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A DESCRIPTIVE MORPHOLOGICAL STUDY ON ADULT FACIAL AGEING IN BLACK SOUTH AFRICAN MALES

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1253452

A Dissertation submitted to the Faculty of Health Science, University of the Witwatersrand, in fulfilment of the requirements for the degree of Master of Science in Medicine.

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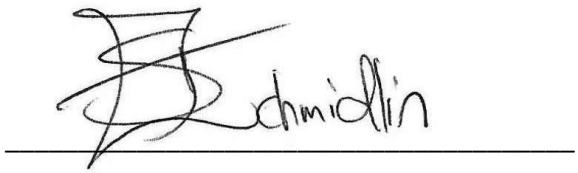
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Johannesburg, 2019

Declaration

I, Estha J Schmidlin, declare that this Dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science in Medicine by dissertation at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



Signed this 12th day of March 2019, in Johannesburg, Gauteng

Presentations and Publications

- Preliminary results were presented at the International Association for Craniofacial Identification (IACI) biennial conference in Brisbane, Australia, July 2017. The oral presentation was titled 'A descriptive morphological study on adult facial ageing in black South African males'.

- The results obtained in this project were further presented at the Anatomical Society of Southern Africa (ASSA) annual conference in Muldersdrift, SA, April 2018. The oral presentation was titled 'Age changes in the faces of South African adult males'.

- A peer-reviewed paper was published in Forensic Science International.

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This paper, along with a signed declaration by the co-authors, is included in Appendix K.

Abstract

Facial ageing research contributes to the knowledge spheres of plastic surgery, dermatology and craniofacial depiction. No South African specific facial ageing data are available. The aim of this study was therefore to assess aspects of facial ageing in a group of South African black males, using anterior and lateral facial photographs of 189 South African males aged 20 years and older. The sample included 30 individuals per decade, except for the 80+ age category that consisted of nine participants. Photos were recorded in a standardized manner and various metric and morphological features, related to increasing age, were assessed on each photograph. Non-metric facial changes were investigated using a facial scoring system based on existing literature. A more global approach to the face was also taken in construction of facial averages using Abrosoft FantaMorph Deluxe software. Socio-economic and demographic factors that may influence facial ageing were included in a lifestyle questionnaire. Overall, the results indicated some deviation from European-based literature on facial ageing. Mouth width increase, nasal elongation, nasal tip dropping, ear width increase and ear length increase did not occur with increasing age. Unique age changes, such as the lack of a lateral nose crease and the occurrence of a dimpled chin, were identified. Overall, wrinkle formation was delayed and cheek hollowing was advanced in this group relative to their European counterparts. A description of facial ageing in a South African male sample is provided by this study.

(238 words)

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Last but not least, each participant in this project deserves thanks. As they remain anonymous due to privacy protection, each cannot be thanked individually. Nevertheless, each contributed equally and generously to the success of this project.

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Chapter 1
Introduction

This research project investigated facial ageing in a black South African male sample. Research on adult facial ageing is applicable to various fields of knowledge. Currently, no research on facial ageing in black South African adults is available, despite the wide applicability of this information. This presents a research gap that the current research project aims to address. A set of objectives were developed to assist in meeting the aim of providing a background of South African population-specific facial ageing.

1.1 Research relevance

Facial ageing is applicable to a variety of research and clinical fields which includes plastic surgery, dermatology and craniofacial depiction. There is a need for accurate, population specific data within each of these three fields. The various benefits of such data vary within each field, and are presented briefly in the following paragraphs.

Plastic surgery, specifically facial surgery, is steadily becoming more common in South Africa (Henderson, 2017). Aside from trauma related medical reconstructions, anti-ageing procedures such as face-lifts are becoming increasingly popular across all South African population and sex groups (Henderson, 2017). Since cosmetic surgery procedures often focus on reversing the effects of ageing, knowledge of patterns of population specific ageing changes allow for optimal pre-surgery preparation, as well as increased chances of favourable surgical outcomes (Forte *et al*., 2015; Lambros, 2008; Pourdanesh *et al.*, 2016).

Accurate knowledge of expected ageing changes would also enable a natural-looking reconstruction for trauma-related facial surgeries. For the developing field of facial surgery in South Africa, population specific facial ageing research would be beneficial. Within the field of dermatology, the catchphrase ‘anti-ageing’ is popular. Topical solutions, skin treatments at beauty centres, and oral supplements, focus on reducing the visible effects of ageing.

Sales of products focused on anti-ageing had an estimated market value of 140.3 billion U.S. dollars (USD) worldwide in 2015, and this market share is projected to nearly double to 216.52 billion USD by 2021 (Statista, 2018). The overall skin-care market in South Africa was valued at 581.7 million USD in 2017, with anti-ageing products set to become an ever-increasing segment of the market (Mordor Intelligence, 2018).

Since the anti-ageing market is of value to the South African economy, research on facial ageing specifically for black individuals is necessary and would allow treatments to be tailored to the actual, rather than perceived, needs of South Africans. Treatments focused on the requirements of a South African population are likely to have a positive effect on consumer spending (AAMSSA, 2018).

Facial representations of deceased individuals may be requested for archaeological/ paleoanthropological museum display purposes, or in an attempt to address forensic law-enforcement questions (Hayes, 2017; Íşcan and Steyn, 2013; Wilkinson, 2004). Regarding museum displays, South Africa is in a unique position to not only present facial approximations of historical individuals, but prehistoric, hominid depictions as well (SA Government, 2014). Facial representations of evolutionary ancestors could be an important tool to reach and engage the broader public, as research seems to suggest that human attention and empathy is preferentially drawn to faces (Bakhshi *et al.*, 2014; Palermo and Rhodes, 2007). Despite obvious differences between hominid ancestors and the modern population, adding facial ageing changes informed by an African rather than European perspective may provide facial representations that are more applicable to a South African population.

With regard to a forensic perspective on facial representation, understanding age related changes of the face is a necessity. Applications of facial ageing knowledge include ageing images of suspects/victims in cases where a long time had lapsed since a person had gone missing or a crime had been committed. Knowledge on facial ageing may then be used to generate an age-appropriate image estimate of how such an individual may appear at present, allowing facial comparisons of the missing person to possible matches. Facial ageing knowledge is also pertinent for facial approximations based on skeletal material. Once a basic face has been rendered, an appropriate number of wrinkles as well as ageing changes need to be applied on a reconstruction/approximation based on the estimated age of the individual.

Google Image photographs often provide artists/ anatomists with the necessary age-appropriate guidelines (Capt. TM Briers, personal communication, June 2017). This strategy is, however, problematic as it does not meet the standards set for good scientific practice (*Daubert v. Merrell Dow Pharmaceuticals, Inc*, 1993), nor is it population specific. Forensic standards require at the very least a replicable methodology with a reported error rate, both of which are not attainable when using a Google Image search.

Building a comprehensive knowledge base on facial ageing in South Africans would likely require multiple research studies conducted over time, when considering the lack of a universal, highly predictable facial ageing patterns applicable to all individuals (Albert *et al.*, 2007). This research project is a first step in the direction of such a comprehensive knowledge base, and aims to provide an overview of facial ageing in a population of South African black males.

1.2 Aim and objectives

This study aimed to describe age related changes in the faces of black South African adult males, aged 20 years and older.

Specific objectives were to:

- Develop and apply a relevant morphological scoring system to assess age changes in South African black males;
- Apply photo-anthropometric techniques to 2D images in order to describe measurable patterns of facial ageing;
- Assemble the average face for each of the identified age groups using 2D images;
- Collect data on lifestyle and demographic factors that may influence ageing; and
- Compare facial ageing patterns in this South African sample to other population groups described in existing literature.

Chapter 2
Literature Review

This project builds on existing literature to enable bridging of the gaps in published research. For the purposes of this study, a more in depth discussion on the utility of facial ageing in a South African forensic context will be provided. Facial representations for forensic purposes may help mitigate the current high numbers of unidentified South African deceased (Wild, 2017). However, facial appearance is influenced greatly by the ageing process, which motivates research on facial ageing. Such research enables increased accuracy in all facial depictions.

Available research on facial ageing does not consider a South African population specifically (Albert *et al.*, 2007; Sforza *et al.*, 2010a, 2009a, 2009b, 2010b; Vashi *et al.*, 2016). However, it is expected that overall ageing changes would be similar in appearance, if not timing of appearance, across populations. Reviewing published facial ageing changes therefore forms a core component of this chapter. The methods used by various researchers to investigate facial ageing are also considered in this literature review, with a short discussion on shortcomings or limitations to each method for a South African setting.

2.1 Facial representation in a forensic context

2.1.1 The role of facial representation in physical anthropology

Identification of the dead starts off by gathering as much information about the deceased as possible. Biological anthropological methods often provide enough material to form a preliminary biological profile, which can subsequently be matched to a list of missing persons. A typical biological profile based on skeletal remains consist of an estimated sex, ancestry, age and stature of the deceased (Íşcan and Steyn, 2013). Such a biological profile could be supplemented with the creation of a likely facial image based on the skeletal remains.

Forensic facial approximation is the process of recreating the face of an individual by considering their unique skull structure and combining artistry, forensic science, anatomy

and osteology to produce a facial image (Hayes, 2017; Íşcan and Steyn, 2013; Wilkinson, 2004). The generated face may then be presented to the public on social and conventional media. By presenting such an image to the public, recognition by family, colleagues or friends may lead to subsequent identification of the skeletal remains (Íşcan and Steyn, 2013).

Identification of skeletal remains based on an anthropological report, which may include a facial representation, depend on the ability to match a biological profile to an individual. One possible manner in which this could be done is to narrow down potential matches from a missing persons list. In South Africa such an elimination process is complicated by the sheer number of unidentified dead as well as a lack of clarity on missing persons (Wild, 2017). The impact of these two challenges is further discussed in the following subsection.

2.1.2 South Africa's unidentified deceased

Despite varying reports on the actual number of homicides occurring currently in South Africa, all statistical releases seem to agree that the numbers are high (Crime Stats SA, 2017; Statistics South Africa, 2016a, 2015; UNODC, 2013). There is no firm data available on the amount of unidentified deceased persons as a consequence of so many homicides.

South African statistics on unidentified deceased persons has to be pieced together from various sources, with many tending to report sporadically on different years, resulting in a lack of knowledge for a given timeframe. In 2015 Independent Online (IOL) published an article from The Star newspaper, quoting the then Gauteng Health MEC, Qedani Mahlangu as stating that 1272 unidentified bodies could be found in Gauteng medico-legal mortuaries alone from the period April 1, 2014 to March 31, 2015 (Mabotja, 2015). The article also mentioned approximately 4 000 unclaimed and unidentified cases in Gauteng mortuaries over a three year period leading up to the interview. This seems to vaguely correspond with the information provided in an interview in 2014 with the then Gauteng health MEC, Hope Papo, who mentioned 5 352 unidentified bodies in Gauteng mortuaries from January 2010 to October 2013 (Jadoo, 2014). It has been reported that between 1 300 and 1 600 unidentified individuals are processed in Gauteng mortuaries yearly (Wild, 2017), once again seemingly in agreement with the earlier articles.

Despite the scarcity of comprehensive statistical reports on the number of unidentified deceased that are available, processes allowing for efficient and effective identification of the dead in a South African context are of importance. Although a comprehensive biological report as well as associated facial reproduction would be of use for identification purposes, complications arise when considering the eliminatory nature of the information provided by these two analyses. Biological reports as well as facial reproductions are corroborative in nature (Íşcan and Steyn, 2013), implying the need for some list or information on potentially matching individuals.

Whereas little (and in some cases conflicting) data could be found on homicides and unidentified deceased, no verifiable data could be found on the number of missing persons reported for any given year. Evert (2011) stated that approximately 4 000 people were reported as missing in 2007, based on a personal communication. In addition, an internet-based search provided a limited, rather than comprehensive, current list of missing persons in South Africa from the South African Police Service (SAPS) website (https://www.saps.gov.za/crimestop/missing/list.php). The lack of comprehensive and accessible data on missing persons suggest that despite the information gleaned from a physical anthropological biological profile and facial approximation, investigators would be hard pressed to narrow down possible matches in an attempt at identification of an unidentified individual's remains.

The varying estimates regarding the number of undocumented migrants in the country is yet another confounding factor to identification of the deceased by means of a list of potential matches. The estimates vary from 500 000, up to 10 million illegal migrants (Crush *et al*., 2006). The higher figures in the range cannot be readily verified, with estimates of 500 000 to one million undocumented migrants seemingly being the consensus (Crush *et al*., 2006). However, some of the lower estimates date back to the 1990's, with the amount of time lapsed till present making it unlikely that these figures are still accurate in 2018. It should also be noted that these statistics reflect the number of detained illegal immigrants, and not the total number of individuals entering the country through unconventional channels. Nevertheless, the lowest estimate of 500 000 still amounts to a vast number of individuals that, if deceased, would likely remain unidentified as no official record of their existence in South Africa would be available. Matching a biological profile to a person is only likely if there is a list of possible candidates available to narrow down the search, which

means that undocumented individuals would not be included on a potential list. As undocumented individuals would not be included in a list of potential matches, should such an individual end up in a morgue as unidentified, an identification of their remains would be unlikely (Bax, 2018).

Despite the issues surrounding missing persons lists as well as undocumented immigrants, a biological profile as well as a facial image associated with unidentified remains do assist the forensic identification process. Many changes occur in the face during ageing (Albert *et al.*, 2007) and appropriate knowledge of said changes would contribute to the accuracy and the likelihood of recognition of any facial depiction. In a country such as South Africa where a need for effective methods of identifying the dead exists, research on facial ageing with an eye on enhancing current facial depiction methods is invaluable.

2.2 The senescent process and craniofacial ageing changes

Morphological differences can be observed as faces age. These differences occur both due to the intrinsic or innate senescent process, as well as extrinsic or environmental influences that may exacerbate the ageing process (Albert *et al.*, 2007; Mydlova *et al.*, 2015; Rexbye *et al.*, 2006; Vashi *et al.*, 2016).

Innate ageing changes occur due to oxidative stress as well as telomere chromosome shortening, resulting in cells being damaged over time (Baumann, 2007; Vashi *et al.*, 2016). The cellular damage affects the underlying bone structure, in turn affecting the overlaying soft tissue (Albert *et al*., 2007). More superficial features that are affected by age-related cellular changes include skin elasticity, muscle tone, and adipose tissue (Albert *et al.*, 2007; Mydlova *et al.*, 2015; Vashi *et al.*, 2016). Skin elasticity decreases due to age-related loss of collagen (Baumann, 2007). Muscle tone as well as cross-sectional area decreases as a person ages, in part due to changes occurring in the properties of myosin (D'Antona *et al.*, 2003; Frontera *et al*., 2000). Subcutaneous adipose concentrations atrophy and are redistributed due to advancing age (Mydlova *et al*., 2015; Vashi *et al.*, 2016). Intrinsic changes may also be ascribed to hyperdynamic facial expressions and gravity (Albert *et al.*, 2007).

With increasing age, the senescent process is regulated progressively less by genetics and more by environmental factors, which is unique for every individual (Albert *et al.*, 2007).

Environmental factors that likely play a role in facial ageing include sun exposure, general health, tobacco and alcohol use, social and economic status and general stress (Albert *et al.*, 2007; Baumann, 2007; Rexbye *et al*., 2006; Vashi *et al*., 2016; Vierkotter and Krutmann, 2012). These sources disagree on the relative contribution of each environmental factor, though most agree that photoaging due to sun radiation exposure as well as tobacco use plays a major role in the appearance of ageing faces (Rexbye *et al.*, 2006; Vashi *et al.*, 2016; Vierkotter and Krutmann, 2012).

These innate as well as environmental influences combine to cause wrinkle formation, drooping of features such as upper eye folds, as well as progressive skin texture coarseness and colour heterogenies (Albert *et al.*, 2007; Rexbye *et al.*, 2006; Vashi *et al*., 2016). The rate of these changes is highly variable across sexes (Mydlova *et al*., 2015), ancestry groups (Vashi *et al.*, 2016; Vierkotter and Krutmann, 2012) and individuals (Albert *et al.*, 2007).

Despite the variable age and rate of facial senescence, some generalizations can be made as to age of first appearance and relative progression of facial ageing. The best guideline to the appearance and progression of facial ageing changes is presented by Albert *et al.* (2007), and are summarized in Table 2.1.

Table 2.1: Adult hard and soft-tissue age-related changes adapted from Albert *et al.* (2007).

Approximate age range (years)	Probable soft tissue or facial appearance effect
20 – 30	• Upper eyelid drooping begins • Eyes appear smaller • Nasolabial lines begin to form • Lateral orbital lines begin to form • Upper lip retrusion begins in females
30 – 40	• Circumoral striae begin to form • Lines begin to form from lateral edges of nose to lateral edges of mouth • Upper lip thickness decreasing
40 – 50	• Facial lines and folds continue to increase in depth • Nose and chin positioning affected as dental arch lengths decrease • Most profound morphological changes of the head, face, and neck are evident
50 – 60	• Facial lines and folds continue to increase in depth • Protuberance of nose and ears due to greater craniofacial convexity
> 60	• Protuberance of nose and ears continues • Concave appearance in cheek hollows due to alveolar bone remodelling • Diminished jaws

Table 2.1 provides a general overview, although it does not detail all facial ageing changes described in literature. In order to provide a more comprehensive description, facial areas such as the eyes, ears, nose and mouth are discussed separately in the following subsections (Subsection 2.2.2 – 2.2.6), starting from the superior most features - the eyes and surrounding orbital area. The subsections detailing each area's ageing changes are followed by a subsection detailing wrinkle placement and aetiology (Subsection 2.2.7), as the timing of wrinkle appearance will only be briefly mentioned under each relevant facial area.

2.2.1 Factors influencing facial ageing

Facial ageing changes include external, environmental factors, as well as internal ageing mechanisms (Albert *et al*., 2007; Vashi *et al.*, 2016). As a person ages, the effects of environmental factors accumulate over time and lead to epigenetic changes (changes in the expression of genetic material), as well as visible surface changes., The latter are in part due to the effects of cellular free radicals/ reactive oxygen species (Albert *et al.*, 2007; Baumann, 2007; Benayoun *et al.*, 2015; Riddihough and Zahn, 2010). It is stated that environmental influences also cause a decrease in collagen production as well as increasing collagen degeneration (Vierkotter and Krutmann, 2012). Epigenetic and collagen changes relate to the intrinsic facial ageing process, as these negative environmental influences enhance internal ageing mechanisms. Environmental factors therefore play a progressively more important role with increasing age.

Many environmental factors have been reported to affect facial ageing (Albert *et al.*, 2007; Rexbye *et al.*, 2006). However, most literature sources agree that the most influential factor is sun exposure (Albert *et al.*, 2007; Baumann, 2007; Rexbye *et al.*, 2006; Vashi *et al.*, 2016; Vierkotter and Krutmann, 2012). Also referred to as photoaging (Baumann, 2007; Vashi *et al.*, 2016; Vierkotter and Krutmann, 2012), elevated levels of sun exposure without UV radiation protection (such as sunscreen) lead to wrinkling, an uneven skin texture, mottled skin colour, vein visibility (telangiectasia) and sallowness of the skin (Albert *et al.*, 2007; Vashi *et al.*, 2016).

The effects of tobacco consumption, in relation to facial ageing, come a close second to that of photoaging (Rexbye *et al.*, 2006). Smoking is reported to lead to premature wrinkling, telangiectasis and elastosis of the skin (Vierkotter and Krutmann, 2012). Tobacco use affects the microvasculature of the skin, leading to disruptions in elastin and collagen structures (Albert *et al.,* 2007). Circumoral striae specifically are mentioned as being exacerbated by smoking (Albert *et al.,* 2007).

Further factors that are reported as influencing facial ageing include, but are not limited to, socio-economic status and general health (Albert *et al.*, 2007; Rexbye *et al.*, 2006). Rexbye *et al.* (2006) reported in their study on Danish twins that being of a lower social standing or suffering from chronic medical conditions such as depression, asthma or cardiovascular disease contribute to an older perceived facial age.

Facial ageing also seems to be accelerated in individuals with no children, individuals with four or more children and individuals that are not married (Rexbye *et al.*, 2006). Having between one and three children, as well as being married, predispose one towards a more youthful appearance. Rexbye *et al.* (2006) ascribes these effects to sharing the burden of worrying, coupled with an increase in economic and social stability and security. Persons with a lower BMI (Body Mass Index) score are inclined to display advanced facial ageing (Rexbye *et al.*, 2006). The abovementioned environmental factors contribute to, or delay, an aged facial appearance.

2.2.2 Orbital changes

Facial ageing changes described for this area can be subdivided into wrinkle presentation as well as feature shape change. Wrinkles that commonly occur include periorbital lines, upper and lower eyelid creases, vertical glabellar lines and infraorbital creases (Hadi and Wilkinson, 2014). It is reported that periorbital creases as well as vertical glabellar lines form initially during the 20's, and deepen from 30 years of age onwards (Albert *et al.*, 2007). The infraorbital crease reportedly presents from around 40 years of age (Albert *et al.*, 2007).

Morphological shape changes such as upper eyelid drooping and eyebrow dropping occurs around 40 years of age (Albert *et al.*, 2007). Suborbital pouch formation may present from 50 years of age and older (Albert *et al.*, 2007). Eyelid drooping as well as pouch formation may be ascribed to a loss of skin collagen, muscle tensile strength and changes in adipose distributions, as well as some bone resorption around the orbital rim (Baumann, 2007; Frontera *et al.*, 2000; Mendelson and Wong, 2012; Mydlova *et al.*, 2015; Vashi *et al.*, 2016).

The Sforza *et al.* (2009b) study relied on metric observations, finding that orbit height and eye fissure inclination increases significantly with progressive age. The inclination increase was observed through the orbitale landmark, defined as the most inferior point on orbital rim (Stephan and Caple, 2016), shifting downwards. In addition, bi-ocular and intercanthal widths, length of the eye fissure and the overall soft-tissue orbital area increased with increasing age (Sforza *et al.,* 2009b). The difficulty in defining the orbit as well as measuring the inclination angle, unless sophisticated digitizing equipment as well as individuals rather than 2D images are used, should be noted.

2.2.3 Auricular changes

Similar to the orbital area, both wrinkles and shape changes are described as occurring around the ear. Periauricular lines develop with increasing age (Hadi and Wilkinson, 2014), although no specific age of initial development is provided.

Albert *et al.* (2007) describe overall ear height and width as increasing. The increase in overall ear dimension is substantiated by the Sforza *et al.* (2009a) and Ferrario *et al.* (2003) studies. As the external ear apparatus is comprised of a cartilage rather than bone supporting structure, growth is expected throughout adult life (Bradham and Horton, 1998; Sforza *et al*., 2009a). The Sforza *et al.* (2009a) results indicate that the ear growth rate increases from about 60 years of age, as do Albert *et al.* (2007). However it is reported that the earlobe accounts for a large portion of the ear length increase, and that the earlobe decreases in width over time (Albert *et al.*, 2007).

The ear width-to-length ratio in correlation with age also provided significant results, decreasing as chronological age increases (Sforza et al., 2009a). The sagittal angle of the auricle also decreased over time, although this measurement once again requires sophisticated equipment to successfully calculate (Sforza *et al.*, 2009a).

2.2.4 Nasal changes

The nose has been described as undergoing measurable shape changes as well as wrinkle formation in the surrounding area. Transverse nasal lines, nasolabial lines and lateral nose creases progressively form as individuals age (Hadi and Wilkinson, 2014). Nasolabial lines as well as transverse nasal lines are reported to form around 30 years of age (Albert *et al.*, 2007). No indication as to the relative age at which lateral nose creases occur has been provided (Hadi and Wilkinson, 2014).

All linear nasal measures such as nasal bridge length, nasal height and alar width increase with age according to literature (Albert *et al.*, 2007; Ferrario *et al.*, 2003; Mydlova *et al.*, 2015; Sforza *et al.*, 2010b). As for the ears, this overall observed increase in nasal volume can be ascribed to the cartilaginous nature of the nasal framework. Since cartilage, unlike bone, continues growth throughout adulthood, nasal size increases are to be expected (Bradham and Horton, 1998; Mydlova *et al.*, 2015). The nasal length increases with age are reported to become visually prominent around 50 years of age (Albert *et al*., 2007; Sforza *et al.*, 2010b).

The nasal tip angle reportedly decreases with progressive ageing (Ferrario *et al.*, 2003; Sforza *et al.*, 2010b). A decrease in this angle could be ascribed to gravitational effects on tissue undergoing collagen loss (Albert *et al.*, 2007), coupled with maxillary bone resorption and bone changes in the piriform region (Mendelson and Wong, 2012; Mydlova *et al.*, 2015).

2.2.5 Oral changes

Both metric changes and wrinkle formation occur in this area. Formation of perioral wrinkles/circumoral striae, chelion /oromental lines as well as the chin/labiomental crease occurs (Albert *et al.*, 2007; Hadi and Wilkinson, 2014). Circumoral striae, oromental lines and labiomental creases tend to show initial formation around 40 years of age (Albert *et al.*, 2007).

Oral shape age-related changes described in literature include upper and lower lip thinning, described as occurring around 50 years of age (Albert *et al*., 2007; Sforza *et al*., 2010a). Mouth as well as philtrum width reportedly increases, and the position of the mouth relative to the other facial features moves downwards (Albert *et al.*, 2007; Ferrario *et al.*, 2003; Sforza *et al.*, 2010a). The oral shape changes can be ascribed to both skeletal and soft tissue changes (Albert *et al.*, 2007; Baumann, 2007; Sforza *et al.*, 2010a). A loss of teeth in old age causes atrophy of the mandible and maxillary bone (Albert *et al.*, 2007; Oettlé, 2014). Such changes in the underlying bony structure would affect the overlying soft tissue. In addition, the multiple adipose tissue and collagen deposits in the lips lend the oral area susceptible to further age-related shape changes (Albert *et al.*, 2007; Baumann, 2007).

2.2.6 General facial changes

Certain facial shape changes as well as wrinkles occur outside of the above defined facial areas. Wrinkles such as horizontal forehead lines, vertical supercilliary arch lines, buccomandibular grooves and cheek folds may appear progressively as an individual ages (Albert *et al.*, 2007; Hadi and Wilkinson, 2014). Horizontal forehead lines are reported to form as early as between 20 and 30 years of age, with buccomandibular lines appearing from age 40 onwards (Albert *et al.*, 2007).

Cheek hollowing as well as sagging of the jawline and subsequent jowl formation are also reported to occur. Cheek hollow becomes pronounced around 60 years of age, especially

when tooth loss co-occurs. The jawline tend to become more varied at 40 years of age, with jowl formation taking place around 50 years of age and older (Albert *et al.*, 2007). Both cheek hollowing and jowl formation relate to adipose tissue concentration changes (Albert *et al.*, 2007; Baumann, 2007). Jowl formation also relates to gravity effects on skin and muscle, coupled with progressively less collagen and elastin (Albert *et al.*, 2007; Baumann, 2007). Bone structure changes due to atrophy related to tooth loss would also affect the jawline (Albert *et al.*, 2007; Oettlé, 2014).

Male pattern baldness, or androgenic alopecia, occurs commonly in men due to genetic predisposition (Ellis *et al.*, 2001). Initial visibility of a receding hairline occurs throughout the adult lifespan, although it is reported for as many as 80% of men by the age of 80 years (Ellis *et al.*, 2001).

Albert *et al.* (2007) report various overall shape changes of the face with increasing age. These changes are based on underlying skeletal changes. Horizontal facial dimensions as well as anterior face height increase from 30 years of age and onwards (Albert *et al.*, 2007). No agreement has been reached on whether any cranial thickness increases or decreases occur with advanced ageing (Albert *et al.*, 2007).

Overall facial appearance is affected by ageing changes in skin colour as well as texture (Vashi *et al.*, 2016). Over time, skin colour heterogenies become more widespread. Pore enlargement as well as increased irregularity formation leading to a roughened appearance of skin texture occurs, although age of onset for skin changes vary (Vashi *et al.*, 2016).

2.2.7 Wrinkles

Wrinkle formation has a three-fold aetiology: bone, soft tissue and skin ageing processes all contribute. Changes in the underlying bony scaffolding that support the overlaying soft tissue and skin layers would affect all the subsequent more superficial layers (Albert *et al.*, 2007). Bone resorption and subsequent atrophy occurs with advanced age, and in doing so contribute to wrinkle formation (Albert *et al.*, 2007; Vashi *et al.*, 2016).

Evenly distributed adipose tissue concentrations can either atrophy or hypertrophy with increasing age (Vashi *et al.*, 2016). Adipose redistribution, coupled with age related changes in muscles (D'Antona *et al.*, 2003), affect the soft tissue layer directly under the skin. Muscle

and adipose tissue changes with age therefore contribute to wrinkle formation. Ageing changes of the skin form the last contributing factor to wrinkle formation (Albert *et al.*, 2007). Skin ageing changes include a flattened dermal-epidermal junction, slower epidermal turnover rate, loss of dermal thickness and altered collagen production (Albert *et al.*, 2007; Baumann, 2007). Ageing skin, coupled with altered support structures, form wrinkles. Hyperdynamic facial expressions as well as gravity exacerbate wrinkle formation (Albert *et al.*, 2007).

Though the timing of wrinkle formation has been mentioned under each of the preceding subsections, the specific placement of each wrinkle has not yet been presented. The multiple wrinkles that are described in literature lends itself to graphical presentation in Figure 2.1, adapted from Hadi and Wilkinson (2014).

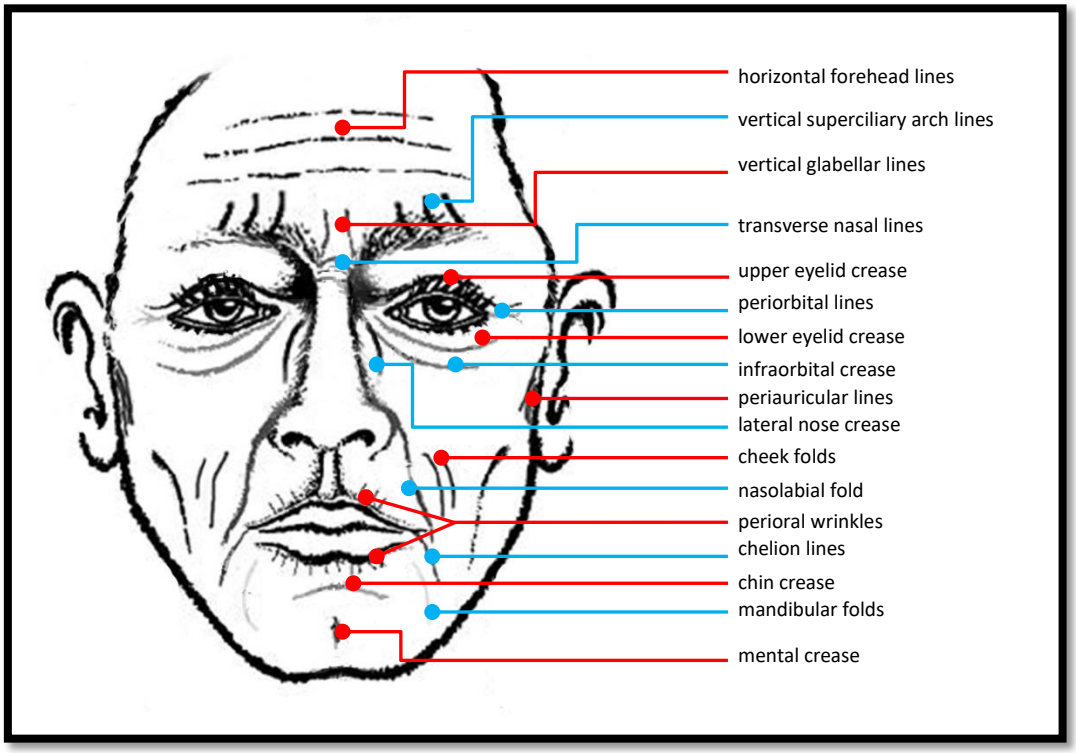


Figure 2.1: *Location of folds and wrinkles on the human face, adapted from Hadi and Wilkinson (2014).*

Hadi and Wilkinson (2014) described two novel wrinkles worthy of inclusion, namely the vertical superciliary arch lines and the lateral nose crease, as can be observed in Figure 2.1. Some discrepancies exist in the terminology used in these images (Hadi and Wilkinson, 2014) and other sources (Albert *et al.*, 2007). Certain terms are used interchangeably, such as perioral wrinkles (Hadi and Wilkinson, 2014) and circumoral striae (Albert *et al.*, 2007). The

consensus terminology used for clarity throughout this current study is presented in Chapter 3, Materials and methods.

