39	4.31	84.70	89.01
Coloured	Female	10	71	72.64	76.35	80.05	3.70	83.75	87.45
Coloured	Female	11	87	74.18	77.87	81.57	3.69	85.26	88.96
Coloured	Female	12	81	74.17	78.09	82.00	3.91	85.91	89.82
Coloured	Female	13	88	72.46	77.93	83.39	5.46	88.85	94.31

Upper face index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	44.31	47.52	50.72	3.20	53.93	57.13
Black	Male	7	42	45.17	48.24	51.30	3.06	54.36	57.43
Black	Male	8	38	44.42	48.35	52.27	3.92	56.19	60.11
Black	Male	9	44	46.14	49.16	52.18	3.02	55.20	58.22
Black	Male	10	47	45.09	48.55	52.02	3.46	55.48	58.95
Black	Male	11	36	44.98	48.73	52.49	3.76	56.25	60.01
Black	Male	12	43	46.27	49.37	52.47	3.10	55.58	58.68
Black	Male	13	37	46.89	50.50	54.12	3.61	57.73	61.35
Black	Female	6	57	43.06	46.70	50.34	3.64	53.97	57.61
Black	Female	7	49	43.98	47.57	51.16	3.59	54.76	58.35
Black	Female	8	46	45.24	48.58	51.92	3.34	55.27	58.61
Black	Female	9	56	43.98	47.93	51.88	3.95	55.83	59.78
Black	Female	10	36	43.93	48.04	52.16	4.11	56.27	60.39
Black	Female	11	50	45.06	48.72	52.37	3.65	56.02	59.68
Black	Female	12	44	45.79	49.24	52.69	3.45	56.14	59.59
Black	Female	13	38	47.97	51.03	54.09	3.06	57.16	60.22
Coloured	Male	6	44	43.79	47.25	50.08	3.46	53.53	56.99
Coloured	Male	7	54	43.92	47.67	50.17	3.75	53.92	57.67
Coloured	Male	8	59	45.24	48.42	50.92	3.17	54.09	57.26
Coloured	Male	9	58	46.00	49.16	51.66	3.16	54.82	57.97
Coloured	Male	10	54	46.08	49.53	52.03	3.45	55.49	58.94
Coloured	Male	11	56	48.03	50.72	53.22	2.68	55.90	58.58
Coloured	Male	12	48	46.70	50.62	53.12	3.93	57.05	60.98
Coloured	Male	13	80	47.56	50.92	53.42	3.36	56.77	60.13
Coloured	Female	6	35	43.57	46.83	50.09	3.26	53.36	56.62
Coloured	Female	7	57	44.76	47.48	50.20	2.72	52.92	55.64
Coloured	Female	8	86	44.69	47.74	50.80	3.05	53.85	56.90
Coloured	Female	9	75	45.18	48.25	51.32	3.07	54.39	57.46
Coloured	Female	10	71	45.36	48.33	51.30	2.97	54.27	57.24
Coloured	Female	11	87	45.32	48.42	51.52	3.10	54.63	57.73
Coloured	Female	12	81	46.17	49.14	52.11	2.97	55.08	58.05
Coloured	Female	13	88	47.37	50.41	53.44	3.04	56.48	59.52

Lip index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	34.44	41.73	49.03	7.29	56.32	63.61
Black	Male	7	42	32.49	40.41	48.33	7.92	56.25	64.17
Black	Male	8	38	32.68	40.59	48.50	7.91	56.41	64.32
Black	Male	9	44	33.29	40.61	47.94	7.33	55.26	62.59
Black	Male	10	47	34.67	41.30	47.94	6.63	54.57	61.21
Black	Male	11	36	35.15	42.46	49.77	7.31	57.08	64.39
Black	Male	12	43	36.81	43.97	51.14	7.16	58.30	65.46
Black	Male	13	37	41.66	46.20	50.74	4.54	55.27	59.81
Black	Female	6	57	31.23	38.72	46.21	7.49	53.69	61.18
Black	Female	7	49	32.89	40.49	48.09	7.60	55.69	63.30
Black	Female	8	46	32.26	39.84	47.42	7.58	54.99	62.57
Black	Female	9	56	33.70	40.64	47.58	6.94	54.52	61.46
Black	Female	10	36	35.41	42.83	50.25	7.42	57.67	65.09
Black	Female	11	50	35.58	42.25	48.93	6.68	55.61	62.28
Black	Female	12	44	34.48	41.72	48.95	7.24	56.19	63.43
Black	Female	13	38	36.09	42.51	48.92	6.42	55.34	61.76
Coloured	Male	6	44	23.69	31.45	39.22	7.77	46.98	54.75
Coloured	Male	7	54	29.63	36.74	43.85	7.11	50.97	58.08
Coloured	Male	8	59	28.59	36.26	43.93	7.67	51.60	59.27
Coloured	Male	9	58	31.43	38.53	45.63	7.10	52.74	59.84
Coloured	Male	10	54	30.14	38.58	47.01	8.43	55.44	63.87
Coloured	Male	11	56	30.82	38.95	47.08	8.13	55.21	63.35
Coloured	Male	12	48	27.74	35.62	43.50	7.88	51.38	59.25
Coloured	Male	13	80	29.22	36.65	44.07	7.42	51.50	58.92
Coloured	Female	6	35	27.49	35.42	43.35	7.93	51.28	59.22
Coloured	Female	7	57	26.17	34.28	42.39	8.11	50.51	58.62
Coloured	Female	8	86	30.02	37.96	45.90	7.94	53.84	61.77
Coloured	Female	9	75	28.80	36.32	43.85	7.53	51.37	58.90
Coloured	Female	10	71	29.12	37.29	45.46	8.17	53.62	61.79
Coloured	Female	11	87	30.59	37.93	45.26	7.34	52.60	59.93
Coloured	Female	12	81	30.68	37.86	45.04	7.18	52.22	59.40
Coloured	Female	13	88	32.68	39.94	47.20	7.26	54.46	61.72

Upper lip thickness index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	25.94	31.15	36.36	5.21	41.57	46.78
Black	Male	7	42	27.39	32.03	36.67	4.64	41.31	45.95
Black	Male	8	38	26.16	31.49	36.81	5.32	42.13	47.46
Black	Male	9	44	28.58	32.81	37.05	4.24	41.29	45.52
Black	Male	10	47	25.15	31.20	37.25	6.05	43.30	49.35
Black	Male	11	36	26.21	31.88	37.55	5.67	43.22	48.89
Black	Male	12	43	27.83	32.98	38.14	5.16	43.30	48.45
Black	Male	13	7	28.37	33.41	38.45	5.04	43.49	48.53
Black	Female	6	57	25.10	30.80	36.5	5.70	42.20	47.90
Black	Female	7	49	27.07	32.00	36.93	4.93	41.86	46.79
Black	Female	8	46	27.16	32.12	37.09	4.97	42.06	47.02
Black	Female	9	56	26.16	31.69	37.21	5.52	42.73	48.26
Black	Female	10	36	28.28	32.78	37.27	4.49	41.76	46.26
Black	Female	11	50	27.18	32.33	37.47	5.14	42.61	47.76
Black	Female	12	44	28.07	32.83	37.59	4.76	42.35	47.11
Black	Female	13	38	31.24	34.60	37.96	3.36	41.32	44.68
Coloured	Male	6	44	24.64	30.47	36.29	5.82	42.11	47.94
Coloured	Male	7	54	24.24	30.29	36.33	6.04	42.37	48.42
Coloured	Male	8	59	27.58	31.98	36.39	4.41	40.80	45.20
Coloured	Male	9	58	26.75	31.67	36.59	4.92	41.51	46.43
Coloured	Male	10	54	26.39	31.55	36.71	5.16	41.87	47.03
Coloured	Male	11	56	28.07	32.48	36.9	4.42	41.32	45.73
Coloured	Male	12	48	26.24	31.82	37.4	5.58	42.98	48.56
Coloured	Male	13	80	27.91	32.82	37.72	4.90	42.62	47.53
Coloured	Female	6	35	23.27	29.71	36.15	6.44	42.59	49.03
Coloured	Female	7	57	23.24	29.77	36.3	6.53	42.83	49.36
Coloured	Female	8	86	25.38	30.96	36.54	5.58	42.12	47.70
Coloured	Female	9	75	25.84	31.20	36.57	5.37	41.94	47.30
Coloured	Female	10	71	26.93	31.77	36.6	4.83	41.43	46.27
Coloured	Female	11	87	27.72	32.17	36.62	4.45	41.07	45.52
Coloured	Female	12	81	27.08	32.11	37.14	5.03	42.17	47.20
Coloured	Female	13	88	29.69	33.82	37.95	4.13	42.08	46.21

Lower lip thickness index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	40.82	46.13	51.44	5.31	56.75	62.06
Black	Male	7	42	43.45	48.11	52.77	4.66	57.43	62.09
Black	Male	8	38	42.70	47.95	53.21	5.25	58.46	63.71
Black	Male	9	44	43.59	47.79	51.99	4.20	56.19	60.39
Black	Male	10	47	39.66	45.69	51.72	6.03	57.75	63.78
Black	Male	11	36	39.66	45.47	51.28	5.81	57.09	62.90
Black	Male	12	43	42.14	47.18	52.22	5.04	57.26	62.30
Black	Male	13	37	41.16	46.56	51.96	5.40	57.36	62.76
Black	Female	6	57	38.34	43.97	49.60	5.63	55.23	60.87
Black	Female	7	49	42.23	47.32	52.41	5.09	57.50	62.58
Black	Female	8	46	41.49	46.68	51.86	5.19	57.05	62.24
Black	Female	9	56	40.88	46.37	51.87	5.50	57.36	62.86
Black	Female	10	36	43.42	47.86	52.30	4.44	56.74	61.18
Black	Female	11	50	40.67	45.81	50.95	5.14	56.10	61.24
Black	Female	12	44	41.98	46.86	51.73	4.87	56.60	61.47
Black	Female	13	38	46.89	50.08	53.27	3.19	56.46	59.64
Coloured	Male	6	44	43.30	49.02	54.74	5.72	60.46	66.17
Coloured	Male	7	54	41.50	47.51	53.51	6.00	59.51	65.52
Coloured	Male	8	59	44.55	49.17	53.80	4.62	58.42	63.05
Coloured	Male	9	58	44.17	48.95	53.72	4.78	58.50	63.27
Coloured	Male	10	54	42.86	48.00	53.14	5.14	58.28	63.42
Coloured	Male	11	56	43.94	48.20	52.46	4.26	56.72	60.98
Coloured	Male	12	48	43.36	49.22	55.07	5.85	60.93	66.78
Coloured	Male	13	80	44.42	49.33	54.23	4.91	59.14	64.05
Coloured	Female	6	35	42.49	48.16	53.83	5.67	59.50	65.17
Coloured	Female	7	57	40.68	47.49	54.31	6.81	61.12	67.93
Coloured	Female	8	86	42.39	48.10	53.81	5.71	59.52	65.23
Coloured	Female	9	75	42.77	48.13	53.49	5.36	58.85	64.21
Coloured	Female	10	71	43.77	48.64	53.52	4.88	58.40	63.28
Coloured	Female	11	87	43.33	47.81	52.29	4.48	56.77	61.24
Coloured	Female	12	81	43.63	48.67	53.70	5.04	58.74	63.78
Coloured	Female	13	88	46.12	50.80	55.49	4.69	60.17	64.86

Mouth width index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	37.97	43.31	48.66	5.35	54.01	59.36
Black	Male	7	42	42.68	46.44	50.19	3.75	53.95	57.70
Black	Male	8	38	42.19	46.49	50.79	4.30	55.09	59.39
Black	Male	9	44	40.35	45.38	50.42	5.04	55.45	60.49
Black	Male	10	47	42.60	47.18	51.76	4.58	56.33	60.91
Black	Male	11	36	42.27	47.03	51.79	4.76	56.54	61.30
Black	Male	12	43	43.27	47.76	52.24	4.48	56.73	61.21
Black	Male	13	37	43.11	47.45	51.79	4.34	56.13	60.47
Black	Female	6	57	42.40	46.00	49.61	3.60	53.21	56.82
Black	Female	7	49	41.67	46.26	50.85	4.59	55.44	60.03
Black	Female	8	46	44.71	48.47	52.22	3.76	55.98	59.73
Black	Female	9	56	41.37	46.69	52.02	5.33	57.34	62.67
Black	Female	10	36	43.11	47.76	52.41	4.65	57.06	61.71
Black	Female	11	50	42.96	47.52	52.08	4.56	56.64	61.19
Black	Female	12	44	44.92	49.08	53.25	4.16	57.41	61.57
Black	Female	13	38	46.01	49.50	53.00	3.50	56.50	59.99
Coloured	Male	6	44	40.71	44.10	47.48	3.38	50.87	54.25
Coloured	Male	7	54	39.44	44.30	49.15	4.86	54.01	58.87
Coloured	Male	8	59	41.79	45.70	49.61	3.91	53.52	57.43
Coloured	Male	9	58	41.28	45.47	49.66	4.19	53.85	58.04
Coloured	Male	10	54	40.65	45.70	50.74	5.04	55.79	60.83
Coloured	Male	11	56	41.79	45.99	50.18	4.20	54.38	58.57
Coloured	Male	12	48	42.90	47.15	51.41	4.26	55.67	59.92
Coloured	Male	13	80	43.46	47.62	51.79	4.16	55.95	60.11
Coloured	Female	6	35	40.02	44.60	49.18	4.58	53.77	58.35
Coloured	Female	7	57	39.98	44.51	49.04	4.53	53.56	58.09
Coloured	Female	8	86	40.62	45.09	49.57	4.47	54.04	58.51
Coloured	Female	9	75	41.71	45.87	50.03	4.16	54.19	58.35
Coloured	Female	10	71	41.98	46.53	51.09	4.55	55.64	60.19
Coloured	Female	11	87	41.32	45.69	50.07	4.37	54.44	58.81
Coloured	Female	12	81	44.07	48.29	52.50	4.22	56.72	60.94
Coloured	Female	13	88	44.21	48.43	52.65	4.22	56.87	61.09

Upper lip height-mouth width index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	40.13	44.84	49.54	4.70	54.24	58.95
Black	Male	7	42	36.27	40.91	45.56	4.65	50.21	54.85
Black	Male	8	38	34.74	39.24	43.74	4.50	48.24	52.74
Black	Male	9	44	34.68	39.15	43.63	4.48	48.11	52.58
Black	Male	10	47	34.46	38.98	43.5	4.52	48.02	52.54
Black	Male	11	36	31.49	36.05	40.61	4.56	45.17	49.73
Black	Male	12	43	33.29	35.65	38.01	2.36	40.37	42.73
Black	Male	13	37	27.66	32.00	36.34	4.34	40.68	45.02
Black	Female	6	57	33.73	37.80	41.88	4.08	45.96	50.03
Black	Female	7	49	35.31	38.37	41.44	3.07	44.51	47.57
Black	Female	8	46	36.06	38.43	40.79	2.36	43.15	45.52
Black	Female	9	56	27.80	33.63	39.46	5.83	45.29	51.12
Black	Female	10	36	27.09	32.99	38.89	5.90	44.79	50.69
Black	Female	11	50	30.04	33.99	37.94	3.95	41.89	45.84
Black	Female	12	44	32.10	34.94	37.78	2.84	40.62	43.46
Black	Female	13	38	33.54	35.61	37.67	2.06	39.73	41.80
Coloured	Male	6	44	39.59	42.97	46.34	3.37	49.71	53.09
Coloured	Male	7	54	38.57	41.37	44.16	2.79	46.95	49.75
Coloured	Male	8	59	35.42	39.64	43.87	4.23	48.10	52.32
Coloured	Male	9	58	36.39	39.95	43.51	3.56	47.07	50.63
Coloured	Male	10	54	33.13	38.06	42.99	4.93	47.92	52.85
Coloured	Male	11	56	37.42	40.14	42.86	2.72	45.58	48.30
Coloured	Male	12	48	28.76	34.00	39.24	5.24	44.48	49.72
Coloured	Male	13	80	24.88	30.38	35.88	5.50	41.38	46.88
Coloured	Female	6	35	35.92	40.59	45.27	4.68	49.95	54.62
Coloured	Female	7	57	38.36	41.77	45.17	3.40	48.57	51.98
Coloured	Female	8	86	33.21	38.15	43.08	4.93	48.01	52.95
Coloured	Female	9	75	32.63	37.75	42.88	5.13	48.01	53.13
Coloured	Female	10	71	32.64	37.25	41.87	4.62	46.49	51.10
Coloured	Female	11	87	34.18	38.01	41.85	3.84	45.69	49.52
Coloured	Female	12	81	32.98	36.37	39.76	3.39	43.15	46.54
Coloured	Female	13	88	32.58	35.76	38.94	3.18	42.12	45.30