The numerous facial ageing changes, including wrinkles and other morphological differences, present with considerable variation (Albert *et al.*, 2007). This variability leads to some difficulty in conducting a comprehensive investigation into facial ageing. However, facial ageing research is necessary in order to bridge the knowledge gap on population specific standards, as this would allow increased accuracy of facial approximations. The need for facial ageing research precipitates a consideration of investigation methods into facial ageing used in literature, which follows in the subsequent section.

2.3 Facial ageing analysis

Two broad methodologies that can be applied to facial ageing research become apparent when considering the literature: Focusing on individual areas/ aspects of the face showing age progression, or a more global approach to facial ageing as a whole.

The first facial ageing research method is based on the consideration of individual areas such as the nasal, oral, orbital and aural regions for assessing ageing changes, using both morphological and metric methods. Morphological methods include visual assessments, or even drafting a scoring system using progression of observable changes (Íşcan and Steyn, 2013). Despite some concerns regarding the subjectivity of such an approach, morphological assessments are widely conducted for assessing age changes in physical anthropology (Íşcan and Steyn, 2013; Merritt, 2014).

A decided benefit of a morphological approach is that expensive, hard to operate equipment are not needed to successfully assess ageing changes. Unfortunately, subjectivity could affect these assessments, resulting in lower repeatability rates due to varying levels of expertise in assessors. Various studies have been done on morphological facial ageing for different facial regions, although no scoring system for facial ageing changes could be found (Albert *et al.*, 2007). A further disadvantage of these studies are the Eurocentric nature of the individuals included in the research samples (Albert *et al., 2007)*. Considering the clarity in literature on population specificity in facial ageing, a lack of African and specifically South African population specific research need to be addressed (Albert *et al.*, 2007; Naval *et al.*,

2014; Vashi *et al.*, 2016; Vierkotter and Krutmann, 2012). Skin ageing such as colour heterogenies specifically has been described in a comparable African American sample, but this excludes other shape changes such as eyelid drooping and wrinkle progression (Vashi *et al.*, 2016).

Measurable facial ageing changes depend on accurate facial measurements between defined landmarks. Participants are photographed using scale measurements (Briers, 2015), or landmarks are placed on the skin of live participants and subsequently recorded using a computerized electromagnetic digitizer (Sforza *et al.*, 2010a, 2009a, 2009b, 2010b). Measurements are then subsequently done on images of participants. These measurements can then be presented accompanied by simple descriptive statistics, or further analysed, using factorial analysis of variance, regression or correlation statistics (Albert *et al.*, 2007; Sforza *et al*., 2010a, 2009a, 2009b, 2010b). An advantage of metric analyses is the lack of subjectivity and high reported accuracy (Sforza *et al.*, 2010a, 2009a, 2009b, 2010b). Disadvantages, on the other hand, include the costly nature of digitization equipment (de Menezes *et al.*, 2009) and once again, the lack of adult South African population specific data (Sforza *et al.*, 2010a, 2009a, 2009b, 2010b). The most comprehensive study on facial ageing using metric features is based on an Italian population (Sforza *et al.*, 2010a, 2009a, 2009b, 2010b).

The second approach to facial ageing is considering ageing changes for the face as a whole. Computerized mesh models based on common facial landmarks (Stephan and Caple, 2016) are constructed and subsequently compared to identify any shape differences that may occur (Ferrario *et al.*, 2003). The Ferrario *et al.* (2003) study is based on an Italian sample. Despite the ground-breaking nature of these analyses, equipment and software may be both expensive and difficult to operate. In a South African context, the highly specialized nature of such analyses prevent easy application of the resulting facial feature maps in forensic art practice (Ferrario *et al.*, 2003). In addition, the available research on mathematical facial ageing mesh maps focus on European samples and only include individuals up to 40 years of age (Ferrario *et al.*, 2003). This limitation is problematic as many age related changes progress and intensify after the age of 40 (Albert *et al.*, 2007).

A global approach to the face as a whole such as that used by Ferrario *et al*. (2003) has long been utilized in psychological studies of face perception (Benson and Perrett, 1991; Coetzee

et al., 2014; Perrett *et al.*, 1998). Similar methods have been used to construct average faces in the craniofacial identification domain (Stephan *et al.*, 2005), although without a focus on age or, once again, an African sample.

Throughout all of the described methodological approaches, the most critical shortcoming to practical application was the lack of consideration of a South African (or African) sample. The sound methodology however described in these studies provided important insights into approaches that could be used to investigate facial ageing. Overall, a combination of specific facial features in isolation, as well as facial averages to include the unified nature of how we perceive faces seem to indicate the most thorough as well as accessible approach.

Using these methods, attempts can be made to describe the complexity of facial ageing for a South African sample specifically. A description of South African facial ageing has not yet been attempted to the best of the researcher's knowledge. Data on population specific facial ageing could help advance the field of facial approximation, which would be advantageous especially in South Africa when considering the many unidentified deceased individuals at morgues across the country. Using these techniques to provide a population specific overview of facial ageing would also benefit the local plastic surgery, as well as dermatology industries.

Chapter 3
Materials and Methods

In order to achieve the overarching aim of describing facial ageing in a South African population, a sample of 189 facial images of black males of various ages were analysed. Age progression observed in facial features was considered in detail for various facial areas, followed by a more global approach for overall facial aging based on facial averages.

Current literature describes the ageing process for several features in isolation (Albert et al., 2007; Sforza et al., 2010a, 2009a, 2009b, 2010b; Vashi et al., 2016). In an attempt to investigate whether these age changes are indeed apparent in a South African sample, the correlations between age and morphology described, as well as measured facial dimensions, were tested. However, perceiving the face as a whole is often required for craniofacial depiction and recognition purposes (Stephan *et al.*, 2005; Wilkinson, 2015). Subsequently, an average facial image for each age decade was generated. This approach allowed for a better understanding of overall, inter-relational shape changes as the face ages, also providing an indication of the age at which specific changes become the norm.

A demographic questionnaire was completed by all participants, providing information on factors influencing facial ageing. Ethical standards were maintained during data collection and analysis. This chapter provides an in-depth look at the participants comprising the sample, as well as methods of analysis and ethical/ permissions procedures.

3.1 Participants and sample composition

The participants in this descriptive study were black South African males between the ages of 20 and 100 years from the Gauteng and Mpumalanga regions of South Africa. Stratified sampling was performed, with 30 participants randomly chosen to be photographed for each arbitrarily divided age category spanning a decade (N=189).

Age categories were defined as 20-29, 30-39, 40-49, 50-59, 60-69, 70-79 and 80+ years of age. Participants classed themselves into an age group, rather than provide their specific age. In South Africa, due to socio-political historical circumstances, many of the older participants in the sample have an overall idea of their age, but no accurate recording or

insight of their actual birth date (Garenne *et al.*, 2016; University of Toronto, 2015). In order to overcome this limitation, participants were required to only indicate their decade of age rather than their immediate age. Only nine participants were aged 80 years and older, which lends support to the merging of further decades into an open-ended group. This is likely a reflection of the relatively low life expectancy for South African males, which is 59.7 years of age (Lehohla, 2016).

Despite the seemingly limited geographic area, the sample is felt to be representative of the Northern regions of the country. Gauteng province contains three of the five largest cities in South Africa (Statistics South Africa, 2016b), with a diverse population of economic migrants from various other regions. Mpumalanga province has a mining based industry, which also promotes a diversity in migrants seeking employment (Statistics South Africa, 2017).

While the sampling location ensures a diverse group of South African citizens, immigrants from neighbouring African countries also enter South Africa to benefit from economic opportunities. This created a dilemma: should an individual currently living in South Africa, but born in a neighbouring country, be included in the sample or not? The deciding factor was the cross-sectional nature of this research project.

The intent of this project was to assess facial ageing in males aged 20 years and upward, who identify with the 'black' population census group and are *currently* living in South Africa. Individuals born in various neighbouring countries, but at present based in South Africa, were thus not excluded from this study. Volunteers with severe facial scarring, suggestive of maxillo-facial trauma that may have required surgery, were excluded from participating in this study. Businesses and retirement centres were visited during the data collection process, provided permission for presenting the research to employees or residents were received from these institutions.

3.2 Data collection methods

Photographs were taken of participants' faces orientated in the Frankfurt plane (Mosby, 2016). The camera angle was directed horizontally and aligned with the face. Maintaining this camera angle decreased foreshortening and prevented other magnification issues (Moreton and Morley, 2011).

The participants were seated or standing in an upright position, in order to help minimize facial distortions observed in imagery taken in supine position (as for CAT scans) or using cadaver material (Íşcan and Steyn, 2013). The participants were asked to maintain a neutral facial expression throughout the photographic process. Both frontal and lateral angles of the face were photographed in high resolution (5184 x 3456 pixels).

A dove grey rather than white backdrop was used to minimize glare from a sharply contrasting light background. A scale ruler with white and black alternating squares, each square measuring 1 cm x 1 cm, was included in each photograph (Briers, 2015). The photographic equipment used was a Canon EOS 1300D standard digital SLR camera, a fully extendable tripod and a Canon Aputure AHL-HC100 LED ring flash. An 18-55 mm EFS lens was used, set to a focal length of 35 mm. The image aspect ratio was kept to 3:2 throughout, ensuring negligible compression artefacts (Adair King, 2016). The camera tripod was set up two meters away from the participant (Verhoff *et al.*, 2008), to help prevent perspective distortion.

Data were captured at various locations, to ensure minimal travelling costs for participants. At each location, attempts were made to ensure sufficient and equal frontal lighting with the help of the Canon ring flash. Lighting was adjusted to ensure equal illumination across the face with no shadows present around or under the eyes, chin and nose. Shutter speed and aperture width together determine the quality of the photograph, as it controls the amount of light allowed through the shutter when taking a photo (Zelditch *et al.*, 2012).

Due to varying conditions at the different data collection locations, camera shutter speed, frame rate and a fixed focus point for participants to normalise facial tilt were controlled as far as is possible in field conditions. Participants with a pronounced cranial tilt or rotation were asked to correct their faces to a more normalized position approximating the Frankfurt plane.

The abovementioned attempts to maintain constant field conditions for image capture may not compare to the laboratory conditions of precision attained in literature such as in the Stephan *et al.* (2004) study. However, in an African context with finite monetary resources sufficient calibration has been attained to enable successful image analysis (Briers, 2015).

3.3 Age correlation with scored morphological features

3.3.1 Methods

The first analysis aimed to test the correlation between specific morphological features and ageing. Observations from previous studies on facial aging in other populations were combined to set up a scoring system (Albert *et al.*, 2007; Vashi *et al.*, 2016). The facial ageing features included in this scoring system is illustrated in Figure 3.1 and 3.2 for anterior and lateral facial views respectively. This scoring system allowed the statistical assessment of the correlation of morphological, non-metric features with age.

Due to observed population differences, slight adjustments had to be made to better describe the South African sample. For example, two creases described in the literature, namely the lateral nose crease and mental pit (Hadi and Wilkinson, 2014), were not observed in the South African male sample at all and were removed from the scoring tables. Instead of a mental pit, the chin in elderly individuals took on an overall multi-dimpled appearance which was added to the facial ageing scoring table.

Separate scoring tables for anterior (Table 3.1) and lateral (Table 3.2) views were created. Each anterior and lateral view photograph was scored on a scale ranging from 1 to 5 according to the criteria set out in Tables 3.1 and 3.2. For the sake of clarity, when allocating scores for skin colour and texture, example images were included in the tables.

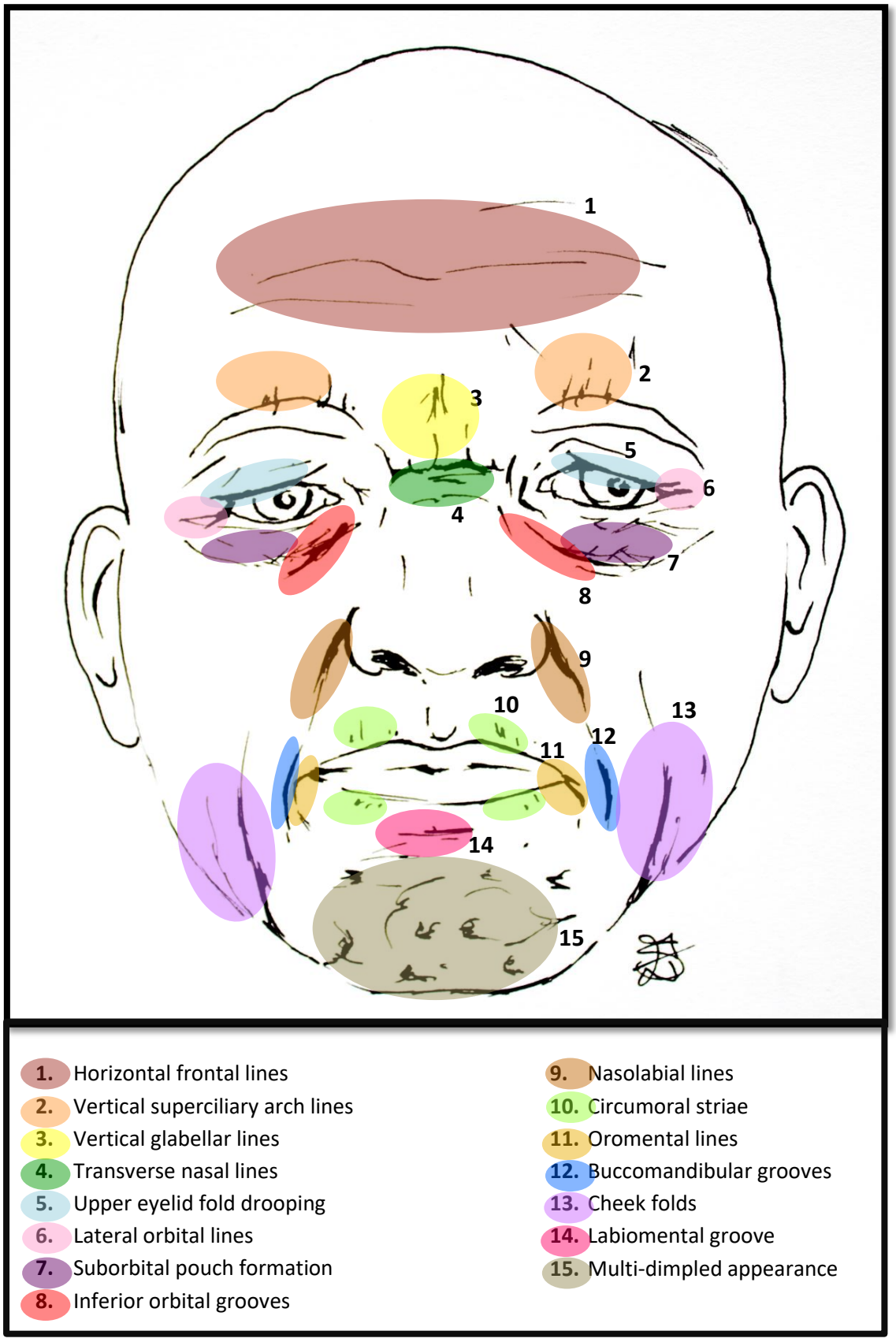


Figure 3.1: *Colour chart of facial ageing changes included in Table 3.1 (anterior view)*

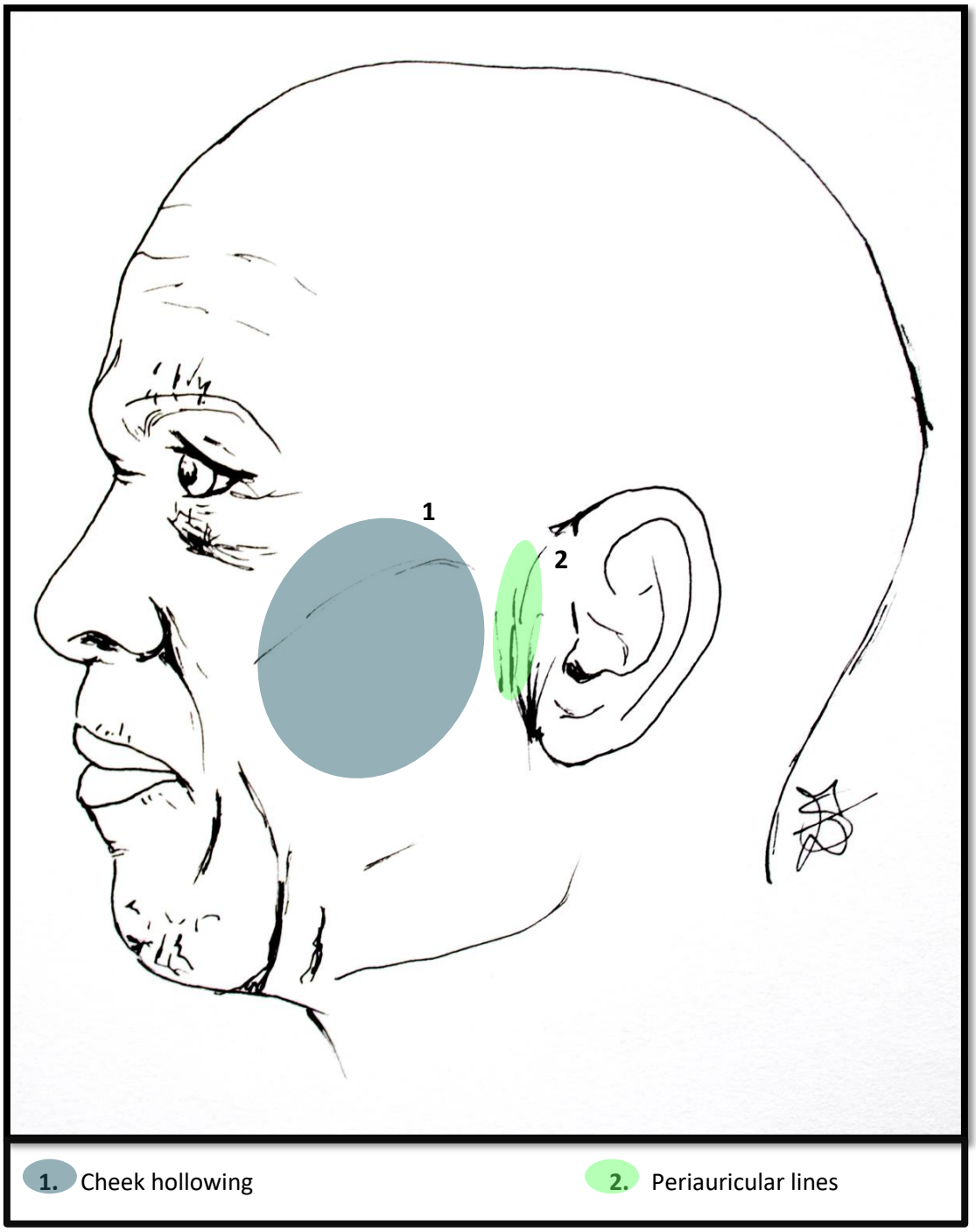
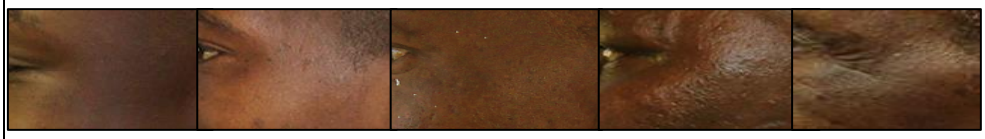


Figure 3.2: *Colour chart of facial ageing changes included in Table 3.2 (lateral view)*

Table 3.1: Facial ageing scoring system - anterior view

		Score				
Area	Aspect	1	2	3	4	5
Orbital						
	Wrinkles	No lines evident	Lateral orbital lines appear	Lateral orbital lines deepen	Vertical glabellar lines appear	Wrinkles increase in depth and number
	Upper eyelid fold drooping	No drooping evident	Slight upper eyelid fold sagging	Obscures 1/3 of upper eyelid crease	Obscures 2/3 of upper eyelid crease	Obscures entire upper eyelid crease
	Suborbital pouch formation	No skin sagging	Slight pouch formation	Definite pouch formation	Pouch formation with fine wrinkles	Pouch formation with defined wrinkles
Oral						
	Wrinkles	No lines evident	Labiomental groove forms	Oromental lines form	Circumoral striae form	Chin has multi-dimpled appearance
Nasal						
	Wrinkles	No lines evident	Faint nasolabial lines form	Nasolabial lines deepen	Transverse nasal lines develop	Transverse nasal lines deepen
Forehead						
	Wrinkles	No horizontal frontal lines evident	Faint horizontal lines appear	Clear horizontal line formation (1-3)	Horizontal lines increase & deepen (4-6)	Vertical superciliary arch lines form
Cheek						
	Wrinkles	No lines evident	Inferior orbital grooves form	Buccomandibular grooves appear	Cheek folds appear	Lines deepen & increase
Overall						
	Skin colouring	Homogeneous colour	≤ 25% of skin shows heterogeneous pigmentation	26 -50% heterogeneous pigmentation area	51-75% heterogeneous pigmentation area	> 75% of skin shows heterogeneous pigmentation
						

Table 3.2: Facial ageing scoring system - lateral view

		Score				
Area	Aspect	1	2	3	4	5
Auricular						
	Wrinkles	No lines evident	Faint periauricular line formation	1-2 clear periauricular lines	3-4 deep periauricular lines	≥5 deep periauricular lines
Cheek						
	Hollowing	No hollowing evident	Slight indentation	Indentation enlarges	Indentation deepens	Sunken appearance
Overall						
	Skin texture	Smooth skin with fine pores	≤ 25% of skin has roughened texture	26– 50% roughened skin area	51-75% roughened skin area	> 75% of skin has roughened skin texture
						

Analysis of the correlation of scored features with age was performed using Microsoft Office Excel 2010 software. Due to the ordinal nature of the scores, Spearman's rank correlation coefficient was utilised to determine whether a monotonic relationship exists with increasing age (Dawson and Trapp, 2004).

Two advantages of using this correlation measure were apparent: the sample distribution does not need to be normal; and relationships other than linear correlation, such as an exponential trend, are indicated (Dawson and Trapp, 2004). Probability density functions were used to test the statistical significance of each correlation (Dawson and Trapp, 2004). It should be noted that any observed correlation does not imply causation. Statistically significant correlations may still occur due to chance.

3.3.2 Intra- and inter-observer agreement

Inter- and intra-observer repeatability was tested in order to investigate reliability and specificity for the assessment of age related features. Stratified sampling was used to select five images of random participants from each age category for reassessment by the main investigator as well as another individual familiar with facial analysis.

Inter-observer reliability was tested using Fleiss' kappa for the scored features. The Fleiss' kappa test was selected specifically to account for cases where one of the observers chose not to score a characteristic due to constraints such as facial hair or a hearing aid, and the other did assign a score. Fleiss' kappa is more robust in calculating agreement in such instances than Cohen's kappa (Cohen, 1960; Fleiss, 1981). The 95% confidence interval (CI) was calculated, as well as the p-value to test for significance.

Intra-observer reliability was assessed using Cohen's kappa (Cohen, 1960). A 95% confidence level is provided. The significance of any observed agreement was assessed using p-values (Dawson and Trapp, 2004).

3.4 Age correlation with measured features

3.4.1 Methods

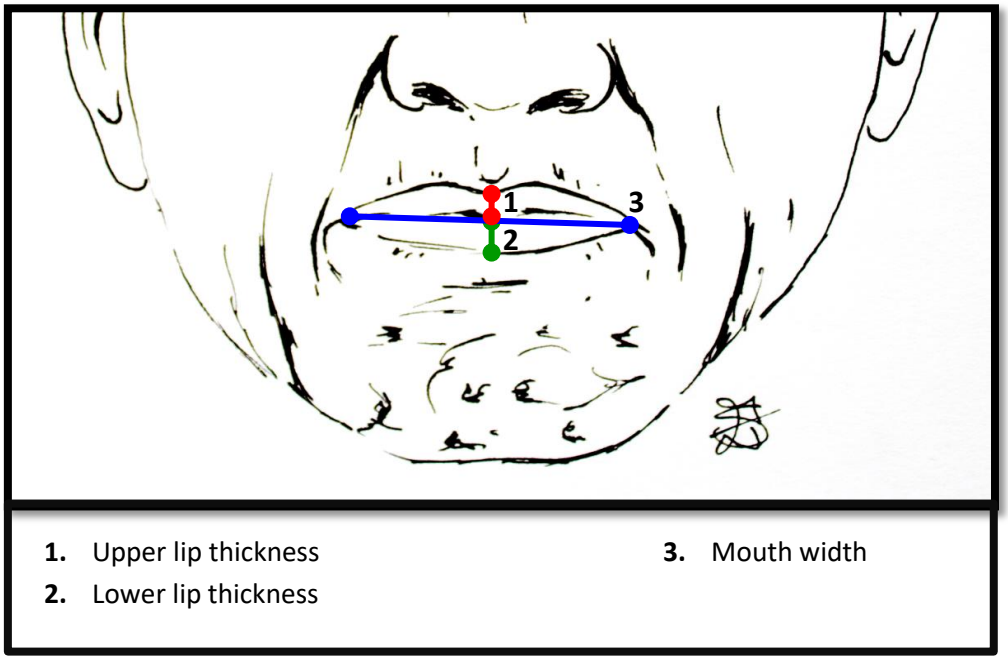
The second analytical step towards the overall aim of investigating facial ageing based on facial images was the assessment of features associated with measurements rather than descriptions (Albert *et al.*, 2007; Sforza *et al.*, 2010a, 2009a, 2010b). The metric features assessed were based on the measurements used in the Sforza *et al.* (2010a, 2009a, 2010b) studies:

- Upper lip thickness measured from labiale superius to stomion;
- Lower lip thickness from stomion to labiale inferius;
- Mouth width from cheilion to cheilion;
- Nasal length from nasion to pronasale;
- Nasal tip measured as the angle between nasion – pronasale – subnasale (°);
- Ear width from preaurale to postaurale; and
- Ear length from superaurale to subaurale.

All measurements were taken in millimetres, with the exclusion of the nasal tip angle which was scored in degrees.

These measurements were used to assess the possible thinning of the lips, increase or decrease in mouth width (Figure 3.3), nasal elongation, dropping of the nasal tip and changes in the size of the ears (Figure 3.4). It should be noted that the landmark defined as 'nasion' by Sforza *et al.* (2010a, 2009a, 2010b) corresponds to the 'sellion' landmark

described by Stephan and Caple (2016). The term 'sellion' will be used throughout this study in the interest of universal consensus and clarity, and refers to the "deepest midline point of the nasofrontal angle" (Stephan and Caple, 2016, p. 874). Measurements were recorded using the ruler tools in Adobe Photoshop image editing software, once each image had been scaled to size using the reference scale included in each photo.



1. Upper lip thickness
2. Lower lip thickness
3. Mouth width

Figure 3.3: *Measurements taken using anterior view images*



1. Nasal length
2. Nasal tip angle
3. Ear width
4. Ear length

Figure 3.4: *Measurements taken using lateral view images*

Some questions have been raised on the validity of photoanthropometry (Kleinberg *et al.*, 2007; Moreton and Morley, 2011). One of the issues raised concerning photoanthropometry techniques touches on technical error of measurement (TEM), as described by Stephan *et al.* (2004, 2015). TEM refers to the reproducibility of measurements under different conditions, as opposed to the repeatability from various assessors. In order to assess the validity of the method for image capture at varying locations, TEM values were calculated for each of the measurements. The calculations were performed on two participants, using five images each, captured at different times and locations with varying light conditions.

Relative TEM (rTEM) values were considered acceptable up to 7.5%, as for the inter-evaluation (accounting for the 5 different images) requirement for a skilful anthropometrist according to Perini *et al.* (2005). Standards ranging from 1% to 10% and more have been reported in literature (Fancourt and Stephan, 2018; Perini *et al.*, 2005), and for the measurements in the current study most of the image pairs scored far below 7.5%. Nasal angle measurements adhered closely to the 2% acceptance standards mentioned in Fancourt and Stephan (2018). It should be emphasized that according to Fancourt and Stephan (2018), there is no universal level of acceptance. Rather, the percentage of acceptance is set on an individual basis by researchers. Given the overall positive TEM results, general trends could be evaluated using the photoanthropometry methodology as presented in the current study.

Correlation analysis of measured features with age was again performed using Microsoft Office Excel 2010 software. Pearson's correlation coefficient was calculated to determine the correlation except in cases where one of the main assumptions, normally distributed data, was violated (Dawson and Trapp, 2004). In these instances Spearman's rank correlation coefficient was again calculated. The statistical significance of each correlation was determined using probability density functions (Dawson and Trapp, 2004).

3.4.2 Intra- and inter-observer agreement

Inter- and intra-observer repeatability was tested for the measured features using stratified sampling. Five random images were selected from each age decade for reassessment, both by the main investigator and a colleague currently working in the field of facial identification. Inter-observer repeatability was tested using the Intraclass Correlation Coefficient (ICC) for

measured features (Hallgren, 2012). The 95% confidence interval (CI) was calculated, as well as the p-value to test for significance.

Intra-observer reliability was also assessed using ICC (Hallgren, 2012). For both cases the ICC test used was a two-way, random effects, absolute agreement model. This model was chosen due to the increased stringent statistical scrutiny provided by the absolute agreement and random effects selection (Hallgren, 2012). The ICC analysis was completed utilizing PQStat statistical software (https://pqstat.com/). A 95% confidence level is provided as well as significance testing using p-values (Dawson and Trapp, 2004).