Mandibular index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	39.71	42.50	45.28	2.79	48.07	50.86
Black	Male	7	42	41.06	44.66	48.26	3.60	51.86	55.46
Black	Male	8	38	41.80	45.19	48.59	3.40	51.99	55.39
Black	Male	9	44	43.47	46.54	49.62	3.07	52.69	55.76
Black	Male	10	47	42.67	46.66	50.64	3.99	54.63	58.62
Black	Male	11	36	43.00	46.62	50.24	3.62	53.87	57.49
Black	Male	12	43	44.22	47.20	50.19	2.98	53.17	56.15
Black	Male	13	37	44.63	47.58	50.52	2.94	53.46	56.41
Black	Female	6	57	40.27	43.56	46.86	3.29	50.15	53.44
Black	Female	7	49	41.13	44.81	48.48	3.68	52.16	55.84
Black	Female	8	46	43.76	46.24	48.72	2.48	51.19	53.67
Black	Female	9	56	43.00	45.92	48.84	2.92	51.76	54.68
Black	Female	10	36	43.19	46.75	50.31	3.56	53.87	57.43
Black	Female	11	50	43.00	46.58	50.17	3.58	53.75	57.33
Black	Female	12	44	43.97	46.96	49.96	2.99	52.95	55.94
Black	Female	13	38	42.90	46.38	49.87	3.48	53.35	56.83
Coloured	Male	6	44	43.60	46.27	48.94	2.67	51.61	54.27
Coloured	Male	7	54	43.41	46.24	49.06	2.83	51.89	54.72
Coloured	Male	8	59	44.73	47.50	50.27	2.77	53.04	55.81
Coloured	Male	9	58	45.03	47.74	50.45	2.71	53.16	55.87
Coloured	Male	10	54	43.30	46.80	50.30	3.50	53.81	57.31
Coloured	Male	11	56	44.24	47.07	49.90	2.83	52.73	55.56
Coloured	Male	12	48	42.98	46.28	49.58	3.30	52.88	56.18
Coloured	Male	13	80	44.55	47.47	50.39	2.92	53.31	56.23
Coloured	Female	6	35	43.25	45.82	48.38	2.57	50.95	53.51
Coloured	Female	7	57	43.32	45.95	48.57	2.62	51.20	53.82
Coloured	Female	8	86	43.32	46.45	49.58	3.13	52.72	55.85
Coloured	Female	9	75	44.15	47.06	49.97	2.91	52.88	55.79
Coloured	Female	10	71	44.35	46.90	49.45	2.55	52.01	54.56
Coloured	Female	11	87	42.63	46.20	49.78	3.58	53.36	56.93
Coloured	Female	12	81	42.59	46.05	49.51	3.46	52.97	56.42
Coloured	Female	13	88	43.51	46.73	49.95	3.22	53.17	56.39

Mandible width-face width									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	68.38	70.88	73.38	2.50	75.88	78.38
Black	Male	7	42	67.26	70.42	73.57	3.15	76.72	79.88
Black	Male	8	38	70.03	72.18	74.32	2.14	76.46	78.61
Black	Male	9	44	68.21	71.34	74.46	3.12	77.58	80.71
Black	Male	10	47	66.75	70.58	74.4	3.82	78.22	82.05
Black	Male	11	36	67.21	70.65	74.08	3.43	77.51	80.95
Black	Male	12	43	67.63	70.32	73.02	2.70	75.72	78.41
Black	Male	13	37	64.72	68.81	72.9	4.09	76.99	81.08
Black	Female	6	57	66.39	69.65	72.92	3.27	76.19	79.45
Black	Female	7	49	66.66	69.81	72.95	3.14	76.09	79.24
Black	Female	8	46	67.03	70.19	73.36	3.17	76.53	79.69
Black	Female	9	56	67.43	70.44	73.45	3.01	76.46	79.47
Black	Female	10	36	67.13	70.34	73.56	3.22	76.78	79.99
Black	Female	11	50	66.76	69.85	72.94	3.09	76.03	79.12
Black	Female	12	44	66.27	69.42	72.57	3.15	75.72	78.87
Black	Female	13	38	66.16	69.14	72.11	2.97	75.08	78.06
Coloured	Male	6	44	65.22	69.13	73.04	3.91	76.95	80.86
Coloured	Male	7	54	65.37	69.31	73.25	3.94	77.19	81.13
Coloured	Male	8	59	65.09	69.36	73.64	4.28	77.92	82.19
Coloured	Male	9	58	65.28	69.60	73.91	4.31	78.22	82.54
Coloured	Male	10	54	66.12	69.86	73.59	3.73	77.32	81.06
Coloured	Male	11	56	67.14	69.99	72.84	2.85	75.69	78.54
Coloured	Male	12	48	66.08	69.51	72.95	3.44	76.39	79.82
Coloured	Male	13	80	65.79	69.32	72.86	3.54	76.40	79.93
Coloured	Female	6	35	66.88	69.67	72.45	2.78	75.23	78.02
Coloured	Female	7	57	66.78	69.65	72.53	2.88	75.41	78.28
Coloured	Female	8	86	65.73	69.22	72.72	3.50	76.22	79.71
Coloured	Female	9	75	67.43	70.18	72.93	2.75	75.68	78.43
Coloured	Female	10	71	67.08	70.14	73.2	3.06	76.26	79.32
Coloured	Female	11	87	65.42	69.27	73.12	3.85	76.97	80.82
Coloured	Female	12	81	65.80	69.19	72.57	3.38	75.95	79.34
Coloured	Female	13	88	66.15	69.34	72.54	3.20	75.74	78.93

Mandible width - face height									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	74.24	80.10	85.96	5.86	91.82	97.68
Black	Male	7	42	74.22	80.15	86.08	5.93	92.01	97.94
Black	Male	8	38	74.94	80.52	86.09	5.57	91.66	97.23
Black	Male	9	44	74.97	80.73	86.50	5.77	92.26	98.03
Black	Male	10	47	73.00	79.23	85.46	6.23	91.68	97.91
Black	Male	11	36	71.96	78.64	85.32	6.68	92.00	98.68
Black	Male	12	43	74.77	79.87	84.97	5.10	90.07	95.17
Black	Male	13	37	72.34	78.61	84.88	6.27	91.15	97.42
Black	Female	6	57	71.81	79.19	86.56	7.37	93.93	101.30
Black	Female	7	49	71.67	79.31	86.94	7.63	94.57	102.21
Black	Female	8	46	75.41	81.24	87.07	5.83	92.90	98.72
Black	Female	9	56	74.27	80.49	86.71	6.22	92.94	99.16
Black	Female	10	36	71.27	78.86	86.45	7.59	94.04	101.63
Black	Female	11	50	72.51	79.43	86.36	6.92	93.28	100.20
Black	Female	12	44	74.62	80.28	85.95	5.67	91.62	97.29
Black	Female	13	38	73.61	79.77	85.92	6.15	92.07	98.22
Coloured	Male	6	44	73.46	79.77	86.09	6.31	92.40	98.71
Coloured	Male	7	54	72.68	79.60	86.51	6.92	93.43	100.34
Coloured	Male	8	59	70.64	78.68	86.72	8.04	94.76	102.80
Coloured	Male	9	58	71.86	79.11	86.36	7.25	93.61	100.86
Coloured	Male	10	54	72.38	79.15	85.91	6.77	92.68	99.44
Coloured	Male	11	56	73.54	79.59	85.64	6.05	91.69	97.74
Coloured	Male	12	48	71.27	78.26	85.25	6.99	92.24	99.23
Coloured	Male	13	80	71.75	78.42	85.09	6.67	91.76	98.43
Coloured	Female	6	35	73.82	80.01	86.20	6.19	92.38	98.57
Coloured	Female	7	57	75.53	80.93	86.32	5.40	91.72	97.12
Coloured	Female	8	86	73.74	80.15	86.57	6.41	92.98	99.39
Coloured	Female	9	75	74.33	80.53	86.74	6.20	92.94	99.14
Coloured	Female	10	71	74.13	80.03	85.93	5.90	91.83	97.72
Coloured	Female	11	87	71.86	78.79	85.72	6.93	92.65	99.58
Coloured	Female	12	81	72.72	79.12	85.53	6.41	91.94	98.34
Coloured	Female	13	88	70.34	77.90	85.45	7.56	93.01	100.56