3.5 Average face construction

After each facial feature was investigated individually, a more global approach was followed by constructing an average face for each age decade using Abrosoft FantaMorph Version 5 Deluxe facial averaging software (http://www.fantamorph.com/index.html). FantaMorph software uses landmarks placed on features to align and warp all faces to a set mesh centred around a common zero point. The layer morph function provided in the software allows for instantaneous uploading of all 30 facial photographs per decade, morphing the various layers into one image simultaneously. FantaMorph rather than PsychoMorph software was used, as FantaMorph is slightly more user-friendly than PsychoMorph despite the lack of texture preserving algorithms and slightly higher cost (Sutherland *et al.*, 2017; Tiddeman *et al.*, 2001).

Anterior and lateral facial views were averaged separately in order to make generalized comments on observed ageing changes within each broad, ten year age grouping. FantaMorph automatically detects facial images and places 112 landmarks in a rough estimation of the anterior face, which is then manually refined to each unique individual's image (Figure 3.5A). These automatic landmarks are placed combining common facial landmarks and a fixed number of delineating landmarks.

For lateral views, however, landmarks had to be manually assigned. The mesh was partially constructed using the automated placement of anterior landmarks as a basic guide. Common facial landmarks in the literature (Stephan and Caple, 2016) were placed on a template, with a set number of landmarks placed at equidistance in between.

Experimentation by trial and error provided the minimum set number of landmarks necessary to effectively outline the profile. A novel mesh was thus constructed using 152 points (Figure 3.5B) and subsequently applied to all lateral images.

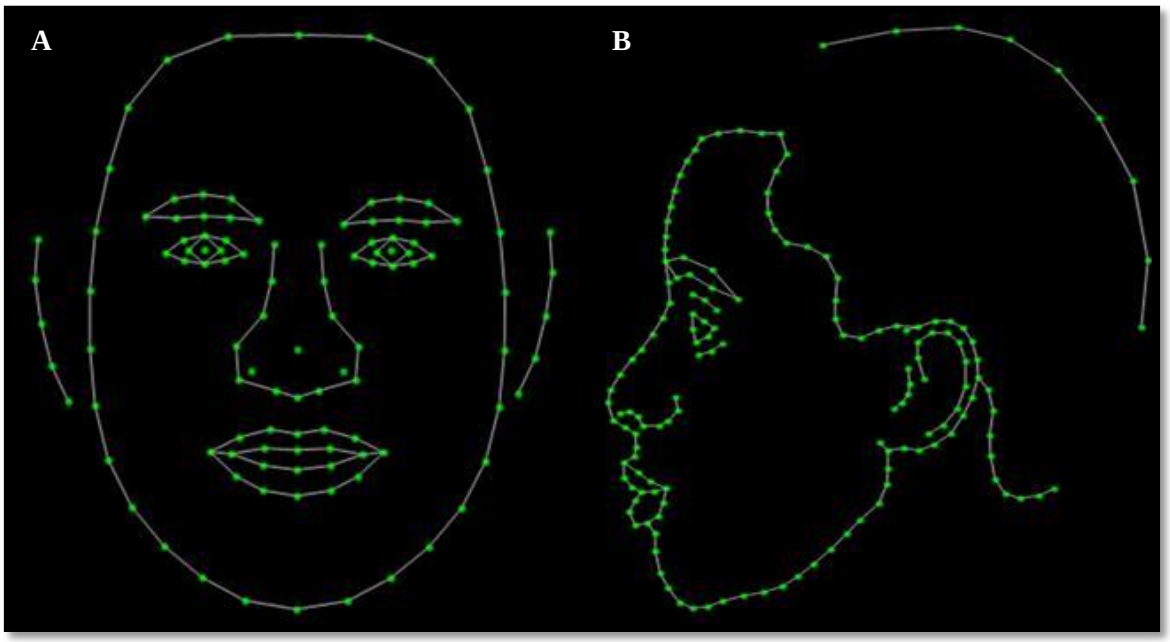


Figure 3.5: *A) Automated anterior and B) novel lateral facial view FantaMorph Deluxe mesh*

3.6 Lifestyle questionnaire

A number of confounding variables may influence the aging process (Albert et *al.*, 2007; Rexbye *et al.*, 2006; Vierkotter and Krutmann, 2012). Therefore, a questionnaire that recorded lifestyle data such as a person's social history, sun exposure and general health (smoking, drinking, etc.) were developed and subsequently completed by all participants (questionnaire provided in Appendix B). Rexbye *et al.* (2006) indicated that smoking and sun exposure along with Body Mass Index (BMI) significantly influenced perceived facial age in men.

Based on the Rexbye *et al.* (2006) paper and others (Albert *et al.*, 2007; Vierkotter and Krutmann, 2012), several questions were included in order to assess which factors might have significance in ageing in a South African sample. These questions included marital status, family size, number of dependents, average hours of sun exposure per day, general fitness, smoking and alcohol intake, as well as having dentures and medical care

requirements. These factors were all previously reported as influencing facial ageing (Albert *et al.*, 2007; Rexbye *et al.*, 2006; Vierkotter and Krutmann, 2012).

The questions included were mostly multiple choice answers to accommodate varying levels of participant literacy. The questionnaire was compiled based on the format of previous South African censuses, and was proofread by five non-participants of various cultural backgrounds to ensure that all questions are culturally sensitive and appropriate. Changes were made according to the recommendations of these five individuals. The questionnaire served as a reference point for data regarding general population trends that are likely to influence ageing. It is important to note that the questionnaire will report participant's answers, and not necessarily facts.

The answers provided in the questionnaire take the form of categorical data. As such, column charts were constructed to provide a visually comprehensive summary of the sample composition for each question. No attempt was made to correlate specific risk factors with individual ageing changes, as this fell beyond the scope of the current study. However, this data are available for future in depth analysis.

3.7 Ethical considerations

The Human Research Ethical Committee (Medical) of the University of the Witwatersrand approved this study (Clearance certificate #: M161023; Appendix C).

3.7.1 Informed consent

Each participant was requested to sign an informed consent form, after the project was explained to them in detail with the help of flashcards with images. In order to help participants make an informed decision, six images of president Zuma and former presidents Mbeki and Mandela distributed in the public domain were used to create a facial average. These images as well as the resulting average were included on the information form provided to participants. This form can be viewed in Appendix A.

Flashcards with simple example illustrations were made to provide a visual guide to explaining the project for individuals who are not familiar with computer technology. Additional permission provided by the participants allowed images and associated

questionnaire answers to be entered into a Wits research database to be used for future academic research purposes. Participants were able to select the level of availability of their images that they were comfortable with. A translator was provided upon request in order to ensure that all participants understood the process as well as what their role would be as a participant, before granting written consent.

3.7.2 Anonymity and confidentiality

A number was assigned to each demographic survey and permission form, to associate the relevant data with the images. No names were requested, to help ensure anonymity. Each participating individual has a unique identifier code, allowing the questionnaire data to be stored alongside the corresponding facial image.

No single individual's images were published in this study in a recognizable format. Instead, an average face or single facial features were used as visual aids. This design was incorporated in order to not expose the identity of any single research participant. The images are stored at the Human Variation and Identification Research Unit (HVIRU) using the REDCap secure database application already in use at Wits.

3.7.3 Risks and benefits

Individuals without the capacity to grant informed consent (e.g. Alzheimer's patients in the elderly sample) were not invited to participate in this study. To help ensure this, the social worker for each individual, especially in the Mthimkhulu Housing for the Aged, was consulted and present during data collection.

No physical harm could ensue from having photographs taken, and participants were warned to expect a light from the camera flash. Care was taken to treat each participant with respect, and answer all questions they might have.

Participating in this research study was of no direct benefit to participants; however results from this research will benefit all citizens of South Africa. Participation was completely based on a voluntary contribution to scientific research on facial ageing among South African males. No payment, monetary or otherwise, was provided.

Chapter 4
Results

In order to describe ageing changes that occur in specific facial areas as well as the overall facial appearance, three analyses were completed. These analyses included analyses of correlation between age decades, and scored morphological and metric ageing changes. A facial average for each age decade was also created, with anterior and lateral facial views for each age group.

Demographic information was gathered during data collection through the use of a questionnaire associated with each facial image. However, in-depth analysis of the relative contribution, if any, of each factor affecting facial ageing is beyond the scope of this study. This data was rather presented in percentage bar graph format, in order to provide an overview of the demographic composition underlying the sample of South African males included in this study.

4.1 Morphological features associated with age progression

4.1.1 Facial feature – age correlations

General descriptive statistics of the scored morphological features were calculated per 10-year age cohort. These general descriptive statistics included density scatterplots that were drafted to indicate the scores obtained for each age-related feature, presented in Figures 4.1 A) and B). All features included in the morphological correlation analysis progress in a unidirectional, positive manner. Looking at the average scores obtained from the general descriptive statistics (Figures 4.1 A & B), three broad ageing trends can be identified. Firstly, suborbital pouch formation as well as upper eyelid fold drooping are the only features with a seemingly linear trend over time. Secondly, a plateau is seen in the ageing rate around 70 years of age for nasal, auricular, cheek and oral wrinkles. Thirdly, an ageing pattern with three phases is visible concerning the forehead and orbital wrinkles, cheek hollowing, overall skin colour and texture. This three step pattern suggest that a plateau is reached around 50 years of age, coupled with a sharp increase in the average score of the older age groups.

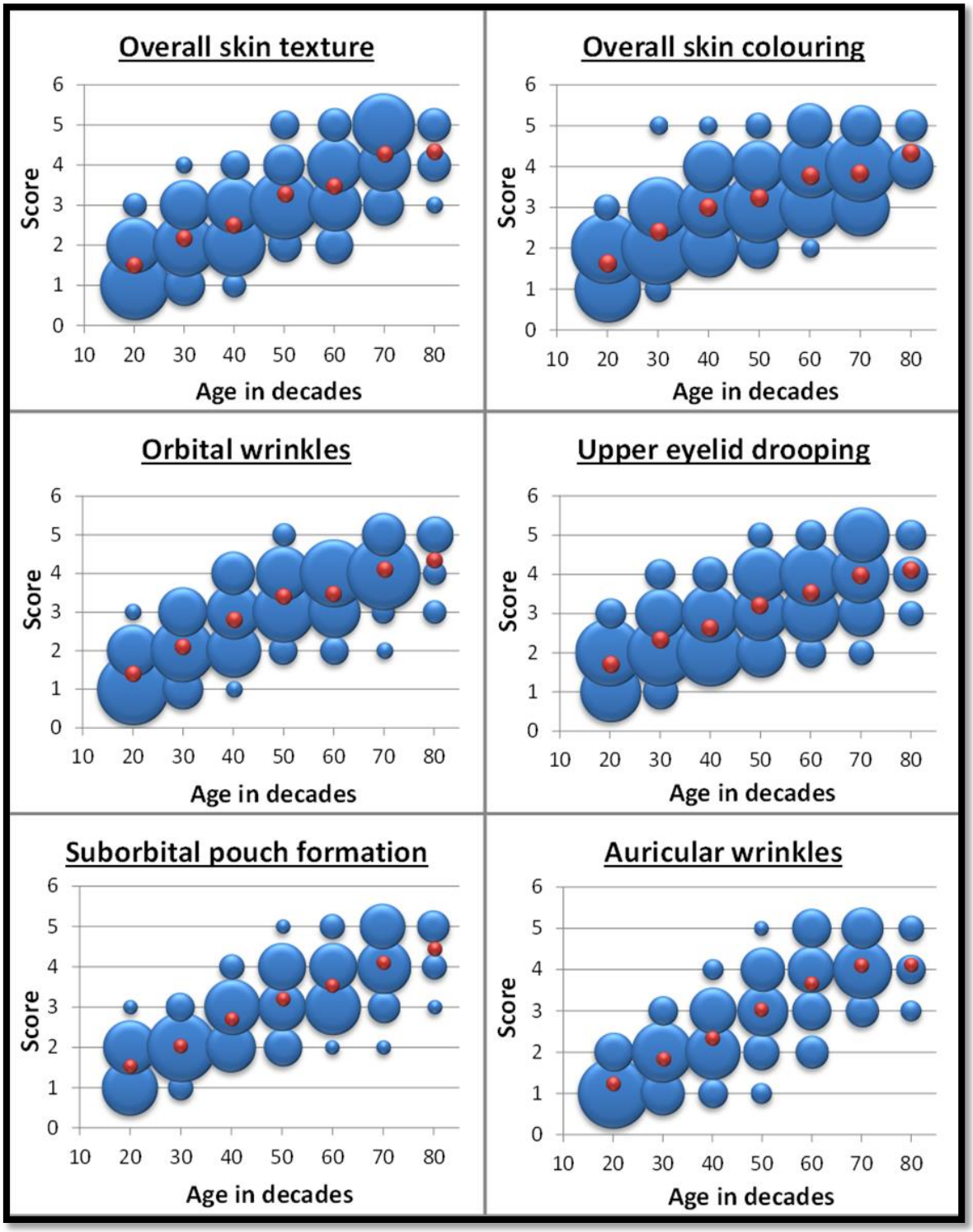


Figure 4.1: *Weighted scatterplots of morphological feature scores per age group. The red dots indicate the average score of the feature per age group. The blue dots indicate the scores obtained per age group, with the size of the dots indicative of the relative number of participants who were assigned a similar score.*

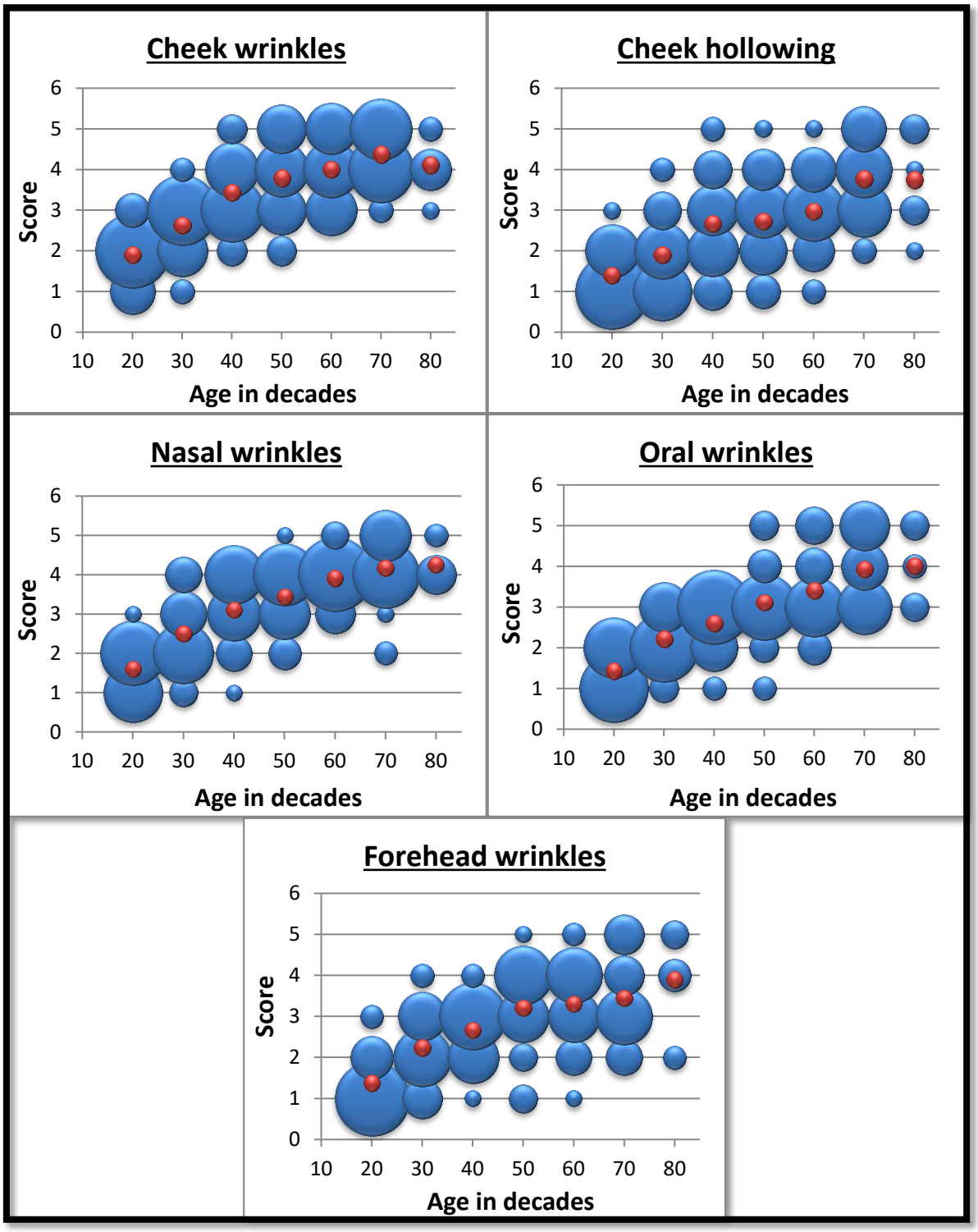


Figure 4.1: *B) Weighted scatterplots of morphological feature scores per age group (continued). The red dots indicate the average score of the feature per age group. The blue dots indicate the scores obtained per age group, with the size of the dots indicative of the relative number of participants who were assigned a similar score.*

The age-morphological feature correlation analysis was performed using Spearman's rank correlation coefficients for the features summarised in Table 4.1. Hypothesis testing was executed under the Fisher paradigm to assess the statistical significance of each correlation, as represented by the last column (indicating p-values) in Table 4.1 (Dawson and Trapp, 2004; Perezgonzalez, 2015). The relationship noted in the correlation between age progression and each feature (second column, Table 4.1) was assessed for significance under the null hypothesis (H_0) that zero correlation occurred (H_0: r=0). Where the p-value was less than 0.05, evidence is provided against H_0 adequately explaining the observed results - as indicated by the double asterisk in Table 4.1.

All the morphological features scored showed a clear positive correlation with age, ranging in strength from moderate to excellent according to the interpretation of correlation coefficients provided by Dawson and Trapp (2004). Significance testing indicated statistical significance for all morphological features at a 0.05 level, with suborbital pouch formation displaying the highest correlation (0.806) and forehead wrinkles the lowest (0.620).

Table 4.1: Correlation of scored morphological features with age in decades

Age related scoring feature	Spearman's correlation coefficient (r_s)	Strength of correlation *	p-value
Orbital wrinkles	0.784	very good to excellent	0.000**
Upper eyelid fold drooping	0.697	moderate to good	0.000**
Suborbital pouch formation	0.806	very good to excellent	0.000**
Oral wrinkles	0.754	very good to excellent	0.000**
Nasal wrinkles	0.747	moderate to good	0.000**
Auricular wrinkles	0.801	very good to excellent	0.000**
Forehead wrinkles	0.620	moderate to good	0.000**
Cheek wrinkles	0.721	very good to excellent	0.000**
Cheek hollowing	0.632	moderate to good	0.000**
Overall skin colouring	0.724	moderate to good	0.000**
Overall skin texture	0.768	very good to excellent	0.000**

* Based on the Coulton rule of thumb as described by Dawson and Trapp (2004).

**p< 0.05, strong evidence against H_0: r_s=0

4.1.2 Intra-observer repeatability of scoring method

To assess the repeatability of the scoring of morphological features, intra-observer agreement was calculated (second column of Table 4.2) using Cohen's kappa (Cohen, 1960). A 95% confidence interval (CI) as well as a p-value to test for significance was calculated (last two columns in Table 4.2). Intra-observer assessment for agreement across morphological features ranged from 0.454 to 0.777, with all features showing significance at a 0.05 level, as can be seen in Table 4.2. The most difficult feature to score consistently was upper eyelid fold drooping, whereas orbital, auricular and cheek wrinkles showed moderate strength in reassessment.

Table 4.2: Intra-observer agreement for scored morphological features

Scored Feature	Cohen's kappa (κ)	Strength of κ *	95% CI for κ	p-value
Orbital wrinkles	0.777	Moderate	0.545 – 1.009	0.000**
Upper eyelid fold drooping	0.454	Weak	0.148 – 0.760	0.004**
Suborbital pouch formation	0.599	Weak	0.314 – 0.883	0.000**
Oral wrinkles	0.529	Weak	0.227 – 0.831	0.001**
Nasal wrinkles	0.485	Weak	0.183 – 0.788	0.002**
Auricular wrinkles	0.777	Moderate	0.545 – 1.009	0.000**
Forehead wrinkles	0.538	Weak	0.232 – 0.844	0.001**
Cheek wrinkles	0.777	Moderate	0.545 – 1.008	0.000**
Cheek hollowing	0.555	Weak	0.264 – 0.845	0.000**
Overall skin colouring	0.774	Moderate	0.540 – 1.009	0.000**
Overall skin texture	0.677	Moderate	0.420 – 0.935	0.000**

* Based on the interpretation of McHugh (2012)

** $p < 0.05$, strong evidence against H_0: $\kappa=0$

4.1.3 Inter-observer repeatability of scoring method

Inter-observer agreement was similarly tested for the assessment of morphological features. This was calculated using Fleiss' kappa (Fleiss, 1981; Fleiss *et al.*, 1979; McHugh, 2012), and is presented in the second column of Table 4.3. The 95% CI as well as the p-value were calculated to test for significance (last two columns of Table 4.3).

Table 4.3 presents inter-observer assessment for the morphological features ranging from -0.004 to 0.686. While a negative Fleiss' kappa indicates less agreement than would be expected by chance, the lack of strength and statistical significance for this value implies that the negative result is not of consequence in this context (Hallgren, 2012; McHugh, 2012).

The results presented in Table 4.3 indicates a marked decrease in agreement strength according to the McHugh interpretation (2012) when compared to intra-observer repeatability results, which reflects the difficulty in scoring morphological features consistently.

Table 4.3: Inter-observer agreement for scored morphological features

Scored feature	Fleiss' kappa (κ)	Strength of κ *	95% CI for κ	p-value
Orbital wrinkles	0.416	Weak	0.246 – 0.586	0.000**
Upper eyelid fold drooping	0.398	Minimal	0.223 – 0.573	0.000**
Suborbital pouch formation	0.265	Minimal	0.086 – 0.444	0.004**
Oral wrinkles	0.253	Minimal	0.071 – 0.435	0.006**
Nasal wrinkles	0.396	Minimal	0.217 – 0.574	0.000**
Auricular wrinkles	0.501	Weak	0.310 – 0.690	0.000**
Forehead wrinkles	0.686	Moderate	0.498 – 0.874	0.000**
Cheek wrinkles	0.123	None	-0.061 – 0.307	0.191
Cheek hollowing	0.157	None	-0.021 – 0.335	0.084
Overall skin colouring	-0.004	None	-0.197 – 0.190	0.971
Overall skin texture	0.087	None	-0.084 – 0.259	0.319

* Based on the interpretation of McHugh (2012)

** $p < 0.05$, strong evidence against H_0: $\kappa=0$

4.2 Measured features associated with age progression

4.2.1 Correlation between age and measured features

The descriptive statistics for the metric features, per age decade, are shown in Table 4.4. The averages, standard deviations, and 95% confidence intervals (CI) were calculated for each measurement. Scatterplots of these measures can be viewed in Figure 4.2.

The averages reported in the Sforza *et al.* (2010a, 2009a, 2010b) papers were also indicated on these graphs. The convention used in the current study was utilising the lowest age per age range as a single value plotting point. Since the age groups described here followed constant, discrete age intervals and those of the Sforza *et al*. (2010a, 2009a, 2010b) papers did not, it was decided to calculate the average age for each age range described in the Sforza *et al.* studies and subsequently apply this as a plotting point.

Table 4.4: Descriptive statistics for the metric facial ageing features

Feature	Age group	Average (mm)	SD*	95% confidence value	95% CI** (mm)
Upper lip thickness	20-29 years	11.6	2.011	0.751	10.8 – 12.3
	30-39 years	9.4	1.935	0.723	8.7 – 10.2
	40-49 years	8.4	2.05	0.766	7.6 – 9.1
	50-59 years	8.9	2.349	0.877	8.1 – 9.8
	60-69 years	7.1	2.518	0.94	6.2 – 8.1
	70-79 years	7.0	3.754	1.402	5.6 – 8.4
	80+ years	6.3	2.256	1.734	4.5 – 8.0
Lower lip thickness	20-29 years	14.5	2.046	0.764	13.7 – 15.2
	30-39 years	12.7	2.141	0.799	12.0 – 13.6
	40-49 years	12.0	2.299	0.858	11.2 – 12.9
	50-59 years	12.5	3.091	1.154	11.3 – 13.6
	60-69 years	9.8	2.708	1.011	8.8 – 10.8
	70-79 years	9.6	3.487	1.302	8.3 – 10.9
	80+ years	8.4	1.794	1.379	7.0 – 9.8
Mouth width	20-29 years	58.4	4.433	1.655	56.7 – 60.0
	30-39 years	56.8	5.462	2.04	54.8 – 58.9
	40-49 years	56.3	5.782	2.159	54.1 – 58.5
	50-59 years	59.6	5.649	2.109	57.4 – 61.7
	60-69 years	57.1	5.574	2.081	55.0 – 59.2
	70-79 years	57.2	5.948	2.221	55.0 – 59.4
	80+ years	54.7	8.941	6.873	47.8 – 61.6
Nasal length	20-29 years	50.2	4.806	1.795	48.4 – 52.0
	30-39 years	49.5	7.245	2.705	46.8 – 52.3
	40-49 years	49.2	4.232	1.58	47.6 – 50.8
	50-59 years	50.2	5.202	1.942	48.3 – 52.2
	60-69 years	48.6	4.244	1.585	47.0 – 50.2
	70-79 years	47.7	7.057	2.635	45.1 – 50.3
	80+ years	48.8	4.394	3.378	45.4 – 52.2

Feature	Age group	Average (mm)	SD*	95% confidence value	95% CI** (mm)
Nasal tip angle	20-29 years	101.8	6.151	2.297	99.5 – 104.1
	30-39 years	100.1	6.223	2.324	97.8 – 102.5
	40-49 years	98.4	6.315	2.358	96.0 – 100.7
	50-59 years	99.1	5.965	2.227	96.9 – 101.3
	60-69 years	103.3	7.136	2.665	100.6 – 106.0
	70-79 years	101.4	5.79	2.162	99.2 – 103.6
	80+ years	103.4	6.039	4.642	98.7 – 108.0
Ear width	20-29 years	41.0	4.158	1.552	39.5 – 42.6
	30-39 years	39.5	4.464	1.667	37.8 – 41.1
	40-49 years	42.1	5.912	2.208	39.9 – 44.3
	50-59 years	42.9	5.447	2.072	40.9 – 45.0
	60-69 years	42.2	4.657	1.739	40.5 – 44.0
	70-79 years	40.8	5.4	2.136	38.6 – 42.9
	80+ years	43.9	5.292	4.068	39.9 – 48.0
Ear length	20-29 years	71.4	6.721	2.557	68.9 – 74.0
	30-39 years	69.0	7.167	2.676	66.4 – 71.7
	40-49 years	71.8	7.714	2.88	68.9 – 74.7
	50-59 years	74.0	7.772	2.956	71.0 – 77.0
	60-69 years	74.1	7.223	2.697	71.4 – 76.8
	70-79 years	71.0	7.555	2.989	68.0 – 74.0
	80+ years	76.5	5.026	3.864	72.6 – 80.4

SD* Standard deviation

CI** Confidence interval

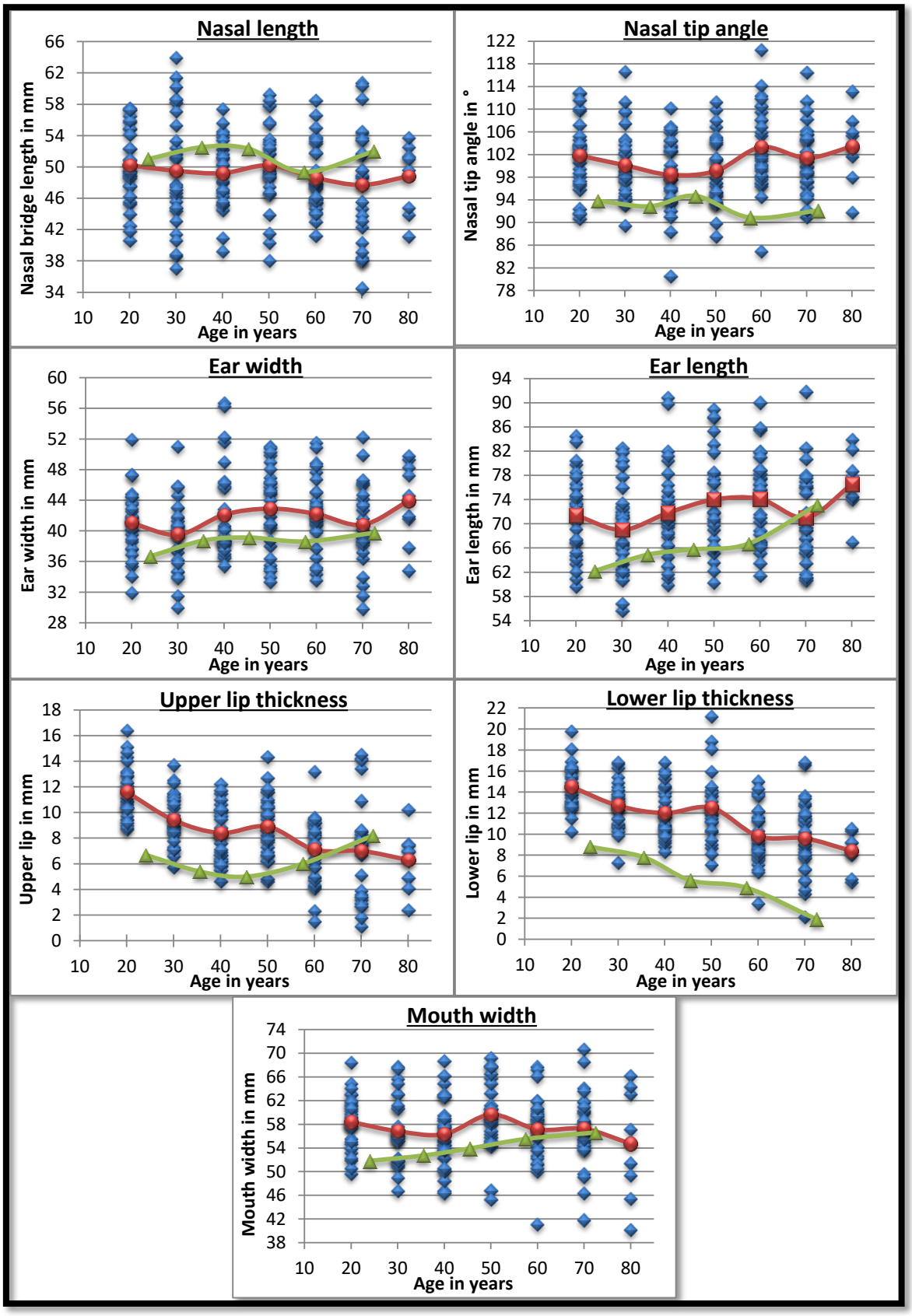


Figure 4.2: *Scatterplots of measured features with trend lines indicated. The red line indicates the average measurement per decade from this study, while the green line indicates the means obtained for the Sforza et al. (2010a, 2009a, 2010b) papers.*

The only two measurable features showing a clear trend are upper and lower lip thinning. Though a negative relationship between age and lip thinning can be observed, an unequal ageing progression is evident with a plateau appearing from 40-50 years of age, followed by a sharp decline from 60 years onwards. This is reminiscent of the three step pattern observed with morphological features such as the forehead and orbital wrinkles, cheek hollowing, overall skin colour and texture. None of the other features show a clear trend with age. The described population values in Sforza *et al.* (2010b, 2010a, 2009a) are very different from that of the South African black male sample. In Figure 4.2 this is especially clear for lower lip thinning, as the Sforza *et al.* (2010a) average trend line lies approximately 5 mm below the South African sample averages. The South African group initially has thicker lips compared to the European population described by Sforza *et al.* (2010a) and this increased value is maintained throughout progressing age decades.

Pearson's correlation coefficient values for the measured features are summarised in Table 4.5. The statistical significance of each correlation was again tested using Fisher's hypothesis testing paradigm (Dawson and Trapp, 2004). Upper and lower lip thinning are the only measurable features with a significant correlation to age. All of the other features proved to have little to no correlation with age, as well as displaying a lack of evidence against the null hypothesis of zero correlation.

Table 4.5 Correlation of measured features with age in decades

Age related scoring feature	Pearson's correlation coefficient (r)	Strength of correlation **	p-value
Upper lip thinning	-0.507	moderate to good	0.000***
Lower lip thinning	-0.561	moderate to good	0.000***
Mouth width increase	-0.021*	little to none	0,786
Nasal elongation	-0.120	little to none	0.100
Nasal tip dropping	0.087	little to none	0.241
Ear width increase	0.124*	little to none	0.093
Ear length increase	0.142*	little to none	0.054

* Spearman's rank correlation coefficient was used, as data did not follow a normal distribution.

** Based on the Coulton rule of thumb as described by Dawson and Trapp (2004).

*** $p < 0.05$, strong evidence against H_0: r=0

4.2.2 TEM reproducibility assessment

Technical error of measurement (TEM) was calculated to determine whether the photometric method was sufficient to allow for further analyses, such as age correlation testing. As Table 4.6 indicates, all features had an acceptable classification, with the nasal tip angle average relative TEM percentage (rTEM) being the most reproducible and upper lip thickness the least – while still being well within the acceptable range according to the Perini *et al.* (2005) standards. Certain measurements, such as upper lip thickness, did show some non-acceptable levels of reproducibility according to the Perini *et al.* (2005) standards. Considering the overall good TEM results when averaged for each measurement though, it was clear that the measurements of facial features taken in this study were of sufficient reproducibility under various photographic conditions to allow for further statistical assessment.

Table 4.6: Pairwise TEM scores for measurement reproducibility

Measurement	Image pair	TEM (mm)	rTEM (%)	Classification
Upper lip thickness	1 and 2	0.27	4.0	Acceptable
	1 and 3	0.70	10.9	Non-acceptable
	2 and 3	0.55	8.5	Non-acceptable
	1 and 4	0.51	8.0	Non-acceptable
	2 and 4	0.43	6.6	Acceptable
	3 and 4	0.21	3.4	Acceptable
	1 and 5	0.25	3.8	Acceptable
	2 and 5	0.14	2.1	Acceptable
	3 and 5	0.46	7.2	Acceptable
	4 and 5	0.30	4.8	Acceptable
Feature average TEM		0.38	5.9	Acceptable
Lower lip thickness	1 and 2	0.43	3.9	Acceptable
	1 and 3	0.14	1.3	Highly Acceptable*
	2 and 3	0.57	5.2	Acceptable
	1 and 4	0.29	2.6	Acceptable
	2 and 4	0.54	4.8	Acceptable
	3 and 4	0.29	2.6	Acceptable
	1 and 5	0.61	5.4	Acceptable
	2 and 5	0.89	7.8	Non-acceptable
	3 and 5	0.54	4.8	Acceptable
	4 and 5	0.35	3.1	Acceptable
Feature average TEM		0.47	4.2	Acceptable

Measurement	Image pair	TEM (mm)	rTEM (%)	Classification
Mouth width	1 and 2	3.82	6.9	Acceptable
	1 and 3	1.46	2.7	Acceptable
	2 and 3	3.26	5.9	Acceptable
	1 and 4	1.05	1.9	Highly Acceptable*
	2 and 4	2.78	4.9	Acceptable
	3 and 4	1.35	2.5	Acceptable
	1 and 5	2.72	5.0	Acceptable
	2 and 5	2.14	3.8	Acceptable
	3 and 5	1.50	2.8	Acceptable
	4 and 5	2.01	3.7	Acceptable
Feature average TEM		2.21	4.0	Acceptable
Nasal length	1 and 2	1.20	3.4	Acceptable
	1 and 3	0.46	1.3	Highly Acceptable*
	2 and 3	1.32	3.7	Acceptable
	1 and 4	0.59	1.6	Highly Acceptable*
	2 and 4	0.62	1.7	Highly Acceptable*
	3 and 4	0.79	2.2	Acceptable
	1 and 5	2.45	6.5	Acceptable
	2 and 5	3.61	9.7	Non-acceptable
	3 and 5	2.62	6.9	Acceptable
	4 and 5	3.00	8.0	Non-acceptable
Feature average TEM		1.67	4.5	Acceptable
Nasal tip angle	1 and 2	0.39	0.4	Highly Acceptable*
	1 and 3	1.90	1.9	Highly Acceptable*
	2 and 3	1.58	1.6	Highly Acceptable*
	1 and 4	1.55	1.6	Highly Acceptable*
	2 and 4	1.36	1.4	Highly Acceptable*
	3 and 4	2.38	2.5	Acceptable
	1 and 5	0.85	0.9	Highly Acceptable*
	2 and 5	0.63	0.6	Highly Acceptable*
	3 and 5	1.87	1.9	Highly Acceptable*
	4 and 5	0.74	0.8	Highly Acceptable*
Feature average TEM		1.33	1.4	Highly Acceptable*

Measurement	Image pair	TEM (mm)	rTEM (%)	Classification
Ear length	1 and 2	2.63	4.7	Acceptable
	1 and 3	0.88	1.5	Highly Acceptable*
	2 and 3	2.34	4.2	Acceptable
	1 and 4	1.65	2.9	Acceptable
	2 and 4	1.11	2.0	Highly Acceptable*
	3 and 4	1.23	2.2	Acceptable
	1 and 5	0.51	0.9	Highly Acceptable*
	2 and 5	2.14	3.9	Acceptable
	3 and 5	0.91	1.6	Highly Acceptable*
	4 and 5	1.23	2.2	Acceptable
Feature average TEM		1.46	2.6	Acceptable
Ear width	1 and 2	2.06	6.6	Acceptable
	1 and 3	0.21	0.6	Highly Acceptable*
	2 and 3	1.98	6.3	Acceptable
	1 and 4	0.83	2.6	Acceptable
	2 and 4	1.24	4.0	Acceptable
	3 and 4	0.79	2.5	Acceptable
	1 and 5	0.75	2.3	Acceptable
	2 and 5	2.17	6.9	Acceptable
	3 and 5	0.57	1.7	Highly Acceptable*
	4 and 5	1.16	3.6	Acceptable
Feature average TEM		1.18	3.7	Acceptable

* Adheres to the stringent standards referred to in Fancourt and Stephan (2018).

4.2.3 Intra-observer repeatability of measurements

The metric features were assessed for repeatability in Table 4.7 using the intraclass correlation coefficient (ICC) (Cicchetti, 1994; Hallgren, 2012). Intra-observer agreement results are presented in Table 4.7, along with a 95% CI for the ICC score and p-values assessing statistical significance. Excellent overall metric feature agreement was found, ranging between 0.853 and 0.989 across the features. It is notable that the metric features reflected a higher level of agreement than the morphological features.

Table 4.7: Intra-observer agreement for measured features

Measured features	ICC	Strength of ICC **	95% CI for ICC	p-value
Upper lip thinning	0.979	Excellent	0.958 – 0.989	0.000*
Lower lip thinning	0.989	Excellent	0.978 – 0.995	0.000*
Mouth width increase	0.967	Excellent	0.936 – 0.983	0.000*
Nasal elongation	0.959	Excellent	0.917 – 0.980	0.000*
Nasal tip dropping	0.853	Excellent	0.729 – 0.923	0.000*
Ear width increase	0.888	Excellent	0.743 – 0.948	0.000*
Ear length increase	0.982	Excellent	0.964 – 1.991	0.000*

* $p < 0.05$, strong evidence against H_0: ICC=0

** Based on the interpretation of Cicchetti (1994)

4.2.4 Inter-observer repeatability of measurements

Inter-observer agreement was also calculated using ICC (Cicchetti, 1994; Hallgren, 2012), with an associated 95% CI for each ICC value as evident in Table 4.8. The significance of the observed agreement was again assessed (last column, Table 4.8) using Fisher's hypothesis testing (Dawson and Trapp, 2004; Perezgonzalez, 2015).

Inter-observer repeatability for the metric features ranged between 0.340 and 0.957, which shows a marked decrease in agreement when compared to intra-observer assessment. This discrepancy between intra- and inter-observer repeatability is similar to that observed for scored morphological features. Metric features overall displayed higher agreement when compared to morphological features for both inter- and intra-observer reassessments.

Table 4.8: Inter-observer agreement for measured features

Measured features	ICC	Strength of ICC ***	95% CI for ICC	p-value
Upper lip thinning	0.821	Excellent	-0.076 – 0.949	0.000**
Lower lip thinning	0.957	Excellent	0.837 – 0.983	0.000**
Mouth width increase	0.728	Good	0.523 – 0.853	0.000**
Nasal elongation	0.450	Fair	-0.075 – 0.796	0.000**
Nasal tip dropping	0.728	Good	0.528 – 0.852	0.000**
Ear width increase	0.340	Poor	-0.055 – 0.776	0.001**
Ear length increase	0.453	Fair	-0.134 – 0.778	0.000**

** $p < 0.05$, strong evidence against H_0: $\kappa=0$ or H_0: ICC=0 for scored and measured features respectively

*** Based on the interpretation of Cicchetti (1994)

4.3 Average face per age decade

Following the feature-specific correlation analyses as described above, an average face per decade (Figure 4.3) was created using FantaMorph software. This figure allows a general visual assessment of the most observable changes, although fine wrinkles tend to be underrepresented due to their variable locations. The highly variable locations cause the wrinkles to subsequently become smoothed out during the averaging process (Sutherland *et al*., 2017). The FantaMorph software results are presented in Figure 4.3, A) – G).

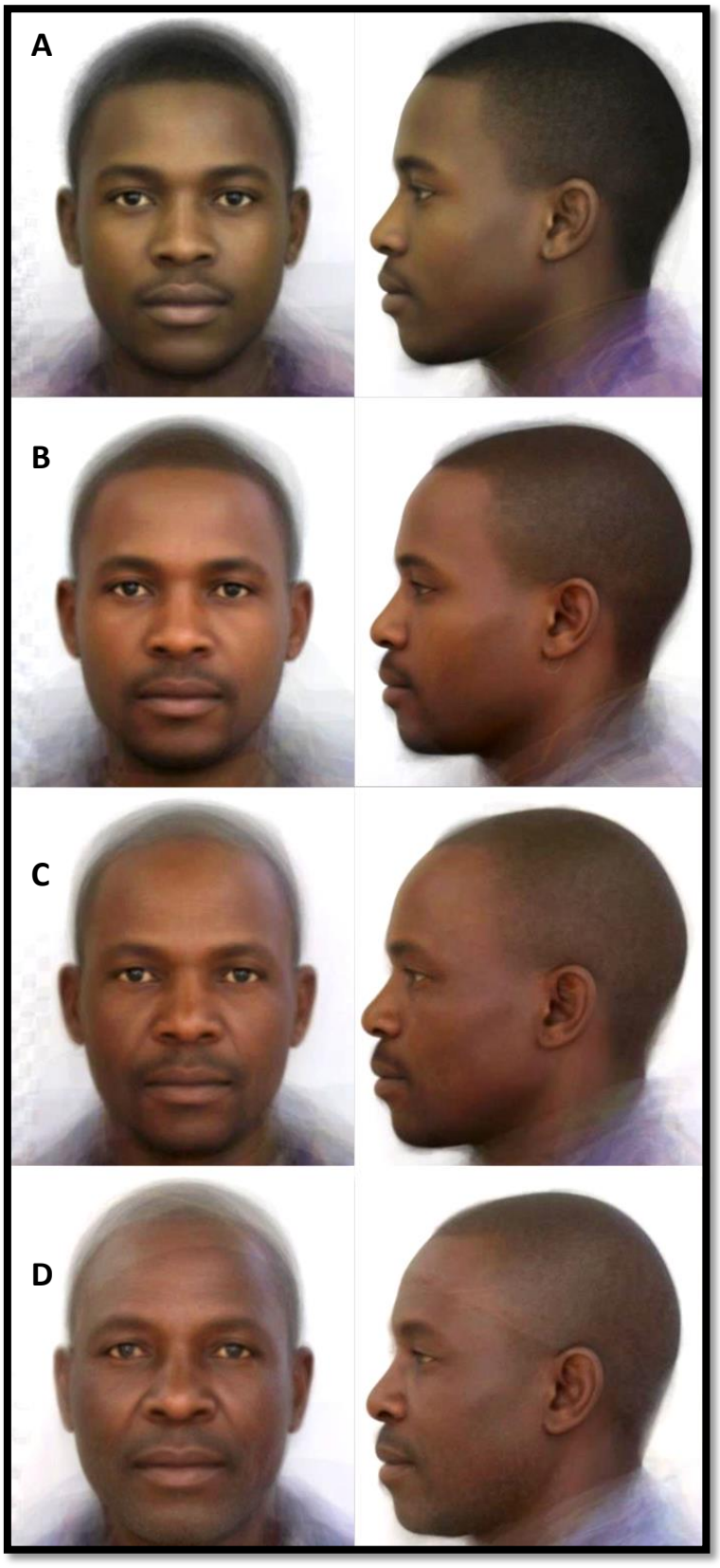


Figure 4.3: *Facial average image of black South African men from top row, anterior and lateral views of A) 20-29 year old; B) 30-39 year old; C) 40-49 year old; D) 50-59 year old individuals.*

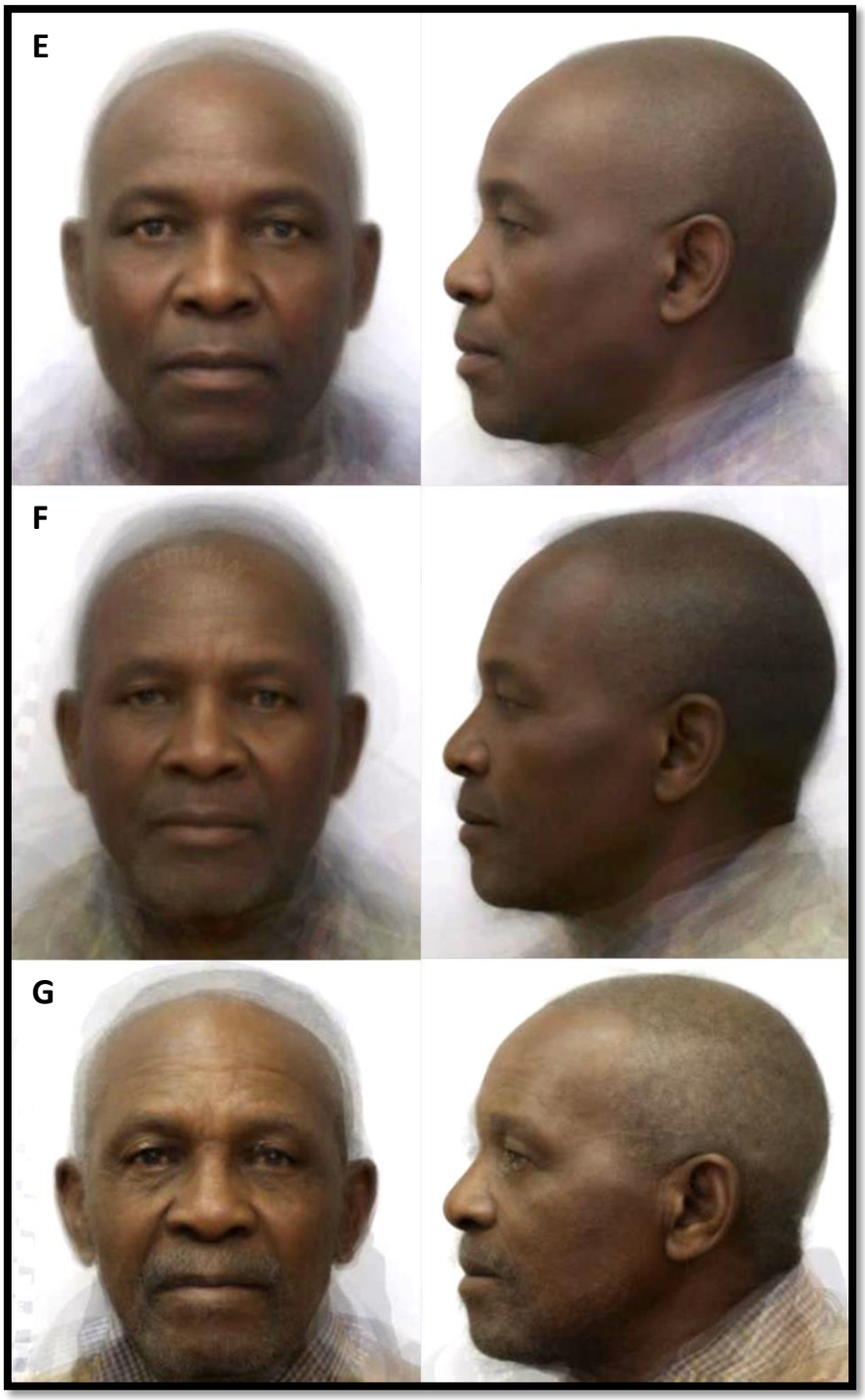


Figure 4.3: *Facial average image of black South African men from top row, anterior and lateral views (continued) of E) 60-69 year old; F) 70-79 year old; and G) 80 years and older individuals.*

4.4 Lifestyle questionnaire

As a final component to the data analysis completed in this study, a questionnaire reflecting sample demographics was completed by all participants. The results of these demographic questionnaires provided insight on the frequency of occurrence for factors that may affect facial senescence. The questionnaire results are visually presented using percentage bar graphs in Figure 4.4 A) and B).

The majority of younger participants was single (60%), whereas the majority of the older participants were in relationships. This trend was maintained until the age of 70, after which more individuals were once again single. Participants with children increased from 46% at age 20 years, to 88% by age 80+ years. Of note is the high number of dependants relying on the majority of participants for financial support, regardless of their relationship status or number of children. Of the total sample, 88% had to financially support others, with 35% of the total sample supporting five or more persons.

Daily sun exposure was observed for 87% of the total sample, and affected people of all ages. Tobacco use seemed to become less prevalent as participants age, as evident by the decrease from 50% of 20 year olds to 33% of participants older than 80 years of age. Daily alcohol use decreased sharply from age 60, with the majority of 70 year and older participants practising teetotalism.

The majority of younger participants did not require medication, whereas the majority of participants from 50 years upwards were using chronic or acute medication. Very few participants adhered to a special diet, with 95% of the sample reporting no specific eating plan. Surprisingly, the number of participants who were edentulous or had dentures did not increase much with age, rising from 7% for 20 year olds to a high of only 13% for 70 year olds.

The majority of participants reported taking part in some activity four days a week or more throughout all the age groups. This contrasts with the expected decrease in physical activity with advanced ageing. The most inactive age groups were the 40 and 50 year olds, with 40% of participants reporting physical activity less than once a week.

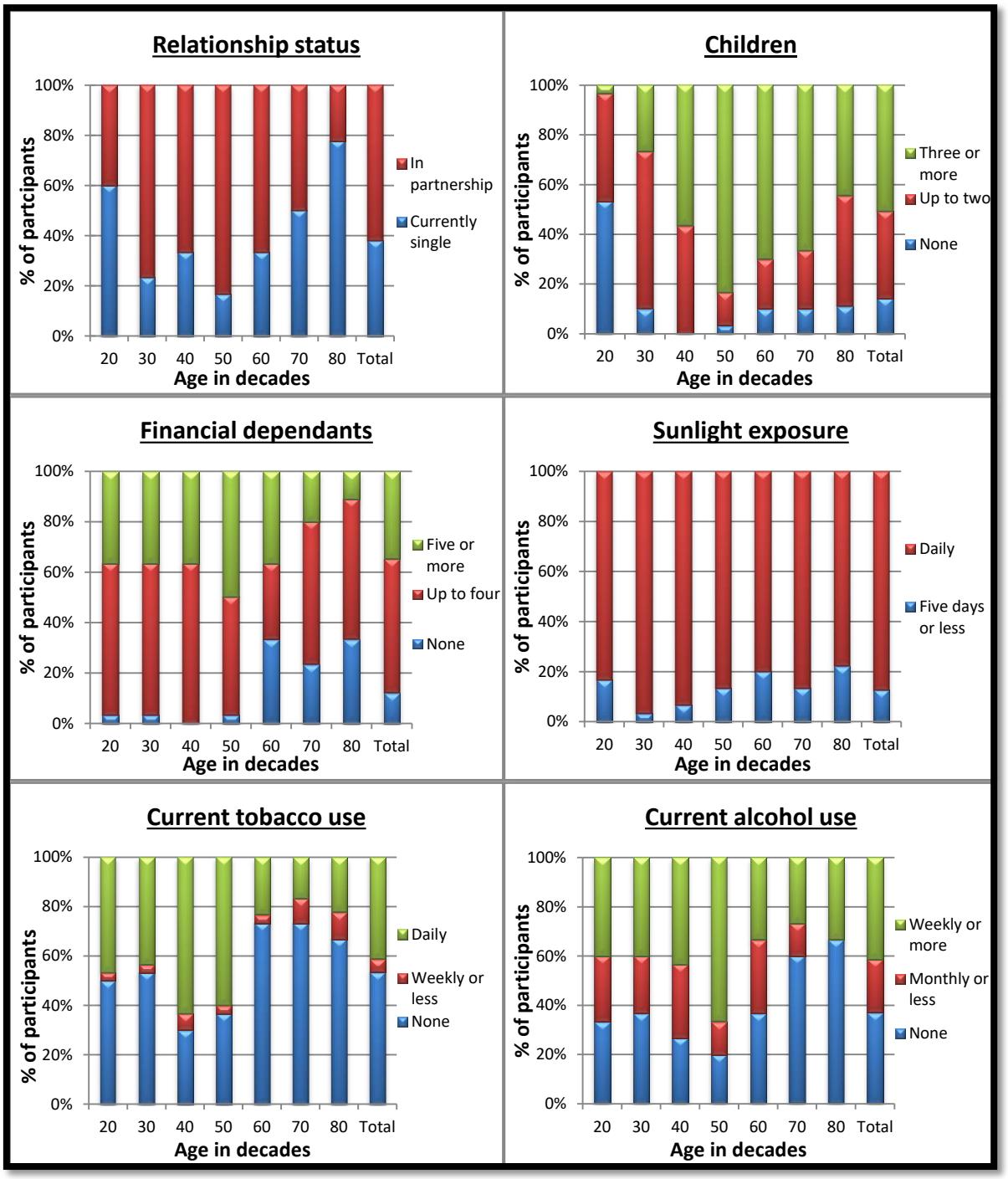


Figure 4.4: *A) Percentage bar graphs illustrating the sample composition for factors that can affect facial ageing.*

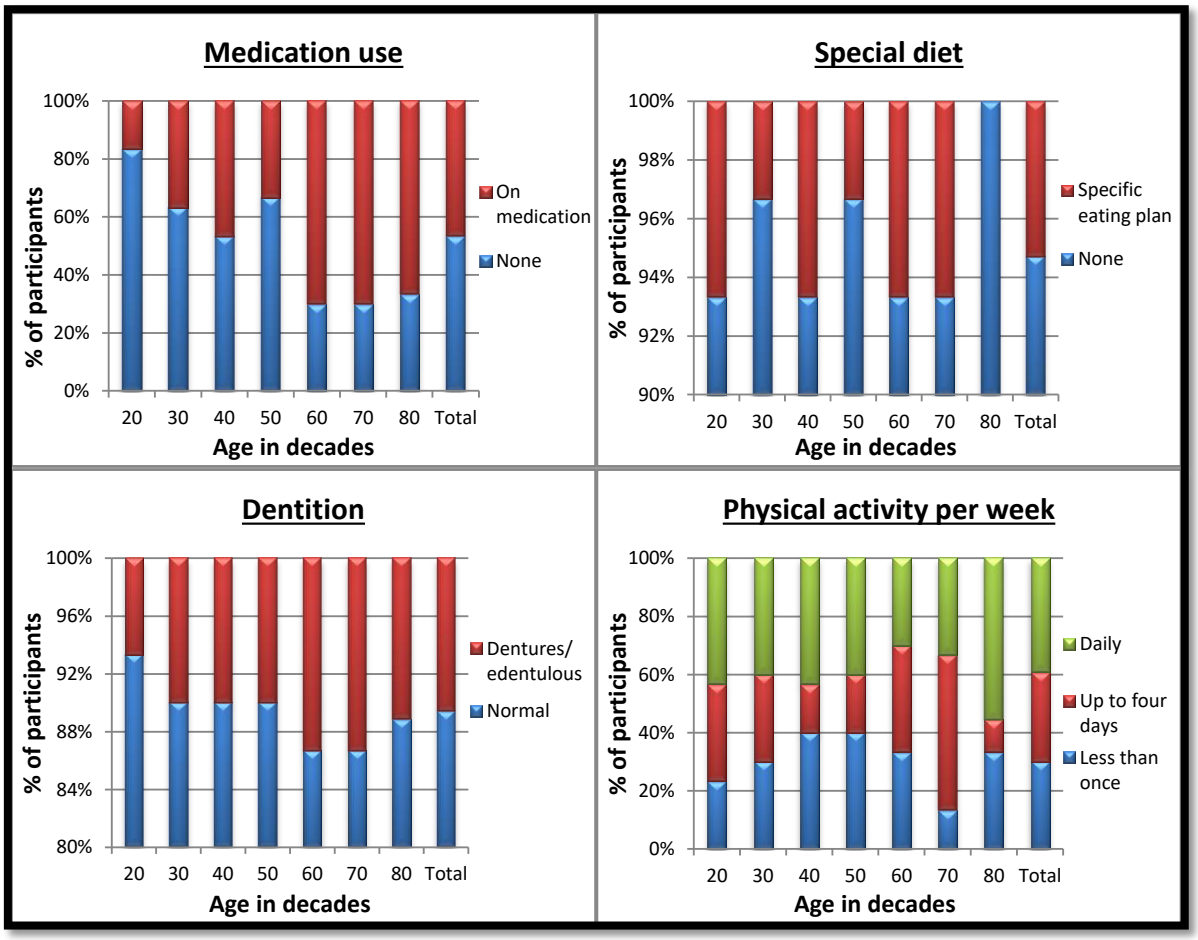


Figure 4.4: *B) Percentage bar graphs illustrating the sample composition for factors that can affect facial ageing (continued).*

Chapter 5
Discussion

In the section, a discussion on observed deviations from existing facial ageing literature as well as unique facial ageing changes is presented. Possible explanations for deviations from existing literature are also presented. Although some overall trends could be observed, this discussion still focuses on each analytical step for greater clarity. Aspects across more than one analysis that corroborate evidence was also mentioned. A brief look at certain limitations, coupled with how these may inform future research directions, is also provided.

5.1 Unique South African facial ageing trends

5.1.1 Trends regarding morphological features

The results obtained for age correlations with scored features indicate various differences and similarities from the ageing process described in existing literature based on European, North American, and Indian populations (Albert *et al.*, 2007; Hadi and Wilkinson, 2014; Vashi *et al.*, 2016).

The first difference between ageing patterns in the South African group and that reported in existing literature was already encountered when setting up the scoring system based on descriptive features. No lateral nose creases were observed at all in the sample, and as such this feature was removed from the scoring system (Tables 3.1 and 3.2). The lack of lateral nose creases could be accounted for when considering the underlying skeletal structure of the nasal bridge. In African populations, the nasal bridge tends to be broad and low, as opposed to sharp and pronounced like those of European populations (Íşcan and Steyn, 2013). Wrinkles form partly as a result of underlying collagen loss that causes the skin to sag under the downward vector of gravity (Albert *et al.*, 2007; Baumann, 2007; Mydlova *et al.*, 2015; Vashi *et al.*, 2016). Accompanied by adipose tissue redistribution, the pronounced angle formed by the high European nasal bridge likely contributes to the appearance of the lateral nose crease. The contribution of a high nasal bridge to lateral nose crease formation is stymied by the more gradual nasal bridge slope in African populations.

The multi-dimpled appearance observed in the chin area for older South African males stands in contrast with the single mental crease described in Hadi and Wilkinson (2014). Skin dimples may appear due to adipose tissue change with age or underlying muscle changes (Kosif, 2015). This multi-dimpled appearance was added to the score five category description for oral wrinkles, and was evident in 20 out of 99 individuals aged 50 years and upwards. An example of the multi-dimpled appearance can be observed in Figure 5.1. Further investigation on an enlarged sample is merited before any generalizations about frequency of appearance of this feature can be applied to the South African population at large.



Figure 5.1: *Example of a multi-dimpled chin*

A third unique aspect of South African ageing involving forehead and orbital wrinkles, cheek hollowing, overall skin colour and skin texture can be seen in the scatterplot graphs presented in Figures 4.1 and 4.2. An unequal ageing pattern is evident, seemingly first characterised by a gradual increase/decrease of the specified feature with age, up to around 50 years. At this age the increase/decrease slows dramatically, forming a plateau. Subsequently the ageing seems to accelerate again in the 70 to 80 years and upward groups. Although the authors did not comment on a similar three-step trend observed, the Sforza *et al.*(2010a, 2009a) data does show a similar three-step trend for ear width and length, as well as lower lip thinning. As for the South African sample, the European sample displayed a decrease in age progression, visible as a plateau, around 45 to 50 years of age (Sforza *et al.*, 2010a, 2009a). Normal age progression was evident in the older ages, as for the current South African sample. Even though the Sforza *et al.*(2010a, 2009a) studies were based on

metric features, the observation of the general age progression trend is similar. No other research studies testing the correlation between age and the scoring of morphological features specifically could be found in order to serve as comparison for the three-step trend observable for the South African sample.

This three-step trend may to some extent be explained by considering the average 60-year-old life expectancy of South African men (Lehohla, 2016). Individuals that outlive this age might be either genetically inclined to longevity and/or healthier than average through chance and circumstance. Their faces may therefore not show the same severe age progression as their counterparts, resulting in a seemingly younger looking older sample. The plateau observed from age 50 years, for some features, seem to fit this trend. The three-step trend, as described here, corresponds with the demographic composition of South Africans, and may disappear over time due to the secular trend of increased life expectancy (Rossi *et al.*, 2013).