Nasal index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	77.13	87.78	98.44	10.65	109.09	119.75
Black	Male	7	42	77.04	86.22	95.40	9.18	104.57	113.75
Black	Male	8	38	77.44	86.69	95.93	9.24	105.18	114.42
Black	Male	9	44	76.70	87.13	97.57	10.44	108.00	118.44
Black	Male	10	47	74.71	87.29	99.87	12.58	112.45	125.03
Black	Male	11	36	75.69	86.41	97.13	10.72	107.86	118.58
Black	Male	12	43	79.34	88.22	97.11	8.89	106.00	114.88
Black	Male	13	37	79.44	86.70	93.95	7.25	101.21	108.46
Black	Female	6	57	76.61	87.74	98.88	11.14	110.01	121.15
Black	Female	7	49	75.39	85.89	96.40	10.50	106.90	117.40
Black	Female	8	46	74.87	84.88	94.89	10.01	104.89	114.90
Black	Female	9	56	74.10	84.80	95.49	10.69	106.18	116.88
Black	Female	10	36	76.74	87.08	97.41	10.34	107.75	118.08
Black	Female	11	50	77.19	86.87	96.55	9.68	106.23	115.91
Black	Female	12	44	73.98	84.66	95.34	10.68	106.02	116.70
Black	Female	13	38	78.74	85.50	92.26	6.76	99.02	105.78
Coloured	Male	6	44	71.46	81.48	91.49	10.01	101.50	111.51
Coloured	Male	7	54	76.26	84.44	92.62	8.18	100.80	108.98
Coloured	Male	8	59	77.22	85.60	93.98	8.38	102.36	110.74
Coloured	Male	9	58	72.75	83.09	93.42	10.33	103.76	114.09
Coloured	Male	10	54	77.96	86.51	95.06	8.55	103.61	112.16
Coloured	Male	11	56	79.26	85.41	91.56	6.15	97.71	103.86
Coloured	Male	12	48	71.56	83.12	94.68	11.56	106.24	117.81
Coloured	Male	13	80	75.04	83.06	91.08	8.02	99.10	107.12
Coloured	Female	6	35	70.17	80.44	90.71	10.27	100.99	111.26
Coloured	Female	7	57	73.05	82.22	91.39	9.17	100.56	109.73
Coloured	Female	8	86	75.08	84.81	94.54	9.73	104.27	113.99
Coloured	Female	9	75	77.25	85.96	94.68	8.72	103.39	112.11
Coloured	Female	10	71	77.53	85.89	94.25	8.36	102.61	110.97
Coloured	Female	11	87	75.88	85.38	94.89	9.51	104.40	113.90
Coloured	Female	12	81	76.01	83.54	91.07	7.53	98.60	106.13
Coloured	Female	13	88	67.48	78.47	89.45	10.99	100.44	111.43

Nasofacial index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	32.48	35.50	38.52	3.02	41.54	44.56
Black	Male	7	42	32.42	35.57	38.72	3.15	41.87	45.02
Black	Male	8	38	31.97	35.27	38.58	3.30	41.88	45.18
Black	Male	9	44	32.62	35.61	38.60	2.99	41.59	44.58
Black	Male	10	47	32.22	35.28	38.33	3.05	41.38	44.43
Black	Male	11	36	32.44	35.53	38.62	3.09	41.71	44.80
Black	Male	12	43	33.24	35.82	38.39	2.58	40.97	43.54
Black	Male	13	37	34.39	36.70	39.02	2.32	41.33	43.65
Black	Female	6	57	32.14	35.38	38.62	3.24	41.87	45.11
Black	Female	7	49	31.68	35.01	38.34	3.33	41.68	45.01
Black	Female	8	46	32.78	35.58	38.38	2.80	41.18	43.98
Black	Female	9	56	31.71	35.03	38.35	3.32	41.67	44.99
Black	Female	10	36	32.87	35.55	38.23	2.68	40.91	43.59
Black	Female	11	50	31.83	35.09	38.35	3.26	41.61	44.87
Black	Female	12	44	32.50	35.49	38.49	3.00	41.49	44.48
Black	Female	13	38	34.21	36.61	39.01	2.40	41.41	43.81
Coloured	Male	6	44	35.25	37.41	39.58	2.16	41.74	43.91
Coloured	Male	7	54	31.84	35.63	39.42	3.79	43.21	47.00
Coloured	Male	8	59	32.11	35.73	39.35	3.62	42.97	46.58
Coloured	Male	9	58	34.59	37.07	39.55	2.48	42.03	44.51
Coloured	Male	10	54	34.35	36.71	39.08	2.37	41.44	43.81
Coloured	Male	11	56	34.68	36.94	39.20	2.26	41.46	43.72
Coloured	Male	12	48	33.62	36.52	39.42	2.90	42.32	45.22
Coloured	Male	13	80	34.82	37.01	39.20	2.19	41.39	43.57
Coloured	Female	6	35	34.71	36.92	39.14	2.21	41.35	43.56
Coloured	Female	7	57	35.07	37.20	39.33	2.13	41.46	43.59
Coloured	Female	8	86	34.41	36.69	38.97	2.28	41.25	43.52
Coloured	Female	9	75	34.59	36.93	39.28	2.34	41.62	43.97
Coloured	Female	10	71	35.05	37.03	39.02	1.99	41.01	43.00
Coloured	Female	11	87	34.11	36.46	38.82	2.35	41.17	43.52
Coloured	Female	12	81	34.25	36.61	38.97	2.36	41.33	43.69
Coloured	Female	13	88	32.74	35.95	39.16	3.21	42.37	45.58

Nose face width index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	25.80	27.38	28.96	1.58	30.53	32.11
Black	Male	7	42	26.52	27.97	29.41	1.44	30.86	32.30
Black	Male	8	38	24.86	27.22	29.58	2.36	31.94	34.30
Black	Male	9	44	26.07	28.16	30.24	2.09	32.33	34.42
Black	Male	10	47	25.62	27.95	30.28	2.33	32.61	34.94
Black	Male	11	36	25.70	27.84	29.99	2.14	32.13	34.28
Black	Male	12	43	26.08	28.24	30.40	2.16	32.57	34.73
Black	Male	13	37	26.58	28.47	30.36	1.89	32.26	34.15
Black	Female	6	57	25.89	27.53	29.18	1.64	30.82	32.46
Black	Female	7	49	26.59	28.15	29.71	1.56	31.26	32.82
Black	Female	8	46	25.95	27.87	29.79	1.92	31.71	33.63
Black	Female	9	56	25.10	27.66	30.21	2.56	32.77	35.32
Black	Female	10	36	26.33	28.47	30.61	2.14	32.75	34.89
Black	Female	11	50	26.58	28.45	30.32	1.87	32.19	34.06
Black	Female	12	44	26.71	28.74	30.77	2.03	32.80	34.83
Black	Female	13	38	25.75	28.32	30.89	2.57	33.46	36.03
Coloured	Male	6	44	23.93	26.33	28.74	2.40	31.14	33.54
Coloured	Male	7	54	25.11	26.97	28.83	1.86	30.69	32.55
Coloured	Male	8	59	25.83	27.38	28.93	1.55	30.48	32.03
Coloured	Male	9	58	25.34	27.52	29.70	2.18	31.88	34.05
Coloured	Male	10	54	25.95	28.04	30.14	2.09	32.23	34.33
Coloured	Male	11	56	26.46	28.28	30.10	1.82	31.92	33.74
Coloured	Male	12	48	25.87	28.25	30.64	2.39	33.03	35.42
Coloured	Male	13	80	26.52	28.52	30.52	2.00	32.52	34.52
Coloured	Female	6	35	24.02	26.33	28.63	2.30	30.94	33.24
Coloured	Female	7	57	24.73	26.84	28.95	2.11	31.06	33.16
Coloured	Female	8	86	25.47	27.45	29.42	1.97	31.40	33.37
Coloured	Female	9	75	26.15	28.02	29.88	1.87	31.75	33.62
Coloured	Female	10	71	25.72	27.83	29.93	2.10	32.04	34.14
Coloured	Female	11	87	26.22	28.12	30.03	1.90	31.93	33.83
Coloured	Female	12	81	25.58	27.73	29.88	2.15	32.03	34.18
Coloured	Female	13	88	25.46	27.69	29.92	2.23	32.15	34.39

Intercanthal index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	33.17	35.68	38.19	2.51	40.70	43.20
Black	Male	7	42	33.65	35.87	38.08	2.21	40.29	42.51
Black	Male	8	38	34.16	36.02	37.88	1.86	39.75	41.61
Black	Male	9	44	32.82	35.35	37.87	2.53	40.40	42.92
Black	Male	10	47	30.47	33.78	37.10	3.31	40.41	43.73
Black	Male	11	36	31.39	34.20	37.01	2.81	39.81	42.62
Black	Male	12	43	32.47	34.90	37.33	2.43	39.76	42.19
Black	Male	13	7	29.76	33.51	37.26	3.75	41.02	44.77
Black	Female	6	57	33.01	35.39	37.77	2.38	40.15	42.52
Black	Female	7	49	33.63	35.68	37.73	2.05	39.78	41.82
Black	Female	8	46	33.07	35.22	37.38	2.16	39.54	41.69
Black	Female	9	56	32.83	35.05	37.27	2.22	39.49	41.71
Black	Female	10	36	32.40	34.76	37.12	2.36	39.48	41.84
Black	Female	11	50	31.33	34.12	36.92	2.80	39.72	42.51
Black	Female	12	44	31.47	34.36	37.25	2.89	40.15	43.04
Black	Female	13	38	32.71	34.94	37.17	2.23	39.40	41.63
Coloured	Male	6	44	31.83	34.41	36.99	2.58	39.57	42.15
Coloured	Male	7	54	32.09	34.45	36.81	2.36	39.16	41.52
Coloured	Male	8	59	31.16	33.96	36.75	2.80	39.55	42.34
Coloured	Male	9	58	32.03	34.38	36.72	2.35	39.07	41.42
Coloured	Male	10	54	31.04	33.73	36.43	2.70	39.13	41.83
Coloured	Male	11	56	31.33	33.73	36.12	2.39	38.52	40.91
Coloured	Male	12	48	31.52	34.09	36.66	2.57	39.23	41.80
Coloured	Male	13	80	31.00	33.82	36.64	2.82	39.46	42.28
Coloured	Female	6	35	33.13	35.20	37.28	2.08	39.36	41.43
Coloured	Female	7	57	31.38	34.27	37.15	2.89	40.04	42.92
Coloured	Female	8	86	32.26	34.66	37.06	2.40	39.46	41.86
Coloured	Female	9	75	31.66	34.36	37.06	2.70	39.76	42.46
Coloured	Female	10	71	31.42	34.04	36.65	2.62	39.27	41.89
Coloured	Female	11	87	30.91	33.64	36.37	2.73	39.11	41.84
Coloured	Female	12	81	30.91	33.86	36.80	2.94	39.75	42.69
Coloured	Female	13	88	31.01	33.88	36.75	2.87	39.62	42.50

Eye fissure index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	25.13	30.05	34.98	4.93	39.91	44.84
Black	Male	7	42	26.02	30.44	34.86	4.42	39.29	43.71
Black	Male	8	38	25.71	30.24	34.76	4.53	39.29	43.82
Black	Male	9	44	23.57	29.00	34.44	5.43	39.87	45.30
Black	Male	10	47	26.03	30.21	34.39	4.18	38.56	42.74
Black	Male	11	36	24.36	29.35	34.34	4.99	39.33	44.31
Black	Male	12	43	23.17	28.70	34.23	5.53	39.76	45.29
Black	Male	13	7	24.91	29.53	34.15	4.62	38.78	43.40
Black	Female	6	57	24.06	29.49	34.92	5.43	40.36	45.79
Black	Female	7	49	23.16	28.87	34.57	5.71	40.28	45.99
Black	Female	8	46	25.35	29.80	34.26	4.46	38.71	43.17
Black	Female	9	56	23.73	28.93	34.12	5.20	39.32	44.52
Black	Female	10	36	24.68	29.37	34.05	4.69	38.74	43.43
Black	Female	11	50	24.12	29.28	34.43	5.16	39.59	44.75
Black	Female	12	44	23.84	29.00	34.16	5.16	39.32	44.48
Black	Female	13	38	24.27	29.36	34.44	5.09	39.53	44.62
Coloured	Male	6	44	24.06	28.76	33.46	4.70	38.17	42.87
Coloured	Male	7	54	23.69	28.80	33.91	5.11	39.02	44.13
Coloured	Male	8	59	25.20	29.37	33.53	4.16	37.70	41.86
Coloured	Male	9	58	24.96	29.11	33.25	4.14	37.39	41.54
Coloured	Male	10	54	23.51	28.46	33.41	4.95	38.36	43.31
Coloured	Male	11	56	23.59	28.42	33.24	4.83	38.07	42.89
Coloured	Male	12	48	21.61	27.35	33.09	5.74	38.83	44.57
Coloured	Male	13	80	24.18	29.00	33.82	4.82	38.64	43.46
Coloured	Female	6	35	22.85	28.03	33.20	5.18	38.38	43.56
Coloured	Female	7	57	22.31	28.14	33.97	5.83	39.81	45.64
Coloured	Female	8	86	23.46	28.56	33.66	5.10	38.76	43.86
Coloured	Female	9	75	23.73	28.55	33.36	4.82	38.18	42.99
Coloured	Female	10	71	23.92	28.76	33.60	4.84	38.43	43.27
Coloured	Female	11	87	22.68	27.91	33.14	5.23	38.37	43.60
Coloured	Female	12	81	23.29	28.33	33.38	5.05	38.43	43.48
Coloured	Female	13	88	25.20	29.35	33.51	4.15	37.66	41.82

Bi-ocular-face width index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	63.97	66.78	69.59	2.81	72.40	75.20
Black	Male	7	42	63.98	66.78	69.58	2.80	72.38	75.18
Black	Male	8	38	61.72	65.52	69.32	3.80	73.13	76.93
Black	Male	9	44	63.81	66.59	69.38	2.79	72.16	74.95
Black	Male	10	47	62.15	65.64	69.13	3.49	72.62	76.11
Black	Male	11	36	63.25	66.14	69.03	2.89	71.91	74.80
Black	Male	12	43	63.87	66.35	68.82	2.48	71.30	73.77
Black	Male	13	37	63.10	65.81	68.52	2.71	71.23	73.94
Black	Female	6	57	64.13	66.75	69.37	2.62	71.99	74.61
Black	Female	7	49	63.79	66.45	69.11	2.66	71.78	74.44
Black	Female	8	46	62.86	65.81	68.77	2.96	71.72	74.68
Black	Female	9	56	62.99	65.94	68.90	2.95	71.85	74.81
Black	Female	10	36	62.00	65.32	68.64	3.32	71.96	75.29
Black	Female	11	50	63.83	66.16	68.48	2.33	70.81	73.14
Black	Female	12	44	62.99	65.73	68.47	2.74	71.21	73.95
Black	Female	13	38	62.85	65.64	68.42	2.78	71.20	73.98
Coloured	Male	6	44	54.14	61.83	69.51	7.69	77.20	84.88
Coloured	Male	7	54	54.72	62.05	69.39	7.34	76.72	84.06
Coloured	Male	8	59	63.64	66.27	68.90	2.63	71.54	74.17
Coloured	Male	9	58	63.56	66.37	69.18	2.81	71.99	74.79
Coloured	Male	10	54	63.45	66.17	68.88	2.71	71.59	74.30
Coloured	Male	11	56	63.27	66.05	68.83	2.78	71.60	74.38
Coloured	Male	12	48	62.41	65.63	68.85	3.22	72.07	75.29
Coloured	Male	13	80	62.21	65.30	68.39	3.09	71.48	74.58
Coloured	Female	6	35	63.60	66.59	69.58	2.99	72.57	75.56
Coloured	Female	7	57	64.10	66.74	69.37	2.64	72.01	74.64
Coloured	Female	8	86	62.61	65.69	68.77	3.08	71.85	74.93
Coloured	Female	9	75	63.35	66.14	68.92	2.79	71.71	74.50
Coloured	Female	10	71	62.60	65.64	68.68	3.04	71.73	74.77
Coloured	Female	11	87	61.25	64.87	68.50	3.62	72.12	75.74
Coloured	Female	12	81	61.71	65.03	68.34	3.32	71.66	74.98
Coloured	Female	13	88	62.51	65.41	68.30	2.89	71.20	74.09

Intercanthal width-upper face height index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	44.75	49.54	54.34	4.80	59.14	63.93
Black	Male	7	42	44.65	49.13	53.60	4.48	58.08	62.55
Black	Male	8	38	44.34	48.85	53.35	4.51	57.86	62.36
Black	Male	9	44	42.30	47.47	52.65	5.18	57.82	63.00
Black	Male	10	47	40.50	46.47	52.44	5.97	58.40	64.37
Black	Male	11	36	40.32	46.14	51.96	5.82	57.78	63.60
Black	Male	12	43	44.94	48.39	51.84	3.45	55.28	58.73
Black	Male	13	37	35.93	43.22	50.51	7.29	57.79	65.08
Black	Female	6	57	42.58	47.91	53.25	5.33	58.58	63.91
Black	Female	7	49	43.05	47.85	52.65	4.80	57.45	62.26
Black	Female	8	46	43.49	48.02	52.54	4.52	57.06	61.59
Black	Female	9	56	42.23	47.37	52.51	5.14	57.65	62.79
Black	Female	10	36	42.21	47.35	52.48	5.13	57.61	62.74
Black	Female	11	50	40.70	46.30	51.91	5.61	57.51	63.12
Black	Female	12	44	40.99	46.01	51.02	5.02	56.04	61.06
Black	Female	13	38	42.10	45.92	49.74	3.82	53.56	57.38
Coloured	Male	6	44	44.17	48.50	52.82	4.33	57.15	61.48
Coloured	Male	7	54	42.25	47.22	52.18	4.97	57.15	62.12
Coloured	Male	8	59	41.55	46.69	51.84	5.15	56.99	62.14
Coloured	Male	9	58	42.79	47.31	51.83	4.52	56.35	60.87
Coloured	Male	10	54	41.45	46.38	51.31	4.93	56.25	61.18
Coloured	Male	11	56	41.85	46.18	50.52	4.34	54.86	59.20
Coloured	Male	12	48	39.02	44.63	50.23	5.60	55.83	61.44
Coloured	Male	13	80	39.36	44.70	50.04	5.34	55.38	60.72
Coloured	Female	6	35	43.39	48.23	53.06	4.83	57.90	62.73
Coloured	Female	7	57	42.99	47.96	52.92	4.97	57.89	62.86
Coloured	Female	8	86	42.91	47.70	52.49	4.79	57.28	62.08
Coloured	Female	9	75	41.83	47.15	52.48	5.33	57.81	63.13
Coloured	Female	10	71	42.54	47.48	52.41	4.93	57.35	62.28
Coloured	Female	11	87	41.93	46.84	51.75	4.91	56.66	61.57
Coloured	Female	12	81	42.91	46.87	50.84	3.96	54.80	58.77
Coloured	Female	13	88	37.22	43.43	49.64	6.21	55.85	62.06