The morphological ageing changes observed in this study for South Africans are broadly consistent with age changes in other populations (Albert *et al.*, 2007; Vashi *et al.*, 2016). On average, South African men show initial wrinkle formation (Score 2 obtained for features, Tables 3.1 and 3.2) about a decade later than Europeans (Albert *et al.*, 2007), with initial formation starting after 30 rather than 20 years of age. Circumoral striae (Oral wrinkles score 4, Table 3.1) were only evident around 70 years of age, whereas they are described as forming from 30 years onwards in Europeans (Albert *et al.*, 2007). This delayed wrinkling pattern is in accordance with Vashi *et al.* (2016), who note that so-called 'ethnic ' skin has an increased melanin content, larger non-aggregated melanosomes, a thick dermis and more multinucleated fibroblasts. The preceding traits of darker skin types result in greater protection from photoaging and preserved skin elasticity (Vashi *et al.*, 2016). Cheek hollowing (Table 3.1) was evident at an earlier age than for Europeans, with most participants in the sample displaying considerable hollowing around 40 rather than 60 years of age.

Assessment of categorical data such as morphological features is observer specific and therefore often considered problematic with high error rates (Íşcan and Steyn, 2013; Merritt, 2014). Despite the relative fluidity in descriptions for morphological features,

morphology is widely used in conjunction with metric based approaches in biological anthropology (Íşcan and Steyn, 2013).

The inter- and intra-observer results for the scoring system used in the current study do seem to indicate that the descriptive scoring system is not as replicable as would be hoped according to the McHugh (2012) interpretation of repeatability. Despite some concerns on the repeatability, the morphological scoring system does have adequate levels of reliability. It can be argued that the morphological descriptive assessment criteria for ageing are somewhat vague and hard to accurately repeat without significant, population specific experience. The need for experience in assessing facial ageing progression is attested to by the higher reliability for the intra-observer than the inter-observer assessments. It is therefore recommended to create a population specific visual database for each score, rather than rely on descriptions, for future use. Such a database would follow the model of the skin colour and texture templates already provided in Table 3.1 and 3.2, but include multiple templates for each score of all the morphological ageing features.

5.1.2 Trends regarding measured features

The measured features also showed some interesting results. Of the seven features assessed (Figure 4.2 and Table 4.4), only upper and lower lip thinning had a statistically significant correlation with age (Table 4.5). The difference between the mean upper lip thinning measurements according to Sforza *et al*. (2010a) and the averages obtained in this study is illustrated in Figure 4.2. Sforza *et al*. (2010a) reported mean measurements of 5.0-8.2 mm for men aged 18-80, while the South African mean for men aged 20 and older ranged between 6.3 and 11.6 mm (Table 4.4). Sforza *et al*. (2010a) state that the mean lower lip thinning values range from 1.9-8.8 mm. The South African values (Table 4.4), in contrast, range from 8.4-14.5 mm. When compared to their European counterparts, South African adult men tend to have broader lips across all ages.

Considering age-related correlation, the Sforza *et al*. (2010b) nasal ageing study report an increase in nasal length as well as a decrease in nasal tip angle, in accordance with other literature (Albert *et al.*, 2007). The reported Sforza *et al*. (2010b) average data had been charted along with the data from this study in Figure 4.2. Data from Sforza *et al*. (2010b) show a sigmoid as well as non-linear graph respectively, similar to those obtained in this

current study. Such visual representations are not indicative of a clear increase/ decrease. It is unclear what the authors based their interpretation on, and so no definite statement as to the corroboration or disagreement of the current study compared to Sforza *et al*. (2010b) can be made. No significant increase in nasal length or decrease in nasal tip angle was evident in a South African sample, in contrast with other literature sources based on European samples (Albert *et al.*, 2007).

In a similar European-based study (Sforza *et al.*, 2010a), upper lip thickness decreased and mouth width linearly increased with progressing age. For the current South African sample, upper lip thickness distinctly decreased over time, with no distinct change in mouth width. This directly contrasts with the results of the European sample, although whether this reflects actual population differences rather than sample artefacts can only be commented on after further investigation.

Another contrast found in this study to results obtained for a European sample (Sforza *et al.*, 2009a) relates to ear length. Whereas the ear length showed no significant change over time for a South African sample, lengthening was reported in the European sample (Sforza *et al*., 2009a). Ear width did not show a significant change with increasing age in the current study, similar to the European sample's results (Sforza *et al.*, 2009a).

The inter- and intra-observer agreement statistics indicated that the metric features are all highly repeatable, regardless of whether they show actual age progression or not (Tables 4.7 and 4.8). The interpretation of the agreement statistics is based on the work of Cicchetti (1994). This high repeatability, as expected, contrasts with the non-metric, morphologically scored features' lower agreement rating according to the McHugh (2012) criteria. Both the Cicchetti (1994) and McHugh (2012) interpretations of the strength of agreement rely on similar cut-off ranges for each level of strength. The slightly lower inter-observer agreement may once again be an indication of experience necessary for the accurate measurement of these features.

5.1.3 Trends regarding average faces over time

When considering the South African male average faces of each decade (Figure 4.3), general senescent changes are observed. An overall visual description of the sequence of facial

ageing changes visible on the average face is provided, rather than a statistically determined sequence of events.

Few differences are apparent between the 20-29 and 30-39 year olds. The infraorbital groove and nasolabial lines become more prominent, with a slight receding of the hairline. This receding hairline is visible as an increased irregularity on the anterior image (Figure 4.3). The formation of nasolabial lines, as well as a receding hairline, at this age is in accordance with existing literature (Albert *et al.*, 2007; Ellis *et al.*, 2001). The infraorbital groove, in contrast, is reported to form a decade later in European samples (Albert *et al.*, 2007).

From the 30-39 and 40-49 year groups, eyelid drooping and pouch formation start to become visible. The infraorbital groove and nasolabial line also become clearly defined during this time period. The hairline recedes even more, and slight cheek hollowing becomes evident. Eyelid drooping is reported to also occur around 40 years of age in European samples, although suborbital pouches form only later in other populations, according to literature (Albert *et al.*, 2007). Cheek hollowing in the current South African sample appears two decades earlier than reported for European samples (Albert *et al.*, 2007).

In the 50-59 year category, the lateral forehead and eye creases start to become prominent. Lip thinning as well as oromental and labiomental grooves makes an appearance. The lateral forehead, eye, oromental and labiomental creases/grooves all appear delayed when compared to European samples (Albert *et al.*, 2007). Albert *et al.* (2007) provides estimated ages of appearance ranging from the twenties to forties for the abovementioned creases and grooves. Lip thinning, in contrast, is expected to become visible around 50 years of age according to literature (Albert *et al.*, 2007; Sforza *et al.*, 2010a).

From the 60-69 year category onwards, the overall appearance of the face becomes more rounded than elongated, with the jawline becoming more variable and jowls forming. Bone atrophy related to tooth loss likely contribute to the variable jawline evident (Oettlé, 2014). The hairline becomes difficult to distinguish due to the extent of its retreat, and the buccomandibular as well as cheek folds begin to appear. Once again the buccomandibular creases and cheek folds appear delayed in this South African sample, compared to the age of wrinkle appearance for European populations described in literature (Albert *et al.*, 2007).

South African jowl formation, in contrast, appears at a similar age as for Europeans (Albert *et al.*, 2007).

During the 70-79 year time period, upper eyelid drooping and suborbital pouch formation becomes prominent. Visually there does not appear to be many distinctive differences between the average face of 60-69 and 70-79 year olds, except that all ageing changes that have already been observed are intensified. Existing literature tends to group ages over sixty together (Albert *et al.*, 2007; Sforza e*t al.*, 2010a, 2009a, 2009b, 2010b). It can be speculated that this is done due to a lack of sufficient numbers of individuals over 60 years of age willing or able to participate in studies. The age progression visible for 70 and 80 year old categories in this South African sample (Figure 4.3) can therefore not be readily compared to existing literature.

By 80 years of age, protrusion of the ears is visible. Cheek hollowing is pronounced, and the overall shape of the face seems almost completely round. This can likely be ascribed to advanced age-related atrophy of the jaw, in which senescent dentoalveolar loss plays a prominent role (Albert *et al.*, 2007; Oettlé, 2014). All wrinkles are more pronounced, specifically auricular wrinkles that are for the first time clearly evident. When compared to 20-29 year old average faces, the slight prognathic nature of the lower face seems to have receded into a near orthognathic lateral facial profile with increasing age.

Certain morphological and metric features investigated individually were not included in this assessment, as their visual appearance was not clearly apparent on the average faces presented in Figure 4.3. This includes features such as skin colour and texture, as well as nose and ear length. The general trend of changes occurring per age group is broadly similar to that provided by Albert *et al.* (2007), as adapted in Table 2.1 of the current study. Wrinkle formation is, however, in general delayed compared to the timeline provided by Albert *et al.* (2007).

5.1.4 Practical application of results

The research presented in this project is envisioned to be of practical use to South African forensic artists. The population specific nature of the results obtained in this study heightens the every-day applicability of the data presented.

To further enhance practical use of this research, a lab manual was drafted titled 'Craniofacial Ageing Lab Manual' (CALM) for South African males. The aim of providing such a manual is to enable forensic artists working in the craniofacial depiction arena to have a short, accessible reference guide to population specific facial ageing changes. Rather than provide an intensive look at the study methodology and all results obtained, only the most relevant for ageing faces in facial depiction practice are briefly provided. These short age descriptions are accompanied with the average faces obtained, allowing a visual assessment by the forensic artist in addition to the summarized unique facial ageing changes. This lab manual is included in Appendix H, and will be provided to all interested parties. It is envisioned that researchers at university units such as the Human Variation and Identification Research Unit (HVIRU) at Wits and forensic artists currently working in the field of facial identification for the South African Police Service (SAPS) would benefit from such a manual.

In addition to the CALM lab manual, some insights into the data collection process have also been provided in the form of an anthropological essay (Appendix I). It is envisioned that this perspective would be of benefit to researchers planning data collection from a South African based sample. Some reflections on the realities facing the population from which data is sourced may provide valuable insights for structuring future data collection drives in the field.

5.1.5 Trends regarding lifestyle questionnaire

Several notable lifestyle/ demographic trends could be detected concerning the South African sample, as presented in Figure 4.4. It should be noted however that the questionnaire answers on lifestyle and demographic factors were self-reported by participants, lending some scope to factual error. Certain factors included in the questionnaire, such as relationship status, medication use and specific diet plans, did not show an unexpected or informative trend. Various other factors did show unexpected or unique trends and are presented here.

As expected, up to the age of 50, the number of participants that have children as well as the number of children per participant increased on average. The 20-29 year old age category notably reported having relatively few children. This may be explained by the population

trend of delayed parental age at the birth of their first child, occurring on a South African national as well as global level (Lehohla, 2011; Morgan, 2003). The most recent South African population census data on the parental age at birth of the first child was in 2011. A shortcoming of the 2011 census data is that women in more than 60% of recorded births do not report the details of the father. This lack of data restricts the statistical use of paternal age at birth of the first child for South African males specifically, even though the sample used in this current study seem to reflect the reported trends (Lehohla, 2011).

Among participants of the current study, the number of financial dependents was high. Most of the participants also reported having to provide for multiple dependents rather than their immediate family only. The prevalence of multiple financial dependents in the South African context has been recorded throughout literature, and is of some economic concern (Bhorat and Khan, 2018; Finn, 2015). Having to provide for many dependents could lead to increased financial stress, which may in turn have an adverse effect on ageing (Albert *et al.*, 2007). Multiple dependents negatively influencing the financial situation of individuals is a well reported occurrence for various other populations beside South Africans (Joo and Grable, 2004; Worthington, 2006).

Alcohol and tobacco use decreased with increasing age among the participants of the current study. The observed decrease in regular use, as individuals age in the South African sample, has been described in other populations as well (Agaku *et al.*, 2014; Grant *et al.*, 2017, 2004). The sharp decline in both alcohol and tobacco use observed from 60 years of age onwards may also be related to mortality rather than a decrease in use. It is reported that excessive alcohol and smoking carry severe health risks, which negatively impacts longevity (Agaku *et al.*, 2014; Grant *et al.*, 2004, 2017; Statistics South Africa, 2016a). Given the 59.7 years life expectancy for South African males, individuals engaging in excessive use may be deceased and so no longer form a part of the sample in the older age groups.

The number of participants using acute or chronic medication increased with age progression. This increase in medication use of older individuals is consistent with expected trends (Levine *et al.*, 2007). What was surprising was the fairly large number of younger individuals without any teeth. The level of edentulism did not increase much as participants aged. It should, once again, be stated that the questionnaire answers were self-reported rather than proof-based, and certain discrepancies may occur. Despite the scope for error in

the reported numbers, several other explanations may also account in part for the reported levels of being edentulous. Possible dietary changes that younger individuals underwent when compared to older participants from rural backgrounds, may negatively affect dental health (Price and Nguyen, 2016). Dietary changes towards a more processed starch and sugar rich diet could cause an increase in carious lesions (Price and Nguyen, 2016). However, it seems unlikely to fully account for the loss of all teeth reported in younger adults. A second factor that could contribute to some tooth loss is the rise of inter-personal violence experienced among South African youth (Otwombe *et al*., 2015). Once again though, as for dietary changes, inter-person violence could result in some teeth missing or broken, but is unlikely to affect all teeth to the extent that edentulousness would occur in young adults. Further investigation of the reported appearance of edentulism in young adults using a broader sample is merited, before any comments on contributing factors to this occurrence can be justified.

Another lifestyle factor that indicated an interesting trend in the South African context was the high level of activity reported across all age groups. Hallal *et al.* (2012) reported that overall, Africa has one of the lowest rates of physical inactivity in adults, despite some gaps in available research for certain African countries. When questioned further off the record on their reportedly high levels of physical activity, participants noted a reliance on public transport, with transport hubs often located a distance from both their home and work. This necessitated walking a significant distance daily, which has long been a documented source of dissatisfaction with public transport in South Africa (Thomas, 2016). A need to improve public transport systems, especially in developing countries and cities, is a universal rather than South African specific issue (Pojani and Stead, 2015). In developed European countries and the USA, urban planning has been focused on encouraging increased, healthy amounts of exercise around access to public transport (Badland and Schofield, 2005; Lee and Moudon, 2004; Pucher and Dijkstra, 2003). This contrasts with the excessive physical exertion needed in order to access public transport in South Africa.

The high levels of physical activity may also be a contributing factor to the reportedly high levels of regular sun exposure across all age groups, especially for individuals reporting daily walks outdoors to transport hubs. The majority of the participants of advanced age were fortunate enough to be part of community programs for the elderly, which were reported to

include light exercise programs. Overall a good level of fitness may reduce outward signs of ageing. However excessively strenuous, enforced exercise as part of a daily commute to a job that may include further physical work could have adverse effects on health and add to stress, in turn increasing visible effects of ageing (Albert *et al.*, 2007). Such strenuous physical activities occurring outdoors would also likely lead to excessive sun exposure, damaging the skin and causing premature signs of ageing (Albert *et al.*, 2007; Vashi *et al.*, 2016).

5.2 Limitations and future research directions

As with any study that needs to be completed within a given timeframe and set budget boundaries, limitations exist. This section briefly mentions some constraints regarding the framework this study was conducted in. Each limiting factor does, however, present an opportunity for future research in order to broaden the understanding of facial ageing in a South African population. In order to present this research project in a timely and feasible manner, the focus was placed on a black South African male population. An expanded sample from a broader region within South Africa should be assessed in future, ideally including both males and females of other South African population groups. Care should be taken to include a variety of socio-economic backgrounds.

The second methodological constraint found in this study is the less than ideal reliability of morphological age progression scoring. As stated earlier in this chapter, reliability concerns regarding morphological feature assessment are not unique to this current study (İşcan and Steyn, 2013; Merritt, 2014) despite the widespread use of such assessments. Reliability errors for the morphological scoring used in this study could potentially be decreased through the use of population specific morphological scoring guides. Such scoring guides should include images of the typical progression indicated at each stage for all features, not just skin colour and texture as included in the current scoring tables. The use of visual guides could likely address the subjectivity issue and reduce experience based repeatability errors in future research.

A third limitation to the analyses methods used in this study is that facial averaging software without texture preserving algorithms was used. The lack of texture preserving algorithms

caused slight smoothing of fine wrinkles on average faces. Given an extended time frame, it would be recommended to construct facial averages using software such as PsychoMorph with texture preserving algorithms as well. A subsequent visual comparison of the obtained facial averaging results using FantaMorph and that obtained using PsychoMorph could then be considered as future research trajectory.

A fourth limitation that arose from the data collected was that the study is based on cross-sectional data (Dawson and Trapp, 2004). This means various individuals were assessed at one moment in time, rather than monitoring the same individuals over time (Dawson and Trapp, 2004). Problems that may arise with this method include the high variability in factors that could have an effect on ageing between different individuals. Suggested research directions include an evaluation on how the face changes over the lifetime of a single individual (longitudinally), providing sufficient funding can be obtained for such a long time period of research. The cross-sectional nature of this current study therefore lends itself to constraints on effectively considering the multiple lifestyle factors and interactions that may contribute to facial ageing. Some factors were not included in the lifestyle questionnaire set up to partly account for these ageing factors, and the following section will provide motivation on the decision to exclude these factors. Weight gain and/ or loss were not included as a factor in this study. Although this greatly influences the face, this study is based on cross-sectional research and so only a specific moment in time, i.e. the moment captured in the facial image, is included in this study (Dawson and Trapp, 2004). Weight changes are not limited to a certain socio-economic status, and so this factor will be a limitation throughout the sample and not a bias in certain categories only, such as high socioeconomic status or low socioeconomic status individuals (Ziraba *et al.*, 2009).

A second factor not accounted for in the questionnaire is individual tooth loss and associated mandibular atrophy. South African population specific age-related changes in dentition are well-described in literature (Oettlé, 2014). However dental changes are not specifically addressed in the questionnaire aside from a question on whether participants have dentures/ are edentulous, and if so how long this has been their status. Ageing changes observed in the underlying bone structure determines the overlying soft tissue changes to a great extent (Albert *et al.*, 2007; Oettlé, 2014). Further population specific research on skeletal ageing changes would help drive the understanding of superficial soft tissue

changes, since this current study focused specifically on the overall external surface of the face and associated soft tissue changes.

The questionnaire attempts to track health by querying chronic or acute medicine use. These answers nevertheless do not indicate which illnesses may be present. Human Immunodeficiency Virus (HIV) is common, affecting approximately 7 million South Africans (Lehohla, 2016). HIV is expected to have a significant influence on facial ageing, especially as this illness also paves the way for a host of accompanying conditions, due to the loss of a functioning immune system (Aloysius and Barber, 2018). The specific influences of HIV and AIDS (Acquired Immunodeficiency Syndrome) and other diseases on facial ageing are beyond the scope of this study. Future research focusing on the specific effect of HIV and AIDS on facial ageing in a South African sample would be beneficial.

As this study was limited in scope due to financial and time constraints, the relative contribution of the various factors that were included in the lifestyle questionnaire could not be fully explored. Statistical analyses such as multiple regression may in future help determine the relative importance of the contribution of each of these lifestyle factors to facial ageing in the South African population group. As envisioned, this current study could be considered foundational research, allowing for the multiple future research directions mentioned in this section within the field of facial ageing.

Chapter 6
Conclusions

Facial ageing research, such as the work presented in this current study, offers clinical as well as forensic applications. This study provided baseline information on facial ageing in black South African males. It tested the presumed correlations between various facial features and ageing based on trends observed in European, North American and Indian samples, and revealed various aspects which did not correlate well with age in a statistically significant manner. Findings include:

- In general, all morphological descriptive features (orbital, nasal, oral, auricular, forehead and cheek wrinkles, upper eyelid fold drooping, suborbital pouch formation, cheek hollowing and overall skin colour and texture) show a correlation to age. The correlation between these features and age has been described in various other populations as well (Albert *et al.*, 2007; Vashi *et al.*, 2016), however black South Africans males displayed a comparatively delayed wrinkle formation and an early onset of cheek hollowing.

- Some of the measurable features such as mouth and ear width increase, ear length increase, nasal elongation and nasal tip dropping do not show any progression with age in a black South African male sample. The lack of observed ageing changes in the nose may be accounted for when considering the underlying skeletal differences between individuals of African and European descent (Íşcan and Steyn, 2013). This lack of correlation with age contrasts with existing literature (Albert *et al.*, 2007; Sforza *et al.*, 2010a, 2010b).

- As ageing progresses, upper as well as lower lip thickness decrease. South African men have thicker lips throughout their lifetime, delayed wrinkle formation and advanced cheek hollowing when compared to a European sample.

- Both inter- and intra-observer measures of reliability for the measured features outperformed the repeatability of the descriptive, morphological features. Cheek

wrinkles and hollowing as well as overall skin color and texture scoring could not be consistently replicated. Intra-observer agreement was comparatively higher than inter-observer agreement, indicating that assessor experience is likely a requirement for facial ageing analysis.

- The facial averages constructed per age decade provide a visual and descriptive guide of overall facial senescence. It is envisioned that this guide will enable easier and more accurate representations of facial ageing in a forensic, health or humanities practical context.

- Several of the lifestyle factors included in a demographic questionnaire proved informative on trends that may influence South African facial ageing, specifically regarding high levels of financial dependents, physical exercise and a relatively good retention of teeth over time.

Overall this study provided novel, South African population specific data on the correlation of several specific features with age, the overall facial ageing trends as well as factors potentially influencing facial ageing. It is envisioned that this study will have a particularly significant impact on the field of facial approximation within South Africa, as it addresses the knowledge gap on population specific facial ageing research. Future research avenues include the addition of South African women and a statistical assessment of the relationships between the lifestyle factors and observed facial ageing.

Chapter 7
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Appendices

Appendix A

Informed consent

A descriptive morphological study on adult facial ageing in black South African males

Dear Sir

I am a Masters student at the Human Variation and Identification Research Unit at the School of Anatomical Sciences, University of Witwatersrand and I am doing research on South African faces. Research is the process of answering a question, and the question I want answered is: How does South African faces age? The answer to this question is important because adding the appropriate ageing details in forensic facial reconstructions may help identify murder victims or find missing persons. The ageing process is also important in plastic surgery and dermatology, and there is no available research on South African faces specifically. I am asking you to take part in this research project by allowing me to take photographs of your face.

Who can participate?

Males of African ancestry between the ages of 20 and 100 years can take part in this study, as long as they are South African citizens. There are no specific requirements as to occupation, health status or use of medication/alcohol/tobacco. I hope to take 30 photographs and ten scans of faces for each age range of ten years.

What will this study look at, specifically?

All assessments will be made on the photographs of the faces and except for the accompanying form that needs to be completed; nothing else will be required from participants. There are three parts to this study. In part one signs of age, like wrinkles, will be scored using the photo that is taken of participants' face. Part two is similar to part three, except measurements like nose and ear length will be taken from the photographs. In part three an average face will be made for each ten years from the age of 20 to 100. This is going to be done using the photos and computer software called FantaMorph. The picture on the following page shows how different the average face looks when compared to the people whose images are used. Your images will be used to complete all three parts of this study.

Average SA Presidential Face 1994-2017



From left to right: President Zuma, previous presidents Mandela and Mbeki; average face made up of all six previous images.

What will participants have to do?

In this study you will not be asked your name or contact details. Instead, the investigator will give your photo/scan a number, and this number will be written on your consent form and on a questionnaire that you will be asked to fill in. This will help investigators to make sure that your information stays with your images. None of your images will be used in this study as they are. No one will be able to recognize you. Only the average faces will be published. The investigator is setting up a digital research database that contains images of faces. You can choose to allow the addition of yours. This database is only for academic research, and your images will not be spread on the internet or anywhere else.

If you decide to take part, you will need to sign a consent form. After this, photographs will be taken of your face from the front and side. This will be like taking ID or passport photographs and should take about 5 minutes. You will also be asked a few short questions, like the questions asked in a census. You can leave any questions you do not want to answer open. The questionnaire will take 5 – 10 minutes to complete.

Do I have to take part in this study?

Taking part in this study is your choice. If you agree but you feel uncomfortable with the photographs/ questions you can say that you do not want to take part any longer. The researcher will then delete your images and tear up any questions you answered in front of you. If you decide that you do not want to take part a few days later, or would like to know more about the study and its results, please contact the principal investigator. You will need your identifying number as on the consent form if you want your images to be deleted.

Researcher: Ms Estha Schmidlin, esthaschmidlin@gmail.com , or phone (27)82 714 3001

Any complaints or problems about the conduct of the researcher or the content of the study may be sent to the Human Research Ethics Committee of the University of the Witwatersrand.

HREC Research Administrator: Ms Zanele Ndlovu, zanele.ndlovu@wits.ac.za , or phone (27)11 717 1252
Research Office: Faculty of Health Sciences, Phillip Tobias Building, 3rd floor, Office 301, 29 Princess of Wales Terrace, Parktown, 2193. Private Bag 3, Wits 2050.

Date: _____ No: _____

Photography Consent Form – A descriptive morphological study on adult facial ageing in black South African males

** Please circle the answer you agree with the most. **

- My photographs can be used to make an average face. This average face can be used in academic sources (dissertations, scientific journal articles and academic conference papers/posters/presentations).

  YES **NO**

- My photographs can be saved in an electronic database. They will be used only for research purposes. My photographs will not be spread around on internet.

  YES **NO**

- My photographs (in the electronic database) will not be printed in a recognizable form in other research studies (dissertations, scientific journal articles and conference papers/presentations/posters).

  YES **NO**

Signature: _____

Appendix B

Questionnaire

Date: _____ No: _____

Background information questionnaire – A descriptive morphological study on adult facial ageing in black South African males

- I confirm that the questions were answered frankly and that my answers can be used with the image of my face in this study, provided that my name will not be linked to the image in any way.

  YES **NO**

- I agree that my answers can be entered into the electronic research database along with the image of my face, provided that my name will not be linked to the image in any way.

  YES **NO**

1) How old are you?

20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-100

2) What work do you do?

_____

3) What is your relationship status?

Single	Married / live in partner	Live in partner	Divorced	Widowed

4) How many children do you have?

No children	1-2 children	3-4 children	5 or more children

5) How many people are in your household?

No additional family members are under my care	1-2 family members	3-4 family members	5-6 family members	7 or more family members

6) How would you describe yourself in terms of your population group?

isiXhosa	isiZulu	siPedi	siSotho	Tsonga
siTswana	isiNdebele	Other: (specify)		

7) How much time do you spend outside in the sun?

Most of the day, every day	A short while each day	Five days every week	One – four days a week	A few days a month

8) How often do you smoke?

Never	Used to, but not any more	About 5 times a year	About once a month
Once a week	Less than 5 times a day	Between 5 and 20 times a day	More than 20 times a day

9) How often do you drink?

Never	Used to, but not any more	About 5 times a year	About once a month
Once a week	One drink per day	Between 2 and 5 drinks a day	More than 5 drinks a day

10) Do you take chronic medication? (every day for a long period of time)

Yes	No

11) Do you currently use acute medication? (just till your illness clears up, short-term)

Yes	No

12) Do you have a special diet?

None	Vegetarian	Vegan	High protein	Low carbohydrate	Low fat

13) Do you have dentures?

No	Yes, upper teeth only	Yes, lower teeth only	Yes, both sets of teeth

14) If you do have dentures, for how long have you been wearing them?

Up to a year	1-3 years	4-6 years	7-9 years	10 years or more

15) How often do you exercise?