Appendix III: Complete lateral craniofacial indices for Black and Coloured South African children aged 6 to 13 years (mean ± 1 SD and ± 2SD)

Head-face height index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	52.79	57.25	61.71	4.46	66.17	70.63
Black	Male	7	42	52.11	56.73	61.35	4.62	65.97	70.59
Black	Male	8	38	52.79	57.16	61.53	4.37	65.90	70.27
Black	Male	9	44	53.84	57.77	61.70	3.93	65.63	69.56
Black	Male	10	47	52.85	57.60	62.35	4.75	67.10	71.85
Black	Male	11	36	53.06	58.06	63.06	5.00	68.06	73.06
Black	Male	12	43	53.63	58.42	63.21	4.79	68.00	72.79
Black	Male	13	37	55.12	59.87	64.62	4.75	69.37	74.12
Black	Female	6	57	51.66	56.21	60.76	4.55	65.31	69.86
Black	Female	7	49	48.27	54.39	60.51	6.12	66.63	72.75
Black	Female	8	46	56.30	58.78	61.26	2.48	63.74	66.22
Black	Female	9	56	54.26	58.06	61.86	3.80	65.66	69.46
Black	Female	10	36	52.86	57.49	62.12	4.63	66.75	71.38
Black	Female	11	50	55.21	58.70	62.19	3.49	65.68	69.17
Black	Female	12	44	55.46	59.41	63.36	3.95	67.31	71.26
Black	Female	13	38	57.42	60.84	64.26	3.42	67.68	71.10
Coloured	Male	6	44	49.14	55.03	60.92	5.89	66.81	72.70
Coloured	Male	7	54	51.55	56.19	60.83	4.64	65.47	70.11
Coloured	Male	8	59	53.33	57.17	61.01	3.84	64.85	68.69
Coloured	Male	9	58	46.29	53.99	61.69	7.70	69.39	77.09
Coloured	Male	10	54	53.49	57.72	61.95	4.23	66.18	70.41
Coloured	Male	11	56	53.34	57.95	62.56	4.61	67.17	71.78
Coloured	Male	12	48	54.29	58.68	63.07	4.39	67.46	71.85
Coloured	Male	13	80	54.80	59.09	63.38	4.29	67.67	71.96
Coloured	Female	6	35	53.93	57.11	60.29	3.18	63.47	66.65
Coloured	Female	7	57	51.47	55.78	60.09	4.31	64.40	68.71
Coloured	Female	8	86	52.82	56.97	61.12	4.15	65.27	69.42
Coloured	Female	9	75	52.72	56.98	61.24	4.26	65.50	69.76
Coloured	Female	10	71	52.92	57.13	61.34	4.21	65.55	69.76
Coloured	Female	11	87	53.61	57.70	61.79	4.09	65.88	69.97
Coloured	Female	12	81	52.93	57.38	61.83	4.45	66.28	70.73
Coloured	Female	13	88	54.24	58.62	63.00	4.38	67.38	71.76

Forehead-head height index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	42.25	51.55	60.85	9.30	70.15	79.45
Black	Male	7	42	41.14	50.29	59.44	9.15	68.59	77.74
Black	Male	8	38	43.78	51.91	60.04	8.13	68.17	76.30
Black	Male	9	44	46.65	52.81	58.97	6.16	65.13	71.29
Black	Male	10	47	54.02	56.21	58.4	2.19	60.59	62.78
Black	Male	11	36	44.14	50.39	56.64	6.25	62.89	69.14
Black	Male	12	43	38.07	47.13	56.19	9.06	65.25	74.31
Black	Male	13	37	38.93	47.52	56.11	8.59	64.70	73.29
Black	Female	6	57	41.36	50.13	58.9	8.77	67.67	76.44
Black	Female	7	49	45.23	51.42	57.61	6.19	63.80	69.99
Black	Female	8	46	44.89	51.11	57.33	6.22	63.55	69.77
Black	Female	9	56	43.90	49.94	55.98	6.04	62.02	68.06
Black	Female	10	36	39.06	47.33	55.6	8.27	63.87	72.14
Black	Female	11	50	41.44	48.39	55.34	6.95	62.29	69.24
Black	Female	12	44	39.71	46.35	52.99	6.64	59.63	66.27
Black	Female	13	38	37.31	44.86	52.41	7.55	59.96	67.51
Coloured	Male	6	44	44.08	52.72	61.36	8.64	70.00	78.64
Coloured	Male	7	54	42.08	50.43	58.78	8.35	67.13	75.48
Coloured	Male	8	59	45.58	52.45	59.32	6.87	66.19	73.06
Coloured	Male	9	58	43.02	50.48	57.94	7.46	65.40	72.86
Coloured	Male	10	54	45.21	51.55	57.89	6.34	64.23	70.57
Coloured	Male	11	56	40.22	47.76	55.3	7.54	62.84	70.38
Coloured	Male	12	48	36.78	45.83	54.88	9.05	63.93	72.98
Coloured	Male	13	80	36.62	45.62	54.62	9.00	63.62	72.62
Coloured	Female	6	35	40.85	49.93	59.01	9.08	68.09	77.17
Coloured	Female	7	57	40.20	49.00	57.8	8.80	66.60	75.40
Coloured	Female	8	86	39.65	48.66	57.67	9.01	66.68	75.69
Coloured	Female	9	75	43.92	50.62	57.32	6.70	64.02	70.72
Coloured	Female	10	71	37.17	46.50	55.83	9.33	65.16	74.49
Coloured	Female	11	87	38.69	46.79	54.89	8.10	62.99	71.09
Coloured	Female	12	81	36.18	44.83	53.48	8.65	62.13	70.78
Coloured	Female	13	88	37.65	45.48	53.31	7.83	61.14	68.97

Upper face-face height index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	54.87	57.18	59.49	2.31	61.80	64.11
Black	Male	7	42	56.26	58.66	61.06	2.40	63.46	65.86
Black	Male	8	38	53.10	57.25	61.40	4.15	65.55	69.70
Black	Male	9	44	50.95	56.47	61.99	5.52	67.51	73.03
Black	Male	10	47	52.60	57.41	62.22	4.81	67.03	71.84
Black	Male	11	36	56.66	59.44	62.22	2.78	65.00	67.78
Black	Male	12	43	57.24	59.82	62.40	2.58	64.98	67.56
Black	Male	13	37	52.39	57.53	62.67	5.14	67.81	72.95
Black	Female	6	57	54.49	57.01	59.53	2.52	62.05	64.57
Black	Female	7	49	55.34	57.91	60.48	2.57	63.05	65.62
Black	Female	8	46	50.21	55.86	61.51	5.65	67.16	72.81
Black	Female	9	56	50.96	56.28	61.60	5.32	66.92	72.24
Black	Female	10	36	56.29	59.41	62.53	3.12	65.65	68.77
Black	Female	11	50	52.26	57.49	62.72	5.23	67.95	73.18
Black	Female	12	44	51.66	57.20	62.74	5.54	68.28	73.82
Black	Female	13	38	51.60	57.21	62.82	5.61	68.43	74.04
Coloured	Male	6	44	55.97	58.05	60.13	2.08	62.21	64.29
Coloured	Male	7	54	49.81	55.57	61.33	5.76	67.09	72.85
Coloured	Male	8	59	50.79	56.17	61.55	5.38	66.93	72.31
Coloured	Male	9	58	49.18	55.66	62.14	6.48	68.62	75.10
Coloured	Male	10	54	48.66	55.51	62.36	6.85	69.21	76.06
Coloured	Male	11	56	60.05	61.63	63.21	1.58	64.79	66.37
Coloured	Male	12	48	58.82	61.12	63.42	2.30	65.72	68.02
Coloured	Male	13	80	51.22	57.42	63.62	6.20	69.82	76.02
Coloured	Female	6	35	55.95	58.06	60.17	2.11	62.28	64.39
Coloured	Female	7	57	48.56	55.01	61.46	6.45	67.91	74.36
Coloured	Female	8	86	50.54	56.04	61.54	5.50	67.04	72.54
Coloured	Female	9	75	49.44	55.79	62.14	6.35	68.49	74.84
Coloured	Female	10	71	58.41	60.49	62.57	2.08	64.65	66.73
Coloured	Female	11	87	58.57	60.87	63.17	2.30	65.47	67.77
Coloured	Female	12	81	58.74	61.00	63.26	2.26	65.52	67.78
Coloured	Female	13	88	51.00	57.17	63.34	6.17	69.51	75.68