Once or more every day	At least four days a week	At least once a week	Less than once a week

Appendix C

Ethics clearance certificate

R14/49 Ms Estha Schmidlin

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M161023

NAME: (Principal Investigator)	Ms Estha Schmidlin
DEPARTMENT:	School of Anatomical Sciences
PROJECT TITLE:	A Descriptive Morphological Study on Adult Facial Ageing in Black South African Males
DATE CONSIDERED:	28/10/2016
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof Maryna Steyn, Dr Nanette Briers and Dr Tobias Houlton
APPROVED BY:	Professor P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	03/02/2017

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 301, Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in October and will therefore be due in the month of October each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

Date 15 February 2017

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix D

Raw data – scored features

Participant identifier code	Orbital wrinkles	Upper eyelid drooping	Suborbital pouch formation	Oral wrinkles	Nasal wrinkles	Forehead wrinkles	Cheek wrinkles	Overall skin colouring	Auricular wrinkles	Cheek hollowing	Overall skin texture
20-29											
BM171	2	2	1	1	2	2	2	1	1	1	1
BM050	1	1	1	2	2	1	1	1	1	1	1
BM073	1	2	1	1	1	2	1	2	1	1	1
BM061	2	1	2	1	1	2	2	1	1	2	1
BM139	1	2	1	1	1	1	2	2	1	2	2
BM033	1	1	2	1	1	2	2	2	2	2	3
BM036	1	2	2	2	2	1	1	3	1	1	3
BM037	2	1	2	1	2	1	2	1	1	2	1
BM039	1	2	2	1	2	1	2	2	1	1	2
BM043	2	2	1	1	2	1	2	2	1	2	2
BM044	1	2	1	2	1	1	2	1	1	1	1
BM045	2	2	2	1	1	2	2	1	2	1	1
BM048	1	1	2	2	2	1	2	2	2	1	2
BM049	2	2	1	1	2	3	2	1	1	2	1
BM051	1	1	3	2	1	1	1	1	1	1	1
BM062	1	1	2	2	1	2	2	2	1	3	1
BM066	2	2	2	2	3	3	2	2	1	2	2
BM078	2	2	2	2	2	1	3	2	2	1	2
BM079	1	2	2	2	2	1	3	2	1	1	2
BM081	2	3	1	1	2	1	2	2	1	1	1
BM082	1	2	1	1	1	1	2	1	1	1	1
BM086	1	2	1	1	2	1	2	2	2	1	2
BM090	2	2	2	2	2	1	3	3	1	1	2
BM099	3	3	2	2	1	1	2	2	2	2	1
BM106	1	1	1	1	1	1	1	1	1	1	1
BM140	1	1	1	1	1	1	1	1	1	1	2
BM144	1	1	1	2	2	1	1	2	2	2	2
BM147	1	3	2	1	2	2	2	2	1	1	1
BM148	1	1	1	1	1	1	2	1	1	1	1
BM166	1	1	1	2	2	1	3	1	1	2	1

Participant identifier code	Orbital wrinkles	Upper eyelid drooping	Suborbital pouch formation	Oral wrinkles	Nasal wrinkles	Forehead wrinkles	Cheek wrinkles	Overall skin colouring	Auricular wrinkles	Cheek hollowing	Overall skin texture
30-39											
BM177	1	1	1	2	1	2	1	1	1	1	1
BM173	2	3	2	2	3	3	2	2	2	2	1
BM057	2	2	2	2	3	4	2	2	3	1	2
BM074	1	1	2	1	2	2	2	2	1	1	3
BM067	1	2	1	1	2	1	1	2	2	3	2
BM034	2	2	3	3	2	3	3	3	2	2	1

BM042	1	2	2	2	3	2	3	2	1	1	1
BM055	3	2	2	3	4	2	4	3	2	3	2
BM058	3	3	3	2	4	3	3	3	2	1	3
BM059	3	3	2	2	4	2	4	2	2	2	2
BM060	3	4	2	1	2	4	3	2	1	3	2
BM070	2	2	3	3	2	3	2	3	2	2	2
BM071	2	4	2	2	4	3	3	2	2	1	3
BM075	2	3	2	2	2	2	3	3	3	2	2
BM088	2	3	2	2	3	1	3	3	3	1	2
BM092	2	2	3	2	3	3	3	3	2	1	3
BM103	3	4	2	2	4	2	3	2	1	2	1
BM104	1	2	2	*	1	1	2	2	2	2	2
BM105	3	2	2	3	3	3	3	2	1	2	3
BM125	2	2	2	2	1	1	2	2	2	2	1
BM126	2	1	1	2	2	2	2	2	3	1	3
BM127	2	2	2	3	2	2	3	2	1	1	2
BM143	2	3	2	3	2	2	3	3	1	4	2
BM146	3	3	2	3	3	3	3	3	2	3	2
BM153	3	2	2	3	2	1	3	2	2	1	3
BM157	3	2	2	3	3	2	3	3	2	2	4
BM160	2	2	2	2	2	2	3	3	2	3	2
BM161	2	2	2	2	2	2	3	2	2	4	3
BM170	1	1	2	2	2	3	2	1	1	1	2
BM185	2	3	2	2	2	1	2	5	2	2	3

Participant identifier code	Orbital wrinkles	Upper eyelid drooping	Suborbital pouch formation	Oral wrinkles	Nasal wrinkles	Forehead wrinkles	Cheek wrinkles	Overall skin colouring	Auricular wrinkles	Cheek hollowing	Overall skin texture
40-49											
BM152	3	3	3	3	4	3	3	3	1	4	2
BM072	1	2	3	1	1	2	2	2	1	3	1
BM102	2	2	2	1	3	3	3	3	1	1	3
BM096	2	3	2	2	2	2	3	2	2	2	2
BM118	2	2	2	3	3	2	3	2	2	1	3
BM010	3	3	2	3	4	3	4	3	3	2	2
BM052	4	3	4	3	3	3	5	4	4	2	4
BM056	2	3	2	3	4	2	3	2	3	3	3
BM068	4	4	2	3	3	1	2	2	2	1	4
BM069	4	2	4	3	4	3	4	4	4	4	3
BM076	2	2	2	2	3	2	3	3	2	2	2
BM083	3	2	3	2	3	3	4	5	3	3	4
BM087	3	2	3	3	4	3	4	4	3	2	3
BM101	4	2	2	2	3	2	4	3	3	5	3
BM117	4	3	3	3	4	3	3	2	2	2	2
BM119	4	2	3	2	4	3	3	3	2	1	3
BM138	2	2	2	3	2	3	3	2	2	3	2

BM141	2	4	2	3	2	3	4	4	3	5	2
BM142	4	4	3	3	4	3	5	4	2	3	3
BM158	2	3	3	3	2	2	2	3	3	1	2
BM165	3	3	4	2	3	3	4	2	3	3	2
BM167	2	2	2	3	4	3	5	2	1	4	2
BM168	3	3	3	3	3	2	3	3	2	2	3
BM169	3	3	3	2	3	4	4	3	3	3	2
BM178	3	4	3	3	4	2	3	3	2	2	2
BM179	3	3	3	3	4	3	3	4	2	2	3
BM180	2	2	2	2	2	2	3	2	2	3	2
BM181	3	2	3	3	3	4	3	3	2	4	2
BM182	3	2	3	3	4	3	4	4	3	3	3
BM184	2	2	3	3	4	3	4	4	2	4	1

Participant identifier code	Orbital wrinkles	Upper eyelid drooping	Suborbital pouch formation	Oral wrinkles	Nasal wrinkles	Forehead wrinkles	Cheek wrinkles	Overall skin colouring	Auricular wrinkles	Cheek hollowing	Overall skin texture
50-59											
BM191	3	2	2	1	3	3	2	2	2	4	4
BM200	4	2	2	5	4	3	4	3	2	2	4
BM197	3	3	4	*	4	3	3	3	2	3	3
BM116	4	4	4	2	3	2	2	4	2	2	3
BM131	3	4	2	3	2	4	4	3	3	5	2
BM009	4	3	5	3	4	4	4	5	3	3	3
BM054	4	3	4	5	5	4	5	3	5	3	5
BM089	3	2	3	3	4	3	3	4	3	1	3
BM114	4	4	4	3	4	4	4	3	3	2	4
BM120	4	4	2	3	3	2	2	3	1	1	2
BM121	3	2	4	3	3	3	5	3	4	3	2
BM123	5	5	4	3	4	4	3	3	4	3	3
BM124	3	3	3	*	2	4	*	4	3	3	4
BM132	3	3	4	3	3	4	5	4	4	4	5
BM133	3	3	4	3	4	3	3	4	3	2	3
BM151	3	4	3	3	4	3	5	3	4	2	3
BM155	4	4	3	3	3	4	4	2	1	2	3
BM159	2	2	2	3	2	4	4	3	3	4	3
BM163	3	2	3	4	4	3	3	4	3	4	3
BM164	3	4	3	3	4	2	4	2	4	2	3
BM175	3	3	4	5	4	3	3	3	2	3	3
BM186	4	2	3	3	3	4	4	3	3	4	4
BM189	5	5	4	4	4	5	5	4	4	3	5
BM193	4	3	4	2	3	4	4	3	3	3	3
BM194	4	4	3	4	2	1	4	4	4	3	3
BM196	3	3	3	1	4	1	3	2	4	1	3
BM198	2	2	3	2	3	1	3	3	2	1	3
BM199	3	4	2	3	4	3	5	5	3	3	4
BM229	2	3	3	3	3	4	5	2	3	2	3

BM230	4	4	2	4	4	4	5	3	4	4	2

Participant identifier code	Orbital wrinkles	Upper eyelid drooping	Suborbital pouch formation	Oral wrinkles	Nasal wrinkles	Forehead wrinkles	Cheek wrinkles	Overall skin colouring	Auricular wrinkles	Cheek hollowing	Overall skin texture
60-69											
BM130	4	4	3	2	4	4	3	3	5	3	3
BM192	4	4	4	3	4	3	3	3	3	3	3
BM224	3	3	3	5	5	2	3	4	4	4	4
BM209	4	5	3	2	4	2	3	4	4	4	4
BM001	4	2	3	3	3	2	3	5	2	1	3
BM006	2	3	4	3	3	3	3	5	3	2	2
BM007	4	4	3	5	4	4	5	3	4	5	2
BM016	3	4	4	5	4	1	4	5	3	3	4
BM020	4	4	4	*	4	5	3	4	5	3	3
BM031	3	2	4	2	4	3	4	3	4	3	3
BM108	4	4	5	4	3	3	5	3	4	2	4
BM110	4	4	3	3	3	4	4	4	3	3	3
BM111	3	3	3	4	4	4	4	5	3	3	3
BM112	4	3	3	3	4	4	3	3	4	3	4
BM113	2	4	4	3	4	3	5	3	2	3	2
BM128	4	2	4	*	4	3	*	3	*	*	3
BM129	4	3	3	5	5	4	4	2	3	2	5
BM134	3	3	3	3	4	3	5	4	2	3	2
BM156	2	3	3	4	4	2	5	4	4	4	5
BM190	4	4	4	3	4	3	4	5	5	4	2
BM195	4	3	2	3	4	4	5	3	4	3	5
BM201	4	4	3	3	5	5	5	3	4	2	4
BM202	3	3	4	*	4	4	4	4	5	4	3
BM205	3	3	4	4	4	4	5	5	2	2	4
BM207	3	4	5	3	4	4	3	3	5	4	4
BM208	3	3	3	2	3	2	4	4	2	3	4
BM213	4	4	5	3	3	4	4	4	5	4	4
BM214	4	4	4	3	4	3	4	4	4	3	5
BM223	4	5	3	5	4	3	5	4	3	1	3
BM225	3	5	3	4	4	4	4	4	5	2	4

Participant identifier code	Orbital wrinkles	Upper eyelid drooping	Suborbital pouch formation	Oral wrinkles	Nasal wrinkles	Forehead wrinkles	Cheek wrinkles	Overall skin colouring	Auricular wrinkles	Cheek hollowing	Overall skin texture
70-79											
BM204	2	2	4	4	2	4	5	4	5	4	4
BM012	5	3	5	4	5	2	4	4	3	4	5
BM109	5	3	4	5	4	5	5	3	4	4	3
BM017	4	5	4	5	4	3	4	3	4	3	3
BM203	5	4	5	3	5	3	4	4	3	3	5
BM002	4	3	3	3	4	3	4	4	4	3	4

BM003	4	5	3	4	4	3	4	4	5	3	3
BM004	5	3	4	3	4	5	4	5	4	3	5
BM005	4	4	4	4	5	2	4	5	3	2	4
BM008	4	5	5	3	3	2	5	3	3	3	4
BM013	5	5	5	3	5	4	5	4	4	4	4
BM014	4	5	5	5	5	5	5	3	5	4	3
BM018	4	5	5	4	4	3	5	4	4	5	4
BM021	4	3	4	4	5	4	4	4	4	3	3
BM022	4	4	4	5	5	4	5	4	4	5	5
BM024	4	4	4	4	4	5	5	4	5	4	4
BM026	4	5	3	*	4	3	4	5	*	3	5
BM027	5	5	5	*	5	3	4	4	4	3	5
BM028	4	4	4	3	2	3	4	4	4	4	3
BM030	3	3	4	5	4	5	5	4	5	5	5
BM115	4	4	3	5	5	*	4	3	5	2	5
BM206	4	2	4	4	4	2	4	3	4	4	4
BM211	5	5	4	5	5	3	5	3	4	4	5
BM212	4	4	5	3	4	4	4	3	4	3	5
BM215	3	4	4	3	4	3	3	5	4	4	5
BM216	4	4	4	3	4	2	4	4	4	5	4
BM217	4	4	5	5	4	4	5	5	4	5	5
BM218	4	4	5	3	4	3	3	3	5	5	5
BM221	4	3	3	5	4	5	5	4	5	5	5
BM228	4	5	2	3	4	3	5	3	3	4	4

Participant identifier code	Orbital wrinkles	Upper eyelid drooping	Suborbital pouch formation	Oral wrinkles	Nasal wrinkles	Forehead wrinkles	Cheek wrinkles	Overall skin colouring	Auricular wrinkles	Cheek hollowing	Overall skin texture
80+											
BM029	4	3	5	3	4	5	5	4	3	5	5
BM025	5	5	4	5	4	5	4	5	4	5	3
BM210	5	5	5	4	5	4	4	5	4	5	4
BM023	4	4	3	5	4	2	4	4	3	*	4
BM137	5	5	5	*	4	4	3	4	4	3	5
BM032	3	3	4	3	*	2	4	4	5	2	5
BM135	3	4	4	3	4	4	4	5	5	3	4
BM136	5	4	5	5	5	4	5	4	4	4	5
BM219	5	4	5	4	4	5	4	4	5	3	4

* Scores could not be allocated due to obstruction (e.g. facial hair, tumour)

Shaded rows indicate individuals, in order of random selection, for each age cohort's intra- and inter-observer agreement assessments

Appendix E

Raw data – intra- and inter-observer agreement for scored features

Participant identifier code	***Overall skin colour*** Score A	Score B	Score C	***Overall skin texture*** Score A	Score B	Score C
20-29						
BM171	1	1	2	1	1	2
BM050	1	1	1	1	1	2
BM073	2	2	2	1	1	2
BM061	1	1	2	1	1	1
BM139	2	1	2	2	2	2
30-39						
BM177	1	2	1	1	1	3
BM173	2	2	1	1	1	2
BM057	2	2	2	2	2	3
BM074	2	2	3	1	3	3
BM067	2	2	2	2	2	3
40-49						
BM152	3	2	2	2	2	4
BM072	2	2	2	1	1	4
BM102	3	3	2	3	3	5
BM096	2	2	2	2	2	3
BM118	2	2	2	4	3	5
50-59						
BM191	2	2	2	4	4	5
BM200	3	3	2	4	4	5
BM197	3	3	2	3	3	5
BM116	4	4	2	3	3	5
BM131	3	3	2	3	2	5
60-69						
BM130	3	3	3	3	3	4
BM192	3	3	1	4	3	4
BM224	4	4	3	4	4	4
BM209	4	4	2	5	4	5
BM001	5	4	2	3	3	4
70-79						
BM204	4	3	2	4	4	4
BM012	4	4	1	4	5	5
BM109	3	3	2	4	3	4
BM017	3	2	2	5	3	4
BM203	4	4	3	5	5	5
80+						
BM029	4	4	3	5	5	4
BM025	5	5	3	4	3	4
BM210	5	5	2	4	4	4
BM023	4	4	2	4	4	4
BM137	4	4	2	5	5	5

Cheek wrinkles				***Cheek hollowing***		
Participant identifier code	**Score A**	**Score B**	**Score C**	**Score A**	**Score B**	**Score C**
20-29						
BM171	2	2	3	1	1	1
BM050	1	1	1	1	1	1
BM073	1	1	2	1	1	1
BM061	2	2	3	2	2	2
BM139	1	2	2	1	2	1
30-39						
BM177	1	1	2	1	1	1
BM173	2	2	2	2	2	1
BM057	2	2	3	2	1	2
BM074	3	2	2	1	1	1
BM067	1	1	3	3	3	2
40-49						
BM152	3	3	4	4	4	2
BM072	2	2	4	3	3	2
BM102	3	3	3	2	1	2
BM096	3	3	1	2	2	2
BM118	3	3	3	1	1	2
50-59						
BM191	3	2	4	2	4	2
BM200	4	4	4	3	2	2
BM197	3	3	3	3	3	3
BM116	2	2	3	2	2	2
BM131	4	4	3	5	5	4
60-69						
BM130	3	3	3	3	3	2
BM192	3	3	2	2	3	1
BM224	4	3	1	3	4	2
BM209	3	3	4	4	4	3
BM001	3	3	2	2	1	2
70-79						
BM204	5	5	5	3	4	3
BM012	4	4	4	2	4	2
BM109	5	5	4	3	4	3
BM017	3	4	3	4	3	3
BM203	4	4	5	3	3	4
80+						
BM029	5	5	4	5	5	5
BM025	4	4	3	5	5	5
BM210	5	4	4	5	5	3
BM023	4	4	3	4	*	2
BM137	3	3	4	3	3	2

Forehead wrinkles				***Auricular wrinkles***		
Participant identifier code	**Score A**	**Score B**	**Score C**	**Score A**	**Score B**	**Score C**
20-29						
BM171	2	2	1	1	1	1
BM050	1	1	1	1	1	1
BM073	2	2	3	2	1	1
BM061	2	2	2	1	1	1
BM139	1	1	2	1	1	1
30-39						
BM177	2	2	2	1	1	1
BM173	3	3	3	2	2	1
BM057	3	4	4	3	3	3
BM074	2	2	2	1	1	1
BM067	2	1	1	2	2	1
40-49						
BM152	2	3	3	1	1	2
BM072	3	2	2	1	1	1
BM102	4	3	3	1	1	1
BM096	2	2	2	2	2	1
BM118	2	2	2	2	2	2
50-59						
BM191	3	3	3	2	2	2
BM200	3	3	2	3	2	2
BM197	3	3	3	2	2	1
BM116	3	2	2	3	2	2
BM131	4	4	4	3	3	2
60-69						
BM130	4	4	3	4	5	3
BM192	3	3	3	2	3	3
BM224	3	2	2	4	4	3
BM209	3	2	2	4	4	3
BM001	2	2	2	2	2	2
70-79						
BM204	4	4	4	5	5	4
BM012	3	2	2	3	3	3
BM109	5	5	5	5	4	4
BM017	3	3	3	3	4	4
BM203	4	3	3	3	3	3
80+						
BM029	5	5	5	3	3	3
BM025	5	5	5	4	4	3
BM210	5	4	3	4	4	3
BM023	3	2	1	3	3	3
BM137	5	4	3	4	4	3

Oral wrinkles				***Nasal wrinkles***		
Participant identifier code	**Score A**	**Score B**	**Score C**	**Score A**	**Score B**	**Score C**
20-29						
BM171	1	1	1	1	2	2
BM050	1	2	1	1	2	2
BM073	1	1	1	1	1	2
BM061	1	1	1	1	1	2
BM139	1	1	1	1	1	1
30-39						
BM177	1	2	2	1	1	2
BM173	1	2	2	2	3	2
BM057	2	2	1	2	3	3
BM074	1	1	2	2	2	2
BM067	1	1	2	2	2	2
40-49						
BM152	3	3	3	3	4	3
BM072	1	1	2	1	1	2
BM102	1	1	1	3	3	4
BM096	2	2	2	2	2	3
BM118	2	3	2	2	3	4
50-59						
BM191	1	1	3	3	3	3
BM200	3	5	3	3	4	4
BM197	*	*	2	4	4	5
BM116	1	2	1	3	3	3
BM131	3	3	1	2	2	4
60-69						
BM130	1	2	1	3	4	4
BM192	3	3	3	4	4	4
BM224	3	5	4	4	5	5
BM209	2	2	2	3	4	3
BM001	3	3	3	3	3	4
70-79						
BM204	4	4	3	2	2	3
BM012	3	4	3	4	5	4
BM109	4	5	5	4	4	4
BM017	4	5	5	4	4	4
BM203	3	3	5	4	5	5
80+						
BM029	3	3	5	3	4	4
BM025	5	5	4	4	4	4
BM210	3	4	3	5	5	5
BM023	5	5	3	3	4	4
BM137	3	*	1	4	4	5

Orbital wrinkles				***Upper eyelid drooping***		
Participant identifier code	**Score A**	**Score B**	**Score C**	**Score A**	**Score B**	**Score C**
20-29						
BM171	2	2	1	3	2	1
BM050	1	1	1	1	1	1
BM073	1	1	1	1	2	2
BM061	2	2	1	1	1	1
BM139	1	1	1	3	2	2
30-39						
BM177	1	1	1	1	1	2
BM173	1	2	2	3	3	3
BM057	2	2	3	1	2	2
BM074	2	1	2	2	1	2
BM067	2	1	1	2	2	2
40-49						
BM152	3	3	2	4	3	5
BM072	1	1	2	2	2	2
BM102	2	2	4	2	2	3
BM096	3	2	4	4	3	4
BM118	2	2	3	3	2	3
50-59						
BM191	3	3	4	2	2	2
BM200	4	4	4	2	2	2
BM197	3	3	3	3	3	3
BM116	4	4	4	4	4	5
BM131	3	3	4	4	4	4
60-69						
BM130	4	4	4	5	4	5
BM192	4	4	3	4	4	3
BM224	3	3	4	3	3	3
BM209	4	4	4	5	5	5
BM001	4	4	4	3	2	2
70-79						
BM204	2	2	3	2	2	2
BM012	3	5	4	2	3	2
BM109	5	5	5	3	3	2
BM017	4	4	4	5	5	5
BM203	5	5	5	5	4	5
80+						
BM029	4	4	3	3	3	1
BM025	5	5	5	4	5	2
BM210	5	5	5	4	5	4
BM023	4	4	4	3	4	4
BM137	5	5	5	5	5	5

Suborbital pouch formation

Participant identifier code	Score A	Score B	Score C
20-29			
BM171	1	1	1
BM050	1	1	2
BM073	1	1	1
BM061	1	2	2
BM139	2	1	2
30-39			
BM177	1	1	2
BM173	2	2	3
BM057	1	2	2
BM074	2	2	2
BM067	1	1	2
40-49			
BM152	3	3	2
BM072	2	3	3
BM102	2	2	2
BM096	2	2	2
BM118	3	2	3
50-59			
BM191	2	2	2
BM200	2	2	2
BM197	2	4	2
BM116	4	4	4
BM131	2	2	2
60-69			
BM130	3	3	2
BM192	3	4	4
BM224	2	3	2
BM209	3	3	2
BM001	2	3	2
70-79			
BM204	4	4	2
BM012	5	5	3
BM109	4	4	4
BM017	3	4	3
BM203	5	5	5
80+			
BM029	5	5	5
BM025	4	4	5
BM210	4	5	4
BM023	3	3	4
BM137	5	5	4

* Feature obscured
Measure A: Original measurement
Measure B: Repeat measure by researcher (intra-observer)
Measure C: Repeat measure by Dr TMR Houlton (inter-observer)

Appendix F

Raw data – measured features

Participant identifier code	Upper lip thickness	Lower lip thickness	Mouth width	Nasal length	Nasal tip angle *	Ear width	Ear length
20-29 years of age							
BM171	11.9	13.7	55.5	50.1	109.8	47.3	76.6
BM050	10.4	14.7	53.1	55.7	107.2	43.7	74.7
BM073	14.3	16.1	54.7	56.5	92.4	41.5	84.5
BM061	12.8	15.9	63	50	104.6	51.9	79.8
BM139	13.2	18.1	57.9	47.6	112.7	41.7	64.8
BM033	9	12.5	53.9	57.3	99.4	35.4	67.5
BM036	10.6	16.1	58.2	54.8	95.8	40.1	70.3
BM037	16.4	16.9	63	40.6	102.2	41.9	63.3
BM039	13.1	15.3	64.8	45.3	103.6	37.6	66.8
BM043	9.4	10.2	58.2	42.5	100.6	38.6	64.1
BM044	8.7	15.5	59	49.4	110.1	37.7	65.3
BM045	15.1	13	68.4	44	98.1	34	59.6
BM048	14	14.9	61	57.5	97.3	39.5	78.5
BM049	14.7	13.5	49.6	48.8	105.2	40.6	73.4
BM051	10.4	14.4	61.3	47.5	91.6	44.8	69.1
BM062	10.8	12.9	51.9	48.6	103.6	41.2	75.9
BM066	11.6	19.8	59.7	48.9	96.6	40.9	71.1
BM078	12.1	16.2	62	54.9	98.7	41.7	66.9
BM079	8.8	12.7	61.7	49.4	103.6	43.5	73.3
BM081	10.4	14.9	58	52.3	112.9	44.4	77.7
BM082	10.9	16.4	60.2	49.2	90.7	47.2	73
BM086	9.5	14.4	50.5	45.5	103.3	31.9	60.9
BM090	12.9	13.1	59.3	46.2	96.9	41.8	74.2
BM099	12.3	12.4	52.2	54.1	103	42.6	72.2
BM106	9.7	12.9	57.7	41.8	102.4	36.9	67.3
BM140	11.1	11.5	57.4	55.9	103.9	40.1	74.6
BM144	11.5	16.2	64.1	52.3	101.6	35.8	62.1
BM147	12.3	13.1	58.6	50.9	101.6	44.5	83.6
BM148	10.3	12.6	55.1	50.8	91.5	38.9	**
BM166	9.2	13.8	60.7	57.3	111.6	42.9	80.4
Participant identifier code	**Upper lip thickness**	**Lower lip thickness**	**Mouth width**	**Nasal length**	**Nasal tip angle ***	**Ear width**	**Ear length**
30-39							
BM177	7.3	12.3	56.7	49.4	104.7	41.3	72
BM173	9.5	15.4	50.8	61.4	98.9	51	82.5
BM057	11.5	14.5	57.6	49.6	97.1	34.6	66.4
BM074	8.9	12.6	49	58.2	102.1	44.6	72.8
BM067	13.7	12.5	67.7	58.7	109.6	37.2	77.7
BM034	8.8	12.8	56.2	38.6	102.3	31.5	61.7
BM042	9.5	10.6	55.2	41.4	102	37.8	71.1
BM055	8.4	13.2	63.1	37	104.4	34	62.4
BM058	11.3	13.8	65.7	63.9	95.8	39.2	76
BM059	8.3	12.4	63	46.3	94	34.7	66.7

BM060	11.5	16.3	60.8	57.1	99.2	40.3	71.2
BM070	6.6	12.4	51.8	45.6	109.4	45.8	71.5
BM071	10.9	14.9	67.4	44.8	93.9	43	81.8
BM075	8.8	10.8	55.8	55.3	103.7	39.7	80.5
BM088	7.1	10.9	52.2	47.7	98.3	39.1	72.6
BM092	8.7	13.4	56.1	58.6	98.1	41.7	73.4
BM103	9.4	13.8	52	44.4	94.6	39.8	68.5
BM104	9.8	16.7	51.1	40.6	93.9	30	55.6
BM105	12.5	13.1	60.6	47.5	107.5	40.5	70.9
BM125	11.2	10.7	57.1	51	94.3	40.7	65.9
BM126	10.4	11.5	46.7	43.1	97.2	43.1	56.8
BM127	9	10.2	55.3	51.6	98.2	40	61.5
BM143	5.7	7.3	55.9	38.8	93	36.2	65.1
BM146	7.1	11	56.4	52.4	111.2	41.8	66.9
BM153	7.1	11.4	51.9	46.7	95.2	40.6	63.3
BM157	11	14.2	61.2	44.8	98.5	33.8	60.7
BM160	7.8	13.4	64.8	47.1	97.9	35.8	62
BM161	12.3	16.8	55.2	51.2	89.4	39.8	63.8
BM170	10.6	13.6	51.7	53.3	116.6	40.6	70.1
BM185	8.5	9.9	55.6	60.2	102.9	45.7	79.5

Participant identifier code	Upper lip thickness	Lower lip thickness	Mouth width	Nasal length	Nasal tip angle *	Ear width	Ear length
40-49							
BM152	5.8	13.9	46.7	49.6	106.8	38.4	73.9
BM072	10	14.4	54.5	54.5	110.2	42.4	74.5
BM102	11.5	12.1	52.2	45.2	105.9	40.3	76.4
BM096	6.4	8.8	50.1	44.5	103.3	46.4	71.5
BM118	10.6	12.2	64.8	53.8	96.1	56.7	90.8
BM010	8.2	13.6	57.3	49.1	93.7	36.7	59.9
BM052	10.2	14.5	66.2	40.9	88.3	38.6	64.5
BM056	11	10.7	62.9	54.2	93.4	40.6	70.6
BM068	8.3	11.6	63	45.1	92	38.2	69.5
BM069	12.2	11.6	62.6	55.6	91	45.8	78.3
BM076	10.2	10.8	54.5	45.3	103.6	36.5	68.6
BM083	11.7	16	59.5	53.4	102.5	39	67.8
BM087	7.6	9.9	55	48	97.5	38.7	66.4
BM101	9.7	14.6	54	47.1	97.6	37	61
BM117	6.2	10.2	58.6	52.2	104.5	38.2	71
BM119	8.3	15.3	46.4	51.2	102.6	38.5	70.2
BM138	6.2	15.7	68.6	51.6	94	37.5	66.4
BM141	8.3	12.6	57.6	48.1	99.1	35.4	63
BM142	6.7	10.4	57.9	39.2	97.6	39.3	73.3
BM158	6.7	10.6	62.7	50.2	93.7	51.6	82
BM165	5.5	8.3	56	51	95.6	49	73.9
BM167	6.9	10.9	57.5	49	80.5	42.8	68.4
BM168	4.6	10.5	48.4	52.6	99.5	52.2	80.4

BM169	8.6	16.8	50	46.7	102.7	40.1	69.9
BM178	8.8	9.2	55.3	57.4	97.6	56.3	89.8
BM179	5.9	9.4	50.1	51.2	95.9	45.6	81.2
BM180	9.5	13.1	53.5	46.3	94.4	38.7	63
BM181	10.2	11.8	53.6	50.3	104.4	46.2	75.4
BM182	8.3	9.7	59	45.5	100.1	38.7	70.7
BM184	7.1	11.6	50.5	47	106.4	38.4	61.7
Participant identifier code	**Upper lip thickness**	**Lower lip thickness**	**Mouth width**	**Nasal length**	**Nasal tip angle ***	**Ear width**	**Ear length**
50-59							
BM191	8.6	11.8	55.2	50.7	93.4	44.8	72
BM200	6.2	8.7	57.9	57.9	95.3	49.9	83.1
BM197	8.6	12.5	63.2	53.2	99.7	46.2	74.9
BM116	12.7	18.8	55.8	57.8	109.9	51	88.9
BM131	6.7	7.1	46.8	46.6	96.4	35.1	63.6
BM009	10.5	11.9	54.8	48.9	94.7	38	67.4
BM054	11.6	12.7	59.2	59.2	97	46.9	87.5
BM089	14.3	18.1	65.8	53.5	106.8	**	**
BM114	6.9	11.2	59.3	55.7	93.2	35.5	73.9
BM120	4.6	14.2	56.3	46.5	97	38.7	65.1
BM121	9.5	13.6	64.8	48.6	97.8	41.8	76.7
BM123	7.3	11.2	45.3	38	101	34.8	60.2
BM124	9	15.9	59.6	51.6	111.3	40.4	69
BM132	10.8	12.7	54.3	52.2	104.8	45.3	70.4
BM133	11	13.6	66.5	47.4	105.1	46.4	71.8
BM151	7.9	10.2	69.2	46.7	93.3	36.4	65.9
BM155	10.4	13.9	61.2	51.7	103.9	50.8	78.2
BM159	8.2	12.4	60.7	55.5	101.3	40.9	74.4
BM163	7.7	12.6	56.8	40.3	95.1	33.9	66.3
BM164	6.2	11.5	54.7	50.3	89.8	49	74.8
BM175	7.9	10.2	58.9	43.9	94.9	40.7	69.8
BM186	9.9	9	58.1	49.3	95.3	44.9	71.8
BM189	6.6	8.1	59.8	49.2	87.5	44	70.8
BM193	9.7	12.7	67.8	58.5	95.4	45.7	85.3
BM194	11.6	14.5	59.7	49.5	101.1	50.3	87.6
BM196	6.7	13.1	60.5	52.9	101.2	48	77.4
BM198	10.4	11.1	67.8	52.4	107.9	40.9	78.5
BM199	11.8	21.2	67.6	49.1	104.6	46.2	81.8
BM229	9.8	10.4	58.4	48.7	93.7	45.1	76.7
BM230	4.8	9.4	60.5	41.5	104.2	33.3	62.2
Participant identifier code	**Upper lip thickness**	**Lower lip thickness**	**Mouth width**	**Nasal length**	**Nasal tip angle ***	**Ear width**	**Ear length**
60-69							
BM130	8.2	7.7	52.6	48.5	109.5	51.5	85.5
BM192	6.4	9.4	60.7	44.2	100.2	47.6	90
BM224	4.1	10.3	67.7	58.5	105.4	35.2	77.4

BM209	4.2	7.1	59.8	53.8	102.7	43.6	77.6
BM001	9.5	13.9	51.2	49.5	84.9	34.3	67
BM006	8.4	8.9	56.1	45.4	112.4	40	66.7
BM007	8.3	7.6	58.6	45.9	103.3	42.8	66.9
BM016	7.5	7.9	67.2	51.8	108.1	43	75.6
BM020	2.3	8	41.1	47.3	96.4	36.5	65.1
BM031	7.2	13.8	54.1	53.6	96.9	37.7	78.2
BM108	9.2	11.5	50	47.4	100.9	41.6	71.6
BM110	4.3	12.2	54.2	47.8	110.6	33.5	66.6
BM111	4.9	11.6	58.8	45.4	105.9	40.7	78.9
BM112	8.8	6.6	52.2	53	102.1	45.1	85.8
BM113	7.6	8.5	58.4	41.2	110.5	41	61.4
BM128	4.7	9.1	66.1	56.6	120.4	40.9	76.4
BM129	9.6	13.6	57	47.6	94.5	41.6	63.5
BM134	9.3	11.2	60.2	44.7	99.1	39.8	68.9
BM156	9.2	8.7	56.6	55	101.8	42	74.1
BM190	1.5	3.4	51.3	51.7	99.9	42.6	81.9
BM195	8.1	15	57.5	46	101.4	50.9	81.8
BM201	13.2	12.2	58.9	53.3	96.9	46.7	76.5
BM202	7.5	6.4	59.5	45.8	108.1	34.9	66.1
BM205	5.7	9.6	62	43	98	48.8	70.3
BM207	9.2	8.5	59.4	47.8	97.7	41.3	68.2
BM208	6.1	8.6	53.6	48	98.3	42.2	74.9
BM213	5	9.5	50.5	45.6	114.2	43.9	71
BM214	9.5	8.3	61.8	44	106.8	45	81
BM223	8.5	11.3	60.7	48.9	99.6	43.3	75.7
BM225	5.7	14.3	55.7	46.1	111.9	48.5	78.8

Participant identifier code	Upper lip thickness	Lower lip thickness	Mouth width	Nasal length	Nasal tip angle *	Ear width	Ear length
70-79							
BM204	1.1	2.1	41.8	34.5	95.1	36.4	61
BM012	7.7	11.5	61.8	40.3	97.1	**	**
BM109	3.2	13.6	56.8	38.4	106.2	41.6	68.9
BM017	7.9	12.7	58.1	38	104.6	37.2	67.5
BM203	3.6	7.8	58.2	38.1	111.4	42.7	67.6
BM002	8.1	6.7	56.1	51.5	96.3	46.1	78
BM003	7.6	9	54.5	38.1	105.5	38.4	71.8
BM004	10.9	8.3	53.6	54.3	99.7	46	82.5
BM005	7.6	10.9	64.1	48.6	90.9	43.5	76
BM008	14.2	11.4	61.7	53.7	108.3	44.2	77
BM013	3.9	8.6	49.6	44.7	101.4	39.5	65.2
BM014	7.4	5.6	58.4	48	99.9	40.6	61.6
BM018	8.3	12.9	55.4	48.7	109.8	46.3	70.9
BM021	2.7	12	46.3	48.9	98.4	32.8	76
BM022	1.8	4.3	59.9	45.5	92.2	31.5	60.7
BM024	3.4	8.1	55	51.5	102.5	43.3	76.3

BM026	5.1	11.7	49.1	39.1	100.7	**	**
BM027	13.4	16.6	68.5	58.7	116.5	52.2	**
BM028	7.1	10.1	60.1	60.7	100.8	46.6	91.8
BM030	2.9	4.7	58.3	54.5	94.8	39.1	69.4
BM115	14.1	16.8	63.6	49.6	97.3	39	75
BM206	8.5	11.3	54	53.4	104.4	40.1	70.2
BM211	7.5	5.5	56.3	49.5	94.2	38.2	66.3
BM212	8.5	10.2	60.3	53.4	102.5	49.9	77.6
BM215	7.9	7.7	54.4	43.8	105.6	33.9	61.1
BM216	6.7	8.9	53.7	51.7	98.8	38.6	65.1
BM217	8.6	11.8	60.9	47.6	99	38.6	63.5
BM218	3.4	6.6	55.4	42.3	104.5	29.8	65.8
BM221	2.7	8	58.6	43.1	104.8	**	69
BM228	14.5	13.4	70.6	60.4	98.8	44.7	80.7
Participant identifier code	**Upper lip thickness**	**Lower lip thickness**	**Mouth width**	**Nasal length**	**Nasal tip angle ***	**Ear width**	**Ear length**
80+							
BM029	2.4	5.4	40.1	52.5	91.8	49.3	77.8
BM025	4.9	5.7	45.4	51.3	113.1	48.3	74
BM210	4.1	8.5	51.4	43.9	101.6	44.6	74.4
BM023	7.5	9.2	66.2	51.2	105.3	37.8	75.9
BM137	7	10.3	63.1	49.6	103	47.2	78.7
BM032	6.2	10.5	49.4	44.8	97.9	34.8	66.9
BM135	10.2	8.5	57.1	51	107.8	41.6	83.9
BM136	7.4	8	64.3	53.7	103.9	49.8	82.3
BM219	6.9	9.2	55.1	41.1	105.9	41.9	74.5

* Measurement in degrees (°). All other measurements are in mm

** Feature obscured (e.g. hearing aid, hairstyle)

Shaded rows indicate individuals, in order of random selection, for each age cohort's intra- and inter-observer agreement assessments

Appendix G

Raw data – intra- and inter-observer agreement for measured features

Nasal length				***Nasal tip angle ****		
Participant identifier code	**Measure A**	**Measure B**	**Measure C**	**Measure A**	**Measure B**	**Measure C**
20-29						
BM171	50.1	48.2	41.3	109.8	112.9	111.6
BM050	55.7	53.6	43.6	107.2	108.4	107.5
BM073	56.5	54.7	44.1	92.4	92	92.2
BM061	50	52.1	38.0	104.6	105.4	106.4
BM139	47.6	48.4	45.5	112.7	112.7	116.5
30-39						
BM177	49.4	51.3	43.7	104.7	102.6	106.4
BM173	61.4	60.1	50.4	98.9	102	100.9
BM057	49.6	49.6	44.8	97.1	95.7	99.0
BM074	58.2	60	49.6	102.1	103	102.7
BM067	58.7	58.4	49.9	109.6	112	117.2
40-49						
BM152	49.6	51.9	40.3	106.8	108.3	107.1
BM072	54.5	52.3	51.5	110.2	109	110.3
BM102	45.2	44.2	35.1	105.9	109.3	111.8
BM096	44.5	44.2	39.1	103.3	102.8	102.1
BM118	53.8	54.3	46.0	96.1	96.1	94.8
50-59						
BM191	50.7	51.9	43.8	93.4	91.5	96.9
BM200	57.9	60.8	44.0	95.3	96.6	99.0
BM197	53.2	56	44.1	99.7	99.4	101.6
BM116	57.8	62	43.6	109.9	104.8	104.5
BM131	46.6	48.2	44.7	96.4	91	95.6
60-69						
BM130	48.5	50.7	39.2	109.5	107.5	102.7
BM192	44.2	43.1	35.6	100.2	102	103.0
BM224	58.5	56.2	42.6	105.4	106.9	105.1
BM209	53.8	57.4	46.8	102.7	100	103.1
BM001	49.5	51.6	39.5	84.9	100.3	107.9
70-79						
BM204	34.5	34.7	31.3	95.1	90.2	89.2
BM012	40.3	41.3	33.4	97.1	100.3	95.9
BM109	38.4	37.3	28.0	106.2	110.5	102.5
BM017	38	38.7	34.0	104.6	102.3	103.4
BM203	38.1	38	33.7	111.4	113.5	111.4
80+						
BM029	52.5	52.4	46.7	91.8	93	95.4
BM025	51.3	55.1	40.5	113.1	113	112.4
BM210	43.9	43.6	38.2	101.6	103.3	99.7
BM023	51.2	54.8	43.2	105.3	112.1	109.3
BM137	49.6	50.5	44.0	103	105.9	103.4

	Ear width			***Ear length***		
Participant identifier code	**Measure A**	**Measure B**	**Measure C**	**Measure A**	**Measure B**	**Measure C**
20-29						
BM171	47.3	49.1	39.6	76.6	78.4	67.9
BM050	43.7	43.9	40.6	74.7	75.7	68.2
BM073	41.5	43.2	38.7	84.5	84.9	73.8
BM061	51.9	48.5	39.7	79.8	79.8	65.6
BM139	41.7	40.8	40.1	64.8	64.9	60.3
30-39						
BM177	41.3	39	39.3	72	70.1	65.1
BM173	51	50	43.5	82.5	83.6	73.8
BM057	34.6	32	31.9	66.4	64.7	63.0
BM074	44.6	45.1	41.2	72.8	72.1	71.1
BM067	37.2	37.9	41.6	77.7	77.4	74.9
40-49						
BM152	38.4	38.8	40.5	73.9	73	66.5
BM072	42.4	38.7	37.1	74.5	74.7	63.2
BM102	40.3	39.3	35.7	76.4	77.4	69.4
BM096	46.4	42.9	40.3	71.5	70.8	64.6
BM118	56.7	55.7	44.7	90.8	90.9	78.8
50-59						
BM191	44.8	37.2	40.9	72	69.3	70.0
BM200	49.9	46.7	39.3	83.1	82.8	66.4
BM197	46.2	41.3	39.4	74.9	70.2	65.2
BM116	51	47.2	37.6	88.9	88.4	66.5
BM131	35.1	31.6	32.7	63.6	63.7	59.8
60-69						
BM130	51.5	51.2	42.0	85.5	83	73.3
BM192	47.6	44.8	38.6	90	90.8	78.7
BM224	35.2	35.2	41.1	77.4	77.2	75.5
BM209	43.6	40.6	42.4	77.6	76.7	71.2
BM001	34.3	31	35.2	67	64	61.9
70-79						
BM204	36.4	37.8	34.4	61	61.6	57.6
BM012	**	**	33.9	**	**	59.6
BM109	41.6	40.6	37.6	68.9	69.3	64.2
BM017	37.2	40.8	34.8	67.5	67.2	63.2
BM203	42.7	40.8	35.6	67.6	68.2	59.8
80+						
BM029	49.3	48.3	44.0	77.8	77.3	74.1
BM025	48.3	46.8	39.5	74	74.4	60.1
BM210	44.6	45.3	42.5	74.4	75	68.1
BM023	37.8	42.4	40.9	75.9	73.7	72.4
BM137	47.2	45.4	38.9	78.7	78.8	72.2

	Upper lip thickness			***Lower lip thickness***		
Participant identifier code	**Measure A**	**Measure B**	**Measure C**	**Measure A**	**Measure B**	**Measure C**
20-29						
BM171	11.9	12.2	13.8	13.7	14.3	13.9
BM050	10.4	9.9	14.1	14.7	14	14.1
BM073	14.3	13.1	15.1	16.1	16.1	14.0
BM061	12.8	12.2	13.1	15.9	15.2	14.3
BM139	13.2	12.4	14.1	18.1	18.3	17.4
30-39						
BM177	7.3	6.7	11.1	12.3	12.4	12.2
BM173	9.5	8.5	10.9	15.4	15.3	13.9
BM057	11.5	12	14.1	14.5	14.3	14.3
BM074	8.9	9	10.8	12.6	12	11.4
BM067	13.7	12.9	14.9	12.5	12.5	13.1
40-49						
BM152	5.8	5.6	9.1	13.9	13	14.0
BM072	10	9.7	11.9	14.4	15.1	14.6
BM102	11.5	12.7	12.5	12.1	11.5	12.1
BM096	6.4	6.9	8.2	8.8	8.6	8.5
BM118	10.6	9.7	10.9	12.2	12.1	12.9
50-59						
BM191	8.6	8.7	10.5	11.8	11.6	11.6
BM200	6.2	6.4	8.7	8.7	8.1	8.1
BM197	8.6	8.8	11.6	12.5	11.7	10.9
BM116	12.7	10.3	12.7	18.8	17.4	17.6
BM131	6.7	7.8	9.9	7.1	6.5	6.0
60-69						
BM130	8.2	8.1	11.1	7.7	7.6	7.1
BM192	6.4	6.7	8.0	9.4	9.5	9.1
BM224	4.1	4.6	7.5	10.3	11.5	9.8
BM209	4.2	4.6	4.9	7.1	7.1	7.8
BM001	9.5	9.4	11.1	13.9	14.8	14.2
70-79						
BM204	1.1	1.4	**	2.1	2	**
BM012	7.7	7.8	10.3	11.5	11	10.5
BM109	3.2	3.5	5.7	13.6	14	11.6
BM017	7.9	8.1	8.9	12.7	12.7	11.8
BM203	3.6	3.3	5.5	7.8	7.8	6.3
80+						
BM029	2.4	2.1	3.2	5.4	5.3	5.3
BM025	4.9	5.2	6.9	5.7	6.2	6.5
BM210	4.1	4.1	3.6	8.5	7.4	6.3
BM023	7.5	7.5	6.9	9.2	8.8	8.2
BM137	7	7.6	8.2	10.3	10.3	9.6

Mouth width

Participant identifier code	Measure A	Measure B	Measure C
20-29			
BM171	55.5	56.8	52.8
BM050	53.1	53.3	56.3
BM073	54.7	54.2	51.9
BM061	63	64.3	57.6
BM139	57.9	58.4	56.5
30-39			
BM177	56.7	55.8	54.8
BM173	50.8	50.4	50.6
BM057	57.6	57.6	57.8
BM074	49	51.1	51.8
BM067	67.7	68.4	65.7
40-49			
BM152	46.7	48	53.5
BM072	54.5	53.9	54.3
BM102	52.2	51	49.0
BM096	50.1	49.9	53.9
BM118	64.8	62.8	71.0
50-59			
BM191	55.2	57.2	57.7
BM200	57.9	57.9	60.1
BM197	63.2	62.1	57.9
BM116	55.8	58.1	53.5
BM131	46.8	45.9	43.7
60-69			
BM130	52.6	51.4	52.2
BM192	60.7	61.4	64.0
BM224	67.7	68.3	64.6
BM209	59.8	56.4	64.5
BM001	51.2	49.9	53.9
70-79			
BM204	41.8	43.4	62.1
BM012	61.8	56.7	58.1
BM109	56.8	54.9	57.1
BM017	58.1	57.5	52.8
BM203	58.2	56.7	54.9
80+			
BM029	40.1	42	40.8
BM025	45.4	45	44.1
BM210	51.4	53.1	49.7
BM023	66.2	63.5	59.8
BM137	63.1	60	57.4

*Measurement in degrees (°). All other measurements are in mm
** Feature obscured
Measure A: Original measurement

Measure B: Repeat measure by researcher (intra-observer)
Measure C: Repeat measure by Dr TMR Houlton (inter-observer)

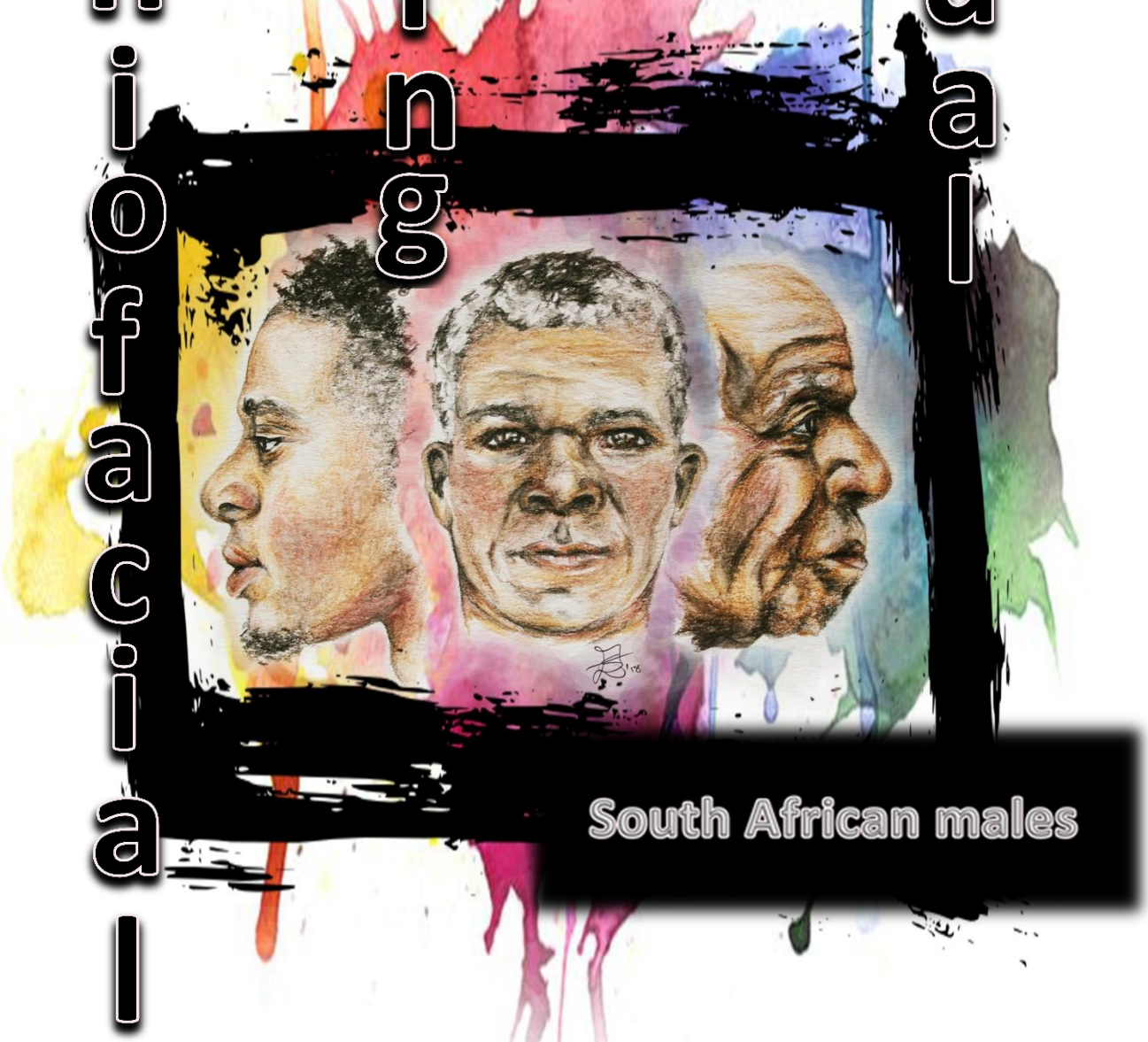
Appendix H

Craniofacial Ageing Lab Manual (CALM)

- South African males -

CALM

Craniofacial ageing manual



Estha J Schmidlin, Maryna Steyn,
Tobias MR Houlton, Nanette Briers

Craniofacial Ageing Lab Manual (CALM)

- South African males -

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Preface

The purpose of the Craniofacial Ageing Lab Manual (CALM) based on South African black male data is to provide a practical reference guide to facial ageing changes evident within each decade of life. This reference guide is based on a concise summary of the results obtained in the MSc thesis titled 'A descriptive morphological study on adult facial ageing in black South African males'. A peer reviewed paper on the contents of this thesis has also been published in Forensic Science International (Schmidlin *et al.*, 2018). This paper can be accessed at [http://www.sciencedirect.com/science/article/pii/S0379073818302299].

The data analysis presented within CALM is based on a sample of black South African males who were assessed for facial ageing changes per age decade. The sample included 30 individuals per decade from twenty years of age and upwards, with the 80 years and older age category consisting of only nine individuals (N=189). The Human Research Ethical Committee (Medical) of the University of the Witwatersrand approved this study under clearance certificate #: M161023.

Following a brief presentation of the process of facial ageing, the results obtained for each age decade is presented. The facial average image, both anterior and lateral views, for each age range is provided along with a short description of features showing visible age changes. These images provide a visual guideline of the average South African face at each age and could be used with individualized features to provide a likely facial representation.

The facial averages include a table containing morphological facial ageing changes described in literature (Albert *et al.*, 2007; Vashi *et al*., 2016). The percentages of the South African sample displaying progressive stages of the described facial ageing features are presented. Features that did not correlate well with age in the South African sample is indicated, as described in Schmidlin *et al.* (2018). These tables provide an indication of how common each stage of the described age related features were in each age category. This could help inform decisions on the likely stage of age progression to include in facial reproductions.

A table displaying the South African specific average measurements and 95% confidence interval (CI) for metric features reported in literature (Sforza et al., 2010b, 2010a, 2009a) are also included under each chapter. Features that do statistically correlate with age according to the results obtained on a South African sample are indicated (Schmidlin *et al.*, 2018). These tables provide an age-specific point estimate and value range for various facial measurements that could be used in facial depictions of South African black men.

In order to further elucidate facial ageing differences described in the literature (Albert et al., 2007; Sforza et al., 2010b, 2010a, 2009a; Vashi et al., 2016) and the results of this study, a list of general differences will form the last section of this lab manual. Caution should be used in generalizing the observed differences to the greater South African population. Despite the necessity of further research on expanded samples, these unique facial ageing traits inform part of the ageing considerations that should ideally be applied in South African specific facial depictions.

It is envisioned that CALM would be of use in a practical context when portraying South African faces. CALM provides a brief guide to facial changes observed during the adult ageing process, which may subsequently be applied to provide population specific age-appropriate markers on facial representations.

Introduction to Facial Ageing

As faces age, morphological changes can be observed. These occur both due to the intrinsic/ innate senescent process every person undergoes, as well as extrinsic/ environmental influences (Albert *et al.*, 2007; Mydlova *et al.*, 2015; Rexbye *et al.*, 2006; Vashi *et al.*, 2016).

Innate ageing changes occur due to oxidative stress as well as telomere chromosome shortening, resulting in cells being damaged over time (Baumann, 2007; Vashi *et al.*, 2016). The cellular damage affects the underlying bone structure, in turn affecting the overlaying soft tissue (Albert *et al.*, 2007).

With increasing age, the senescent process is regulated progressively less by genetics and more by environmental factors, which is unique for every individual (Albert *et al.,* 2007). Environmental factors that likely play a role in facial ageing include sun exposure, general health, tobacco and alcohol use, social and economic status and general stress (Albert *et al.,* 2007; Baumann, 2007; Rexbye *et al*., 2006; Vashi *et al*., 2016; Vierkotter and Krutmann, 2012).

More superficial features that are affected by age-related cellular changes include skin elasticity, muscle tone, and adipose tissue (Albert *et al.*, 2007; Mydlova *et al.*, 2015; Vashi *et al.*, 2016). Skin elasticity decreases due to age-related loss of collagen (Baumann, 2007). Muscle tone as well as muscle cross-sectional area decreases as a person ages, in part due to changes occurring in the properties of myosin (D'Antona *et al.*, 2003; Frontera *et al*., 2000). Subcutaneous adipose concentrations reduce and are redistributed due to advancing age (Mydlova *et al*., 2015; Vashi *et al.*, 2016). Innate changes may also be ascribed to hyperdynamic facial expressions and gravity (Albert *et al.*, 2007).

The sources mentioned above vary on the relative contribution of each environmental factor, though most agree that photoaging due to sun radiation exposure as well as tobacco use play major roles in the appearance of ageing faces (Rexbye *et al.*, 2006; Vashi *et al.*, 2016; Vierkotter and Krutmann, 2012). These innate and environmental influences combine to cause wrinkle formation, drooping of features such as upper eye folds, and progressive skin texture coarseness and colour heterogenies (Albert *et al.*, 2007; Rexbye *et al.*, 2006; Vashi *et al*., 2016).

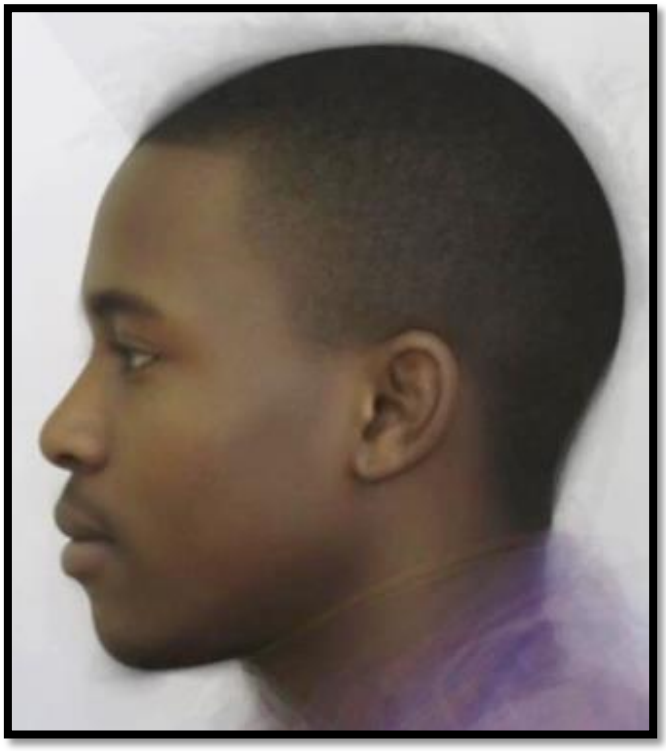
The rate of these changes is highly variable across sexes (Mydlova *et al*., 2015), ancestry groups (Vashi *et al.*, 2016; Vierkotter and Krutmann, 2012) and individuals (Albert *et al.*, 2007). Despite the variability in age-related facial changes, some generalizations can be made as to age of first appearance and relative progression of facial ageing.

20 – 29 year olds

Average facial features



The 20 - 29 year old anterior facial image serves as a baseline, with ageing changes noted as they become evident in subsequent age decades.



The 20 - 29 year old lateral facial image serves as a baseline, with ageing changes noted as they become evident in subsequent age decades.

20 – 29 year olds

Scored facial ageing features with percentages of sample per score

Facial feature *	Score	Description	% of sample obtaining score
Forehead wrinkles	1	No horizontal frontal lines evident	70.0
	2	Faint horizontal lines appear	23.3
	3	Clear horizontal line formation (1-3)	6.7
Orbital wrinkles	1	No lines evident	63.3
	2	Lateral orbital lines appear	33.3
	3	Lateral orbital lines deepen	3.4
Upper eyelid drooping	1	No drooping evident	40.0
	2	Slight upper eyelid fold sagging	50.0
	3	Obscures 1/3 of upper eyelid crease	10.0
Suborbital pouch formation	1	No skin sagging	50.0
	2	Slight pouch formation	46.7
	3	Definite pouch formation	3.3
Nasal wrinkles	1	No lines evident	43.3
	2	Faint nasolabial lines form	53.3
	3	Nasolabial lines deepen	3.4
Oral wrinkles	1	No lines evident	56.7
	2	Labiomental groove forms	43.3
Auricular wrinkles	1	No lines evident	76.7
	2	Faint periauricular line formation	23.3
Cheek wrinkles	1	No lines evident	23.3
	2	Inferior orbital grooves form	63.3
	3	Buccomandibular grooves appear	13.4
Cheek hollowing	1	No hollowing evident	63.3
	2	Slight indentation	33.3
	3	Indentation enlarges	3.4
Overall skin colouring	1	Homogeneous colour	43.3
	2	≤ 25% of skin shows heterogeneous pigmentation	50.0
	3	26 -50% heterogeneous pigmentation area	6.7
Overall skin texture	1	Smooth skin with fine pores	56.7
	2	≤ 25% of skin has roughened texture	36.7
	3	26– 50% roughened skin area	6.6

* All features present with changes that statistically correlate at p< 0.05 level with increasing age (Schmidlin *et al.*, 2018)

20 – 29 year olds

Measured facial ageing features with point estimates for sample

Facial feature	Average measure (mm)	95% CI (mm)
Upper lip thickness *	11.6	10.8 – 12.3
Lower lip thickness *	14.5	13.7 – 15.2
Mouth width	58.4	56.7 – 60.0
Nasal length	50.2	48.4 – 52.0
Nasal tip angle	101.8 **	99.5 – 104.1 **
Ear width	41.0	39.5 – 42.6
Ear length	71.4	68.9 – 74.0

* Features presenting with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018). Both measures decrease with increasing age

** Measured in degrees (°)

30 – 39 year olds

Average facial features



Some differences are apparent between the 20 - 29 and 30 - 39 year olds. The infraorbital groove and nasolabial lines become more prominent, with slight receding of the hairline. This receding hairline is visible as an increased irregularity on the anterior image.



Some differences are apparent between the 20 - 29 and 30 - 39 year olds. The receding hairline is evident in the lateral image, with temporal balding becoming visible. The hairline around the temples is now more rounded and indented compared to the defined margins for 20 - 29 year olds.

30 – 39 year olds

Scored facial ageing features with percentages of sample per score

Facial feature *	Score	Description	% of sample obtaining score
Forehead wrinkles	1	No horizontal frontal lines evident	20.0
	2	Faint horizontal lines appear	43.3
	3	Clear horizontal line formation (1-3)	30.0
	4	Horizontal lines increase & deepen (4-6)	6.7
Orbital wrinkles	1	No lines evident	20.0
	2	Lateral orbital lines appear	50.0
	3	Lateral orbital lines deepen	30.0
Upper eyelid drooping	1	No drooping evident	13.3
	2	Slight upper eyelid fold sagging	50.0
	3	Obscures 1/3 of upper eyelid crease	26.7
	4	Obscures 2/3 of upper eyelid crease	10.0
Suborbital pouch formation	1	No skin sagging	10.0
	2	Slight pouch formation	76.7
	3	Definite pouch formation	13.3
Nasal wrinkles	1	No lines evident	9.9
	2	Faint nasolabial lines form	46.7
	3	Nasolabial lines deepen	26.7
	4	Transverse nasal lines develop	16.7
Oral wrinkles	1	No lines evident	10.4
	2	Labiomental groove forms	58.6
	3	Oromental lines form	31.0
Auricular wrinkles	1	No lines evident	30.0
	2	Faint periauricular line formation	56.7
	3	1-2 clear periauricular lines	13.3
Cheek wrinkles	1	No lines evident	6.6
	2	Inferior orbital grooves form	30.0
	3	Buccomandibular grooves appear	56.7
	4	Cheek folds appear	6.7
Cheek hollowing	1	No hollowing evident	40.0
	2	Slight indentation	36.7
	3	Indentation enlarges	16.7
	4	Indentation deepens	6.6

Facial feature *	Score	Description	% of sample obtaining score
Overall skin colouring	1	Homogeneous colour	6.7
	2	≤ 25% of skin shows heterogeneous pigmentation	53.3
	3	26 -50% heterogeneous pigmentation area	36.7
	5	> 75% of skin shows heterogeneous pigmentation	3.3
Overall skin texture	1	Smooth skin with fine pores	20.0
	2	≤ 25% of skin has roughened texture	46.7
	3	26– 50% roughened skin area	30.0
	4	51-75% roughened skin area	3.3

* All features present with changes that statistically correlate at p< 0.05 level with increasing age (Schmidlin *et al.*, 2018)

30 – 39 year olds

Measured facial ageing features with point estimates for sample

Facial feature	Average measure (mm)	95% CI (mm)
Upper lip thickness *	9.4	8.7 – 10.2
Lower lip thickness *	12.7	12.0 – 13.6
Mouth width	56.8	54.8 – 58.9
Nasal length	49.5	46.8 – 52.3
Nasal tip angle	100.1 **	97.8 – 102.5 **
Ear width	39.5	37.8 – 41.1
Ear length	69.0	66.4 – 71.7

* Features presenting with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018). Both measures decrease with increasing age

** Measured in degrees (°)

40 – 49 year olds

Average facial features



Eyelid drooping and pouch formation are becoming visible. The infraorbital groove and nasolabial line becomes more clearly defined. The increasingly blurred hairline indicates elevated levels of hairline receding.