Lower face-face height index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	55.38	57.77	60.16	2.39	62.55	64.94
Black	Male	7	42	52.47	56.20	59.93	3.73	63.66	67.39
Black	Male	8	38	49.70	54.71	59.72	5.01	64.73	69.74
Black	Male	9	44	46.11	52.64	59.17	6.53	65.70	72.23
Black	Male	10	47	44.64	51.87	59.10	7.23	66.33	73.56
Black	Male	11	36	52.59	55.55	58.51	2.96	61.47	64.43
Black	Male	12	43	53.32	55.75	58.18	2.43	60.61	63.04
Black	Male	13	37	53.92	56.03	58.14	2.11	60.25	62.36
Black	Female	6	57	54.86	57.50	60.14	2.64	62.78	65.42
Black	Female	7	49	52.91	56.26	59.61	3.35	62.96	66.31
Black	Female	8	46	54.60	56.99	59.38	2.39	61.77	64.16
Black	Female	9	56	55.39	57.33	59.27	1.94	61.21	63.15
Black	Female	10	36	54.19	56.59	58.99	2.40	61.39	63.79
Black	Female	11	50	51.68	55.32	58.96	3.64	62.60	66.24
Black	Female	12	44	53.39	55.87	58.35	2.48	60.83	63.31
Black	Female	13	38	53.30	55.75	58.20	2.45	60.65	63.10
Coloured	Male	6	44	52.21	55.90	59.59	3.69	63.28	66.97
Coloured	Male	7	54	51.41	55.03	58.65	3.62	62.27	65.89
Coloured	Male	8	59	50.81	54.58	58.35	3.77	62.12	65.89
Coloured	Male	9	58	50.52	54.32	58.12	3.80	61.92	65.72
Coloured	Male	10	54	51.06	54.59	58.12	3.53	61.65	65.18
Coloured	Male	11	56	53.45	55.76	58.07	2.31	60.38	62.69
Coloured	Male	12	48	44.96	51.50	58.04	6.54	64.58	71.12
Coloured	Male	13	80	53.60	55.75	57.90	2.15	60.05	62.20
Coloured	Female	6	35	54.53	56.77	59.01	2.24	61.25	63.49
Coloured	Female	7	57	53.85	56.17	58.49	2.32	60.81	63.13
Coloured	Female	8	86	53.63	56.05	58.47	2.42	60.89	63.31
Coloured	Female	9	75	46.69	52.55	58.41	5.86	64.27	70.13
Coloured	Female	10	71	53.89	56.08	58.27	2.19	60.46	62.65
Coloured	Female	11	87	53.59	55.90	58.21	2.31	60.52	62.83
Coloured	Female	12	81	53.69	55.87	58.05	2.18	60.23	62.41
Coloured	Female	13	88	52.99	55.44	57.89	2.45	60.34	62.79

Mandibulo-upper face height index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	33.89	36.09	38.29	2.20	40.49	42.69
Black	Male	7	42	29.15	33.49	37.83	4.34	42.17	46.51
Black	Male	8	38	26.17	31.96	37.75	5.79	43.54	49.33
Black	Male	9	44	27.07	32.18	37.29	5.11	42.40	47.51
Black	Male	10	47	32.17	34.58	36.99	2.41	39.40	41.81
Black	Male	11	36	31.20	34.02	36.84	2.82	39.66	42.48
Black	Male	12	43	30.53	33.51	36.49	2.98	39.47	42.45
Black	Male	13	37	30.44	33.36	36.28	2.92	39.20	42.12
Black	Female	6	57	32.34	35.19	38.04	2.85	40.89	43.74
Black	Female	7	49	31.96	34.73	37.50	2.77	40.27	43.04
Black	Female	8	46	33.42	35.42	37.42	2.00	39.42	41.42
Black	Female	9	56	29.03	32.94	36.85	3.91	40.76	44.67
Black	Female	10	36	30.55	33.69	36.83	3.14	39.97	43.11
Black	Female	11	50	28.05	32.41	36.77	4.36	41.13	45.49
Black	Female	12	44	27.49	32.11	36.73	4.62	41.35	45.97
Black	Female	13	38	32.34	34.44	36.54	2.10	38.64	40.74
Coloured	Male	6	44	33.48	35.67	37.86	2.19	40.05	42.24
Coloured	Male	7	54	29.09	33.29	37.49	4.20	41.69	45.89
Coloured	Male	8	59	29.33	33.32	37.31	3.99	41.30	45.29
Coloured	Male	9	58	31.25	34.27	37.29	3.02	40.31	43.33
Coloured	Male	10	54	27.96	32.56	37.16	4.60	41.76	46.36
Coloured	Male	11	56	33.14	35.07	37.00	1.93	38.93	40.86
Coloured	Male	12	48	32.19	34.42	36.65	2.23	38.88	41.11
Coloured	Male	13	80	32.09	34.34	36.59	2.25	38.84	41.09
Coloured	Female	6	35	32.89	34.98	37.07	2.09	39.16	41.25
Coloured	Female	7	57	27.96	32.43	36.90	4.47	41.37	45.84
Coloured	Female	8	86	29.38	33.12	36.86	3.74	40.60	44.34
Coloured	Female	9	75	27.71	32.24	36.77	4.53	41.30	45.83
Coloured	Female	10	71	32.45	34.52	36.59	2.07	38.66	40.73
Coloured	Female	11	87	31.76	34.06	36.36	2.30	38.66	40.96
Coloured	Female	12	81	31.86	34.09	36.32	2.23	38.55	40.78
Coloured	Female	13	88	31.80	33.91	36.02	2.11	38.13	40.24

Mandibulo-lower face height index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	50.72	55.15	59.58	4.43	64.01	68.44
Black	Male	7	42	55.09	58.42	61.75	3.33	65.08	68.41
Black	Male	8	38	46.17	53.03	59.89	6.86	66.75	73.61
Black	Male	9	44	49.90	55.56	61.22	5.66	66.88	72.54
Black	Male	10	47	56.80	59.74	62.68	2.94	65.62	68.56
Black	Male	11	36	57.78	60.43	63.08	2.65	65.73	68.38
Black	Male	12	43	56.52	59.84	63.16	3.32	66.48	69.80
Black	Male	13	37	51.38	55.71	60.04	4.33	64.37	68.70
Black	Female	6	57	54.66	57.88	61.10	3.22	64.32	67.54
Black	Female	7	49	55.35	58.61	61.87	3.26	65.13	68.39
Black	Female	8	46	57.12	59.70	62.28	2.58	64.86	67.44
Black	Female	9	56	52.57	58.36	64.15	5.79	69.94	75.73
Black	Female	10	36	56.16	59.62	63.08	3.46	66.54	70.00
Black	Female	11	50	51.24	56.73	62.22	5.49	67.71	73.20
Black	Female	12	44	48.29	55.52	62.75	7.23	69.98	77.21
Black	Female	13	38	57.33	59.95	62.57	2.62	65.19	67.81
Coloured	Male	6	44	53.38	57.82	62.26	4.44	66.70	71.14
Coloured	Male	7	54	40.26	50.20	60.14	9.94	70.08	80.02
Coloured	Male	8	59	52.41	57.26	62.11	4.85	66.96	71.81
Coloured	Male	9	58	58.15	60.82	63.49	2.67	66.16	68.83
Coloured	Male	10	54	49.46	55.95	62.44	6.49	68.93	75.42
Coloured	Male	11	56	57.82	60.20	62.58	2.38	64.96	67.34
Coloured	Male	12	48	52.68	57.49	62.30	4.81	67.11	71.92
Coloured	Male	13	80	58.37	61.07	63.77	2.70	66.47	69.17
Coloured	Female	6	35	57.89	60.43	62.97	2.54	65.51	68.05
Coloured	Female	7	57	48.32	55.45	62.58	7.13	69.71	76.84
Coloured	Female	8	86	51.12	56.88	62.64	5.76	68.40	74.16
Coloured	Female	9	75	53.20	58.30	63.40	5.10	68.50	73.60
Coloured	Female	10	71	58.99	61.62	64.25	2.63	66.88	69.51
Coloured	Female	11	87	58.50	61.30	64.10	2.80	66.90	69.70
Coloured	Female	12	81	58.35	61.40	64.45	3.05	67.50	70.55
Coloured	Female	13	88	59.77	62.41	65.05	2.64	67.69	70.33

Upper middle third face depth index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	83.14	86.30	89.46	3.16	92.62	95.78
Black	Male	7	42	83.99	86.24	88.49	2.25	90.74	92.99
Black	Male	8	38	82.56	85.52	88.48	2.96	91.44	94.40
Black	Male	9	44	80.07	83.71	87.35	3.64	90.99	94.63
Black	Male	10	47	75.14	80.52	85.90	5.38	91.28	96.66
Black	Male	11	36	79.96	83.05	86.14	3.09	89.23	92.32
Black	Male	12	43	81.73	84.26	86.79	2.53	89.32	91.85
Black	Male	13	37	80.94	83.28	85.62	2.34	87.96	90.30
Black	Female	6	57	84.87	86.87	88.87	2.00	90.87	92.87
Black	Female	7	49	76.50	82.35	88.20	5.85	94.05	99.90
Black	Female	8	46	81.78	84.41	87.04	2.63	89.67	92.30
Black	Female	9	56	81.66	84.34	87.02	2.68	89.70	92.38
Black	Female	10	36	81.08	83.79	86.50	2.71	89.21	91.92
Black	Female	11	50	79.75	82.80	85.85	3.05	88.90	91.95
Black	Female	12	44	81.78	84.29	86.80	2.51	89.31	91.82
Black	Female	13	38	79.24	82.39	85.54	3.15	88.69	91.84
Coloured	Male	6	44	81.89	85.01	88.13	3.12	91.25	94.37
Coloured	Male	7	54	81.05	83.99	86.93	2.94	89.87	92.81
Coloured	Male	8	59	80.44	83.16	85.88	2.72	88.60	91.32
Coloured	Male	9	58	79.63	82.66	85.69	3.03	88.72	91.75
Coloured	Male	10	54	80.23	82.99	85.75	2.76	88.51	91.27
Coloured	Male	11	56	80.68	83.15	85.62	2.47	88.09	90.56
Coloured	Male	12	48	78.33	82.02	85.71	3.69	89.40	93.09
Coloured	Male	13	80	80.81	83.51	86.21	2.70	88.91	91.61
Coloured	Female	6	35	81.08	84.13	87.18	3.05	90.23	93.28
Coloured	Female	7	57	79.69	82.95	86.21	3.26	89.47	92.73
Coloured	Female	8	86	80.13	83.19	86.25	3.06	89.31	92.37
Coloured	Female	9	75	80.32	82.91	85.50	2.59	88.09	90.68
Coloured	Female	10	71	79.86	82.56	85.26	2.70	87.96	90.66
Coloured	Female	11	87	81.25	83.67	86.09	2.42	88.51	90.93
Coloured	Female	12	81	79.64	82.66	85.68	3.02	88.70	91.72
Coloured	Female	13	88	81.12	83.84	86.56	2.72	89.28	92.00

Lower middle face depth index									
Group	**Sex**	**Age**	**n**	**[- 2SD]**	**[-1SD]**	**Mean**	**SD**	**[+1SD]**	**[+2SD]**
Black	Male	6	53	86.72	90.17	93.62	3.45	97.07	100.52
Black	Male	7	42	87.11	90.54	93.97	3.43	97.40	100.83
Black	Male	8	38	83.46	87.79	92.12	4.33	96.45	100.78
Black	Male	9	44	85.37	88.72	92.07	3.35	95.42	98.77
Black	Male	10	47	85.96	88.89	91.82	2.93	94.75	97.68
Black	Male	11	36	83.76	87.52	91.28	3.76	95.04	98.80
Black	Male	12	43	84.54	87.98	91.42	3.44	94.86	98.30
Black	Male	13	37	84.97	87.86	90.75	2.89	93.64	96.53
Black	Female	6	57	86.48	89.67	92.86	3.19	96.05	99.24
Black	Female	7	49	73.54	82.67	91.80	9.13	100.93	110.06
Black	Female	8	46	85.12	88.03	90.94	2.91	93.85	96.76
Black	Female	9	56	84.82	87.72	90.62	2.90	93.52	96.42
Black	Female	10	36	84.55	87.70	90.85	3.15	94.00	97.15
Black	Female	11	50	84.01	87.33	90.65	3.32	93.97	97.29
Black	Female	12	44	84.78	87.63	90.48	2.85	93.33	96.18
Black	Female	13	38	84.25	87.15	90.05	2.90	92.95	95.85
Coloured	Male	6	44	86.60	89.98	93.36	3.38	96.74	100.12
Coloured	Male	7	54	86.12	89.36	92.60	3.24	95.84	99.08
Coloured	Male	8	59	86.48	89.23	91.98	2.75	94.73	97.48
Coloured	Male	9	58	86.45	89.14	91.83	2.69	94.52	97.21
Coloured	Male	10	54	84.73	87.90	91.07	3.17	94.24	97.41
Coloured	Male	11	56	84.93	87.89	90.85	2.96	93.81	96.77
Coloured	Male	12	48	84.02	87.35	90.68	3.33	94.01	97.34
Coloured	Male	13	80	84.43	87.36	90.29	2.93	93.22	96.15
Coloured	Female	6	35	86.79	89.60	92.41	2.81	95.22	98.03
Coloured	Female	7	57	85.20	88.27	91.34	3.07	94.41	97.48
Coloured	Female	8	86	85.14	88.05	90.96	2.91	93.87	96.78
Coloured	Female	9	75	84.11	87.21	90.31	3.10	93.41	96.51
Coloured	Female	10	71	82.65	86.34	90.03	3.69	93.72	97.41
Coloured	Female	11	87	83.84	86.96	90.08	3.12	93.20	96.32
Coloured	Female	12	81	83.62	86.86	90.10	3.24	93.34	96.58
Coloured	Female	13	88	83.92	87.04	90.16	3.12	93.28	96.40

Appendix IV: Ethical clearance certificate

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria comply with ICH-GCP guidelines and has US Federalwide Assurance. FWA 00002567, Approved dd 22 May 2002 and Expires 24 Jan 2009.
IRB 0000 2235 IORG0001762 Approved dd Jan 2006 and Expires 21 Nov 2008.

Universiteit van Pretoria
University of Pretoria

Faculty of Health Sciences Research Ethics Committee
University of Pretoria

HW Snyman Building, (South) Private Bag X169
Level 2-34 Pretoria
Pretoria 0001

Date: 10/09/2007

PROTOCOL NO.	**85/2007**
NEW TITLE	A Morphological And Biometric Study Of The Facial Characteristics Of Two South African Childhood Populations At Different Age Levels.
PRINCIPAL INVESTIGATOR DEPARTMENT	Nanette Briers Anatomy
SUB INVESTIGATOR	Prof M Steyn
SPONSOR	None.
CONTACT DEATAILS	**Phone:** 012-319 2631 **Fax:**012-319 2240 **E-Mail:** nbriers@up.ac.za **Cell:**0837431134
STUDY DEGREE	PhD (Anatomy) University of Pretoria
VAT NO.	None.
MEETING DATE	25/07/2007

This Protocol and Informed Consent and all the attatchemnts have been considered by the Faculty of Health Sciences Research Ethics Committee, University of Pretoria on 29/08/2007 and found to be acceptable.

*Advocate AG Nienaber	(female)BA(Hons) (Wits); LLB; LLM (UP); Dipl.Delametrics (UNISA)
*Prof V.O.L. Kerusseit	MBChB; MFGP (SA); M.Med (Chir); FCS (SA): Surgeon
*Prof M Kruger	(female) MB.ChB.(Pret); Mmed.Paed.(Pret); PhDd. (Leuven)
Dr N K Likibi	MB.BCh.; Med.Adviser (Gauteng Dept.of Health)
*Snr Sr J. Phetoli	(female) BCur (ELAI) Senior Nursing-Sister
*Dr L Schoeman	(female) Bpharm, BA Hons (Psy), PhD
*Prof J.R. Snyman	MBChB, M.Pharm.Med: MD: Pharmacologist
Dr R Sommers	(female) MBChB; M.Med (Int); MPhar.Med;
Prof TJP Swart	BChD, MSc (Odont), MChD (Oral Path) Senior Specialist; Oral Pathology
*Dr A P van Der Walt	BChD, DGA (Pret) Director: Clinical Services of the Pretoria Academic Hospital
Prof C W van Staden	MBChB; Mmed (Psych); MD; FTCL; UPLM; Dept of Psychiatry

DR R SOMMERS; MBChB; M.Med (Int); MPhar.Med.
SECRETARIAT of the Faculty of Health Sciences Research Ethics Committee - University of Pretoria

* = Members attended the meeting on 29/08/2007.

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