Slight cheek hollowing becomes evident. The infraorbital groove and nasolabial line are now also visible on the lateral image.

40 – 49 year olds

Scored facial ageing features with percentages of sample per score

Facial feature *	Score	Description	% of sample obtaining score
Forehead wrinkles	1	No horizontal frontal lines evident	3.3
	2	Faint horizontal lines appear	33.3
	3	Clear horizontal line formation (1-3)	56.7
	4	Horizontal lines increase & deepen (4-6)	6.7
Orbital wrinkles	1	No lines evident	3.3
	2	Lateral orbital lines appear	36.7
	3	Lateral orbital lines deepen	36.7
	4	Vertical glabellar lines appear	23.3
Upper eyelid drooping	2	Slight upper eyelid fold sagging	50.0
	3	Obscures 1/3 of upper eyelid crease	36.7
	4	Obscures 2/3 of upper eyelid crease	13.3
Suborbital pouch formation	2	Slight pouch formation	40.0
	3	Definite pouch formation	50.0
	4	Pouch formation with fine wrinkles	20.0
Nasal wrinkles	1	No lines evident	3.4
	2	Faint nasolabial lines form	16.7
	3	Nasolabial lines deepen	36.7
	4	Transverse nasal lines develop	43.3
Oral wrinkles	1	No lines evident	6.6
	2	Labiomental groove forms	26.7
	3	Oromental lines form	66.7
Auricular wrinkles	1	No lines evident	13.3
	2	Faint periauricular line formation	46.7
	3	1-2 clear periauricular lines	33.3
	4	3-4 deep periauricular lines	6.7
Cheek wrinkles	2	Inferior orbital grooves form	10.0
	3	Buccomandibular grooves appear	46.7
	4	Cheek folds appear	33.3
	5	Lines deepen & increase	10.0
Cheek hollowing	1	No hollowing evident	16.6
	2	Slight indentation	30.0
	3	Indentation enlarges	30.0
	4	Indentation deepens	16.7
	5	Sunken appearance	6.7

Facial feature *	Score	Description	% of sample obtaining score
Overall skin colouring	2	≤ 25% of skin shows heterogeneous pigmentation	33.3
	3	26 -50% heterogeneous pigmentation area	36.7
	4	51-75% heterogeneous pigmentation area	26.7
	5	> 75% of skin shows heterogeneous pigmentation	3.3
Overall skin texture	1	Smooth skin with fine pores	6.6
	2	≤ 25% of skin has roughened texture	46.7
	3	26– 50% roughened skin area	36.7
	4	51-75% roughened skin area	10.0

* All features present with changes that statistically correlate at p< 0.05 level with increasing age (Schmidlin *et al.*, 2018)

40 – 49 year olds

Measured facial ageing features with point estimates for sample

Facial feature	Average measure (mm)	95% CI (mm)
Upper lip thickness *	8.4	7.6 – 9.1
Lower lip thickness *	12.0	11.2 – 12.9
Mouth width	56.3	54.1 – 58.5
Nasal length	49.2	47.6 – 50.8
Nasal tip angle	98.4 **	96.0 – 100.7 **
Ear width	42.1	39.9 – 44.3
Ear length	71.8	68.9 – 74.7

* Features presenting with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018). Both measures decrease with increasing age

** Measured in degrees (°)

50 – 59 year olds

Average facial features



The lateral forehead and eye creases become prominent. Oromental and labiomental grooves make an appearance.



Lateral forehead and eye creases appear. Lip thinning first becomes evident. Oromental and labiomental grooves are faintly visible.

50 – 59 year olds

Scored facial ageing features with percentages of sample per score

Facial feature *	Score	Description	% of sample obtaining score
Forehead wrinkles	1	No horizontal frontal lines evident	10.0
	2	Faint horizontal lines appear	10.0
	3	Clear horizontal line formation (1-3)	33.3
	4	Horizontal lines increase & deepen (4-6)	43.3
	5	Vertical superciliary arch lines form	3.4
Orbital wrinkles	2	Lateral orbital lines appear	10.0
	3	Lateral orbital lines deepen	46.7
	4	Vertical glabellar lines appear	36.7
	5	Wrinkles increase in depth and number	6.6
Upper eyelid drooping	2	Slight upper eyelid fold sagging	26.7
	3	Obscures 1/3 of upper eyelid crease	33.3
	4	Obscures 2/3 of upper eyelid crease	33.3
	5	Obscures entire upper eyelid crease	6.7
Suborbital pouch formation	2	Slight pouch formation	23.3
	3	Definite pouch formation	36.7
	4	Pouch formation with fine wrinkles	36.7
	5	Pouch formation with defined wrinkles	3.3
Nasal wrinkles	2	Faint nasolabial lines form	13.3
	3	Nasolabial lines deepen	33.3
	4	Transverse nasal lines develop	50.0
	5	Transverse nasal lines deepen	3.4
Oral wrinkles	1	No lines evident	7.2
	2	Labiomental groove forms	10.7
	3	Oromental lines form	57.1
	4	Circumoral striae form	14.3
	5	Chin has multi-dimpled appearance	10.7
Auricular wrinkles	1	No lines evident	6.6
	2	Faint periauricular line formation	20.0
	3	1-2 clear periauricular lines	40.0
	4	3-4 deep periauricular lines	30.0
	5	≥5 deep periauricular lines	3.4
Cheek wrinkles	2	Inferior orbital grooves form	10.3
	3	Buccomandibular grooves appear	27.6
	4	Cheek folds appear	34.5
	5	Lines deepen & increase	27.6

Facial feature *	Score	Description	% of sample obtaining score
Cheek hollowing	1	No hollowing evident	13.3
	2	Slight indentation	26.7
	3	Indentation enlarges	36.7
	4	Indentation deepens	20.0
	5	Sunken appearance	3.3
Overall skin colouring	2	≤ 25% of skin shows heterogeneous pigmentation	16.7
	3	26 -50% heterogeneous pigmentation area	50.0
	4	51-75% heterogeneous pigmentation area	26.7
	5	> 75% of skin shows heterogeneous pigmentation	6.6
Overall skin texture	2	≤ 25% of skin has roughened texture	13.3
	3	26– 50% roughened skin area	56.7
	4	51-75% roughened skin area	20.0
	5	> 75% of skin has roughened skin texture	10.0

* All features present with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018)

50 – 59 year olds

Measured facial ageing features with point estimates for sample

Facial feature	Average measure (mm)	95% CI (mm)
Upper lip thickness *	8.9	8.1 – 9.8
Lower lip thickness *	12.5	11.3 – 13.6
Mouth width	59.6	57.4 – 61.7
Nasal length	50.2	48.3 – 52.2
Nasal tip angle	99.1 **	96.9 – 101.3 **
Ear width	42.9	40.9 – 45.0
Ear length	74	71.0 – 77.0

* Features presenting with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018). Both measures decrease with increasing age

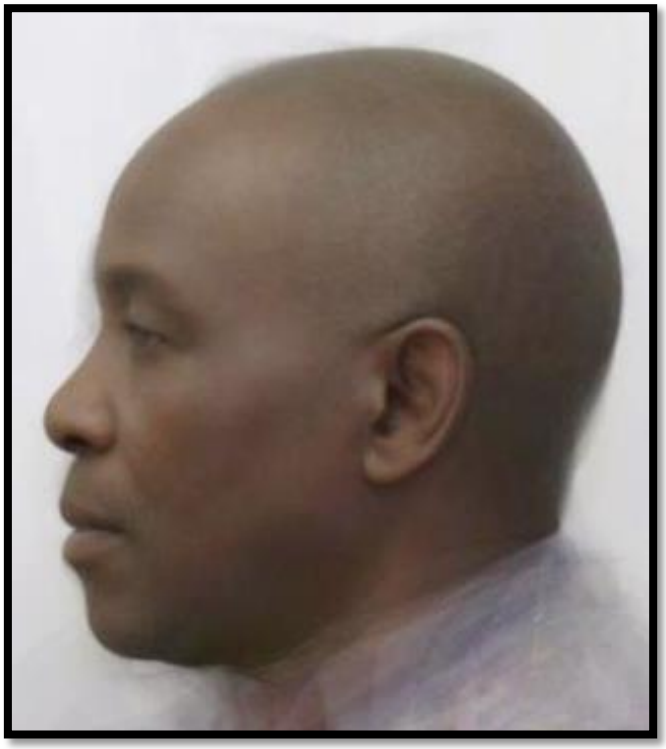
** Measured in degrees (°)

60 – 69 year olds

Average facial features



From the 60 - 69 year category onwards, the overall appearance of the face becomes more rounded (not elongated) in the anterior view. The hairline becomes difficult to distinguish due to the extent of its retreat, and the buccomandibular and cheek folds begin to appear.



The jawline becomes more variable and jowls form. Bone atrophy related to tooth loss likely contributes to the changes observed in the jawlineCheek folds become visible on the lateral aspect, and the cheeks become increasingly hollow.

60 – 69 year olds

Scored facial ageing features with percentages of sample per score

Facial feature *	Score	Description	% of sample obtaining score
Forehead wrinkles	1	No horizontal frontal lines evident	3.3
	2	Faint horizontal lines appear	16.7
	3	Clear horizontal line formation (1-3)	33.3
	4	Horizontal lines increase & deepen (4-6)	40.0
	5	Vertical superciliary arch lines form	6.7
Orbital wrinkles	2	Lateral orbital lines appear	10.0
	3	Lateral orbital lines deepen	33.3
	4	Vertical glabellar lines appear	56.7
Upper eyelid drooping	2	Slight upper eyelid fold sagging	10.0
	3	Obscures 1/3 of upper eyelid crease	36.7
	4	Obscures 2/3 of upper eyelid crease	43.3
	5	Obscures entire upper eyelid crease	10.0
Suborbital pouch formation	2	Slight pouch formation	3.3
	3	Definite pouch formation	50.0
	4	Pouch formation with fine wrinkles	36.7
	5	Pouch formation with defined wrinkles	10.0
Nasal wrinkles	3	Nasolabial lines deepen	20.0
	4	Transverse nasal lines develop	70.0
	5	Transverse nasal lines deepen	10.0
Oral wrinkles	2	Labiomental groove forms	14.8
	3	Oromental lines form	48.2
	4	Circumoral striae form	18.5
	5	Chin has multi-dimpled appearance	18.5
Auricular wrinkles	2	Faint periauricular line formation	17.3
	3	1-2 clear periauricular lines	24.1
	4	3-4 deep periauricular lines	34.5
	5	≥5 deep periauricular lines	24.1
Cheek wrinkles	3	Buccomandibular grooves appear	31.0
	4	Cheek folds appear	37.9
	5	Lines deepen & increase	31.1
Cheek hollowing	1	No hollowing evident	6.9
	2	Slight indentation	20.7
	3	Indentation enlarges	44.8
	4	Indentation deepens	24.1
	5	Sunken appearance	3.5

Facial feature *	Score	Description	% of sample obtaining score
Overall skin colouring	2	≤ 25% of skin shows heterogeneous pigmentation	3.3
	3	26 -50% heterogeneous pigmentation area	36.7
	4	51-75% heterogeneous pigmentation area	40.0
	5	> 75% of skin shows heterogeneous pigmentation	20.0
Overall skin texture	2	≤ 25% of skin has roughened texture	16.7
	3	26– 50% roughened skin area	33.3
	4	51-75% roughened skin area	36.7
	5	> 75% of skin has roughened skin texture	13.3

* All features present with changes that statistically correlate at p< 0.05 level with increasing age (Schmidlin *et al.*, 2018)

60 – 69 year olds

Measured facial ageing features with point estimates for sample

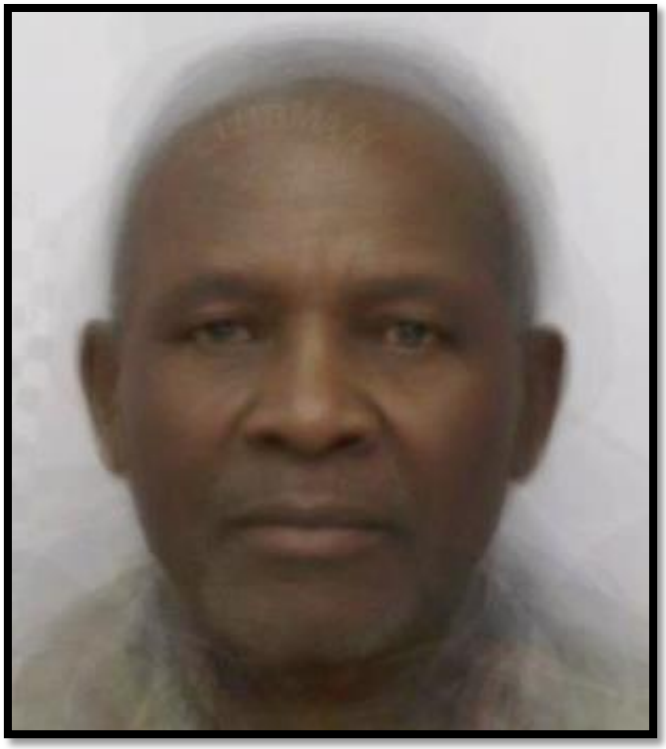
Facial feature	Average measure (mm)	95% CI (mm)
Upper lip thickness *	7.1	6.2 – 8.1
Lower lip thickness *	9.8	8.8 – 10.8
Mouth width	57.1	55.0 – 59.2
Nasal length	48.2	47.0 – 50.2
Nasal tip angle	103.3 **	100.6 – 106.0 **
Ear width	42.2	40.5 – 44.0
Ear length	74.1	71.4 – 76.8

* Features presenting with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018). Both measures decrease with increasing age

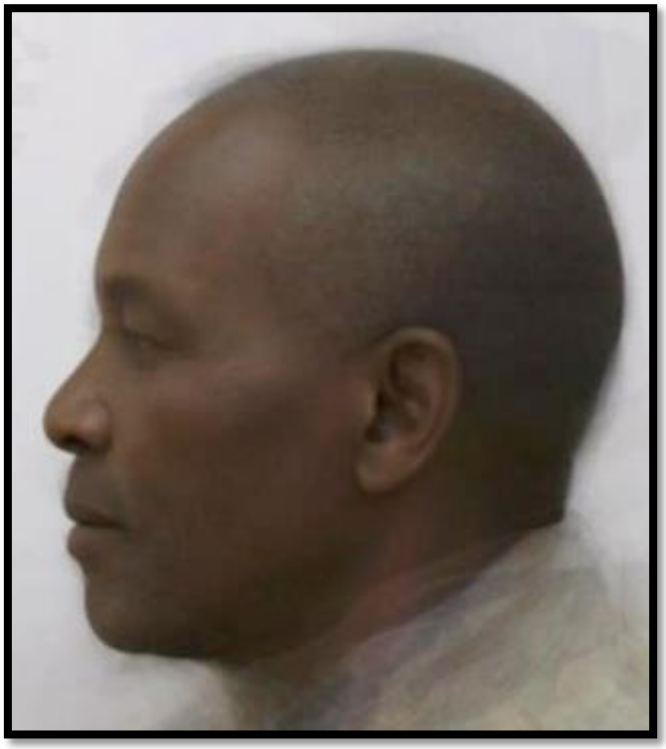
** Measured in degrees (°)

70 – 79 year olds

Average facial features



Upper eyelid drooping and suborbital pouch formation becomes prominent. A lateral nose crease can be observed. Visually there does not appear to be many distinctive differences between the average face of 60 - 69 and 70 - 79 year olds, except that all ageing changes that have already been observed are intensified.



Visually there does not appear to be many distinctive differences between the average face of 60 - 69 and 70 - 79 year olds, except that all ageing changes are intensified. Upper eyelid drooping can now be clearly observed in the lateral image as well.

70 – 79 year olds

Scored facial ageing features with percentages of sample per score

Facial feature *	Score	Description	% of sample obtaining score
Forehead wrinkles	2	Faint horizontal lines appear	17.2
	3	Clear horizontal line formation (1-3)	41.4
	4	Horizontal lines increase & deepen (4-6)	20.7
	5	Vertical superciliary arch lines form	20.7
Orbital wrinkles	2	Lateral orbital lines appear	3.3
	3	Lateral orbital lines deepen	6.7
	4	Vertical glabellar lines appear	66.7
	5	Wrinkles increase in depth and number	23.3
Upper eyelid drooping	2	Slight upper eyelid fold sagging	6.7
	3	Obscures 1/3 of upper eyelid crease	23.3
	4	Obscures 2/3 of upper eyelid crease	36.7
	5	Obscures entire upper eyelid crease	33.3
Suborbital pouch formation	2	Slight pouch formation	3.3
	3	Definite pouch formation	16.7
	4	Pouch formation with fine wrinkles	46.7
	5	Pouch formation with defined wrinkles	33.3
Nasal wrinkles	2	Faint nasolabial lines form	6.7
	3	Nasolabial lines deepen	3.3
	4	Transverse nasal lines develop	56.7
	5	Transverse nasal lines deepen	33.3
Oral wrinkles	3	Oromental lines form	39.3
	4	Circumoral striae form	28.6
	5	Chin has multi-dimpled appearance	32.1
Auricular wrinkles	3	1-2 clear periauricular lines	17.2
	4	3-4 deep periauricular lines	55.2
	5	≥5 deep periauricular lines	27.6
Cheek wrinkles	3	Buccomandibular grooves appear	6.7
	4	Cheek folds appear	50.0
	5	Lines deepen & increase	43.3
Cheek hollowing	2	Slight indentation	6.7
	3	Indentation enlarges	33.3
	4	Indentation deepens	36.7
	5	Sunken appearance	23.3

Facial feature *	Score	Description	% of sample obtaining score
Overall skin colouring	3	26 -50% heterogeneous pigmentation area	33.3
	4	51-75% heterogeneous pigmentation area	50.0
	5	> 75% of skin shows heterogeneous pigmentation	16.7
Overall skin texture	3	26– 50% roughened skin area	20.0
	4	51-75% roughened skin area	33.3
	5	> 75% of skin has roughened skin texture	46.7

* All features present with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018)

70 – 79 year olds

Measured facial ageing features with point estimates for sample

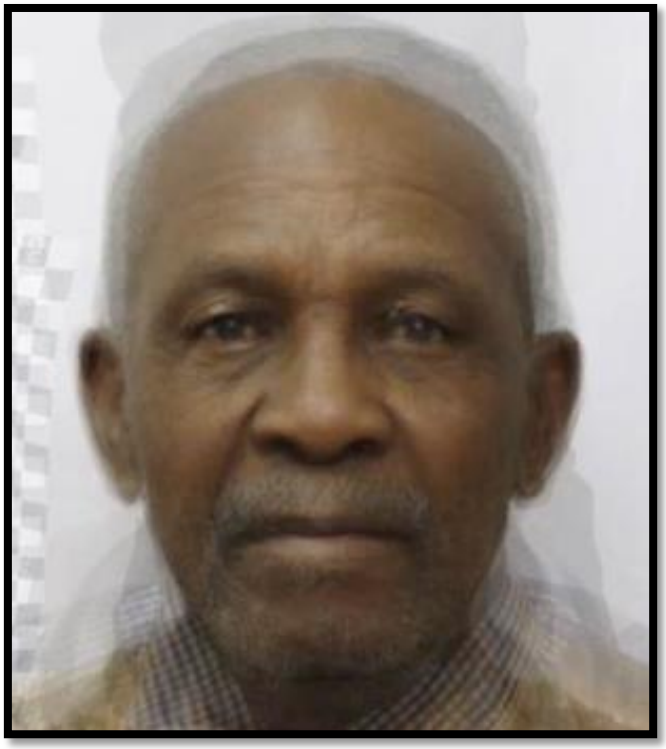
Facial feature	Average measure (mm)	95% CI (mm)
Upper lip thickness *	7.0	5.6 – 8.4
Lower lip thickness *	9.6	8.3 – 10.9
Mouth width	57.2	55.0 – 59.4
Nasal length	47.7	45.1 – 50.3
Nasal tip angle	101.4 **	99.2 – 103.6 **
Ear width	40.8	38.6 – 42.9
Ear length	71.0	68.0 – 74.0

* Features presenting with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018). Both measures decrease with increasing age

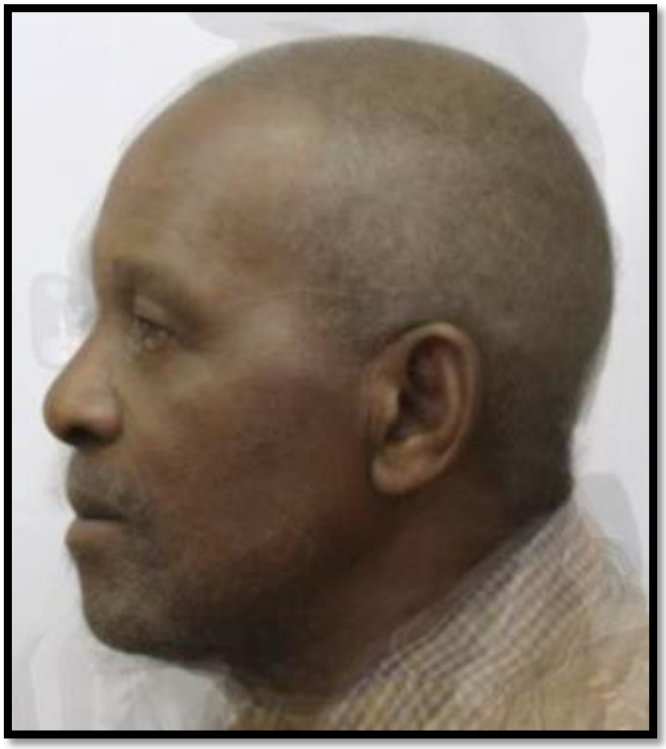
** Measured in degrees (°)

80 years and older

Average facial features



By 80 years of age, protrusion of the ears is visible. Cheek hollowing is pronounced, and the overall shape of the face seems almost completely round. This can likely be ascribed to advanced age-related atrophy of the jaw, in which senescent dentoalveolar loss plays a prominent role. All wrinkles are more pronounced.



From 80 years of age and onwards, auricular wrinkles are for the first time clearly evident in the lateral image. When compared to 20-29 year old average faces, the prognathic nature of the lower face seems to have receded into a near orthognathic lateral facial profile with increasing age.

80 years and older

Scored facial ageing features with percentages of sample per score

Facial feature *	Score	Description	% of sample obtaining score
Forehead wrinkles	2	Faint horizontal lines appear	22.3
	4	Horizontal lines increase & deepen (4-6)	44.4
	5	Vertical superciliary arch lines form	33.3
Orbital wrinkles	3	Lateral orbital lines deepen	22.2
	4	Vertical glabellar lines appear	22.2
	5	Wrinkles increase in depth and number	55.6
Upper eyelid drooping	3	Obscures 1/3 of upper eyelid crease	22.3
	4	Obscures 2/3 of upper eyelid crease	44.4
	5	Obscures entire upper eyelid crease	33.3
Suborbital pouch formation	3	Definite pouch formation	11.1
	4	Pouch formation with fine wrinkles	33.3
	5	Pouch formation with defined wrinkles	55.6
Nasal wrinkles	4	Transverse nasal lines develop	75.0
	5	Transverse nasal lines deepen	25.0
Oral wrinkles	3	Oromental lines form	37.5
	4	Circumoral striae form	25.0
	5	Chin has multi-dimpled appearance	37.5
Auricular wrinkles	3	1-2 clear periauricular lines	22.3
	4	3-4 deep periauricular lines	44.4
	5	≥5 deep periauricular lines	33.3
Cheek wrinkles	3	Buccomandibular grooves appear	11.1
	4	Cheek folds appear	66.7
	5	Lines deepen & increase	22.2
Cheek hollowing	2	Slight indentation	12.5
	3	Indentation enlarges	37.5
	4	Indentation deepens	12.5
	5	Sunken appearance	37.5
Overall skin colouring	4	51-75% heterogeneous pigmentation area	66.7
	5	> 75% of skin shows heterogeneous pigmentation	33.3
Overall skin texture	3	26– 50% roughened skin area	11.2
	4	51-75% roughened skin area	44.4
	5	> 75% of skin has roughened skin texture	44.4

* All features present with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018)

80 years and older

Measured facial ageing features with point estimates for sample

Facial feature	Average measure (mm)	95% CI (mm)
Upper lip thickness *	6.3	4.5 – 8.0
Lower lip thickness *	8.4	7.0 – 9.8
Mouth width	54.7	47.8 – 61.6
Nasal length	48.8	45.4 – 52.2
Nasal tip angle	103.4 **	98.7 – 108.0 **
Ear width	43.9	39.9 – 48.0
Ear length	76.5	72.6 – 80.4

* Features presenting with changes that statistically correlate at $p < 0.05$ level with increasing age (Schmidlin *et al.*, 2018). Both measures decrease with increasing age

** Measured in degrees (°)

List of facial ageing differences between South Africans and other groups

- No lateral nose crease is observable at any age in the South African male sample, in contrast to Hadi and Wilkinson (2014).

- Rather than a mental pit (Hadi and Wilkinson, 2014), the chin develops a multi-dimpled appearance with advanced ageing. As far as could be determined, such dimpling specifically isolated to the chin area has not been described before.

- An ageing plateau is observed approximately from 50 to 69 years of age, with little to no age progression during these two decades. No other literature could be found elaborating on similar age progression plateaus.

- South African men show initial wrinkle formation on average a decade later than described in literature (Albert *et al.*, 2007), with initial formation occurring around 30 years of age rather than in the 20's.

- Circumoral striae were much delayed. These wrinkles occurred around 70 years of age in the South African sample, in contrast to the 30 years of age reported in literature (Albert *et al.*, 2007).

- Cheek hollowing appeared around two decades earlier compared to the age of pronounced hollowing reported in literature (Albert *et al.*, 2007). Cheek hollowing was clearly evident from 40 years onwards, as opposed to developing in the 60's.

- South African men have broader lips across all age categories than is reported for their European counterparts (Albert *et al.*, 2007).

- No statistically significant age correlation for mouth width increase, nasal tip dropping, or increases in nose and ear lengths could be determined in a South African sample. This is in contrast to existing literature (Albert et al., 2007; Sforza et al., 2010a, 2010b, 2009a).

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CALM was inspired by a discussion with a forensic artist from the South African Police Service (SAPS). As this gentleman participated in the research on which CALM is based, he unfortunately will remain anonymous. He does, however, have our gratitude for his suggestions and can be credited with planting the seeds that grew into CALM.

Dr. Susan Hayes' successful lab manual, titled '3D Facial Approximation' (Hayes, 2017), served as a template for the layout of CALM.

None of the research in this lab manual would have been possible without the wonderful individuals who freely volunteered their time and facial images in order to contribute to facial ageing research. The authors would like to thank each and every participant.

Appendix I

Essay – An anthropological perspective on the journey of data collection

An anthropological perspective on the journey of data collection

What a remarkable journey this data collection has been! So many moments that I treasure and hold near my heart occurred along the way, that it is hard to find an appropriate place to start painting a simple snapshot of the depth and breadth of this experience. As they say in musical circles though, the beginning is a very good place to start (Wise, 1965), and that is exactly where I will take up this tale.

At the start of this research project, I knew that I wanted to include as many elderly individuals in my sample as possible to portray the wide range of facial ageing changes occurring at an advanced age. I also knew that with 'elderly', I intended participants to be as old as I could find. Of course this presented a dilemma that most researchers face at some stage in their careers: Where does one find a sufficient number of elderly people?

1. Mthimkhulu Housing for the Aged

The answer to that question seemed simple enough and I was off to find an old age home with primarily African citizens! Of course in a South African context this is slightly problematic, as the African tradition usually involves home care rather than communal nursing homes for the elderly (Ryke *et al.*, 2003). Undaunted though, I managed to come in contact with a wonderful woman named Patience. Patience is the social worker presiding over a small community named Mthimkhulu Housing for the Aged in eMalahleni, Mpumalanga. The reason I refer to Mthimkhulu as a community rather than an old age home will become apparent as the story further unfolds.

As a student researcher, I freely admit that my data collection experience has been relatively limited to controlled environments. However, travelling out to Mthimkhulu provided not only an out of office/lab experience, but also challenged me directly within my social comfort zone. As a white, middle class citizen in South Africa, I rarely get a chance to come into contact with elderly black men from various walks of life. This could be partly ascribed to the last vestiges of Apartheid era South Africa. Truth be told, how many of us purposefully seek out encounters with individuals we do not normally encounter over the course of our regular daily life? Simply travelling to Mthimkhulu already brought me out of my normal city comfort zone and into the township. What struck me immediately was the neatness and care taken in maintaining the area immediately around Mthimkhulu.

On our first day of data collection, we were provided a tour of the facilities. Patience then herded together all the gentlemen residents, and acted as interpreter in presenting the background information on the project. A near unanimous decision was made by all the gentlemen present to participate, and from there it was all systems go. Despite having Dr Houlton present to help ensure the smooth running of the process, the sheer number of willing participants was overwhelming. After yet another photography session coupled with a small lecture on the Frankfurt plane (Mosby, 2016), I turned to find Patience quietly and with remarkable efficiency managing the paperwork.

It was very important to us that all participants were cognisant of the full scope of wat we plan to do with their facial images. As such, considerable time had to be spent guiding participants through this, and keeping each participant's unique identifier code the same for all documents and images. Filling in the consent forms as well as lifestyle questionnaires proved to be unexpectedly time consuming, especially since many of the gentlemen were either sight-impaired or illiterate. Although some of the

men could not read, they were able to sign their own names. It soon became apparent that this was a feat they were extremely proud of! Each aspect had to be explained by the researcher, or in this case an angel named Patience.

Later Patience informed us that they provide reading and writing classes at Mthimkhulu. Personally, this struck a chord within me as I could experience with them how invaluable it was to these gentlemen to finally be able to write their own names. If I had considered it at all, I would have dismissed writing one's own name as a basic skill at best. Yet to these elderly gentlemen, it was a profound achievement! In that moment of awareness, I realized what a tremendous gift basic education for ALL, without any exceptions, is.

Towards the end of our first day of data collection, some younger individuals as well as children wandered into the hall to see what the entire ruckus was about. Upon further enquiries, it became clear that Mthimkhulu provided skills transfer classes (such as needlework) to younger individuals in the community for a minimal fee. In addition, after-care was also provided for school children, and their free clinic was accessible to the broader community once a week. Elderly individuals not residing could join in exercise and social programmes via the free bus service from various points in the surrounding area. Plans were well underway to start a tuck shop, run by residents, for the local community as additional income for the home. By the end of the week it was clear that despite being an old age home, Mthimkhulu was so much more – a true community hub.

2. Mthimkhulu elderly awareness week celebrations

Despite processing a large amount of residents at Mthimkhulu, the full quota of 30 participants per decade we hoped to attain had not been filled. While busy with collecting further data, Patience contacted me regarding their elderly celebration week. She just wanted to confirm whether I would be able to attend, since she had personally managed to organize more elders throughout the community in order to participate in the study! Nearly undone, I vehemently assured her that I would be ready and present, and dressed in a clothing item representing their bright blue festivity colours to boot.

I had decided to create an average face of the Mthimkhulu residents, as a token of gratitude for their assistance. This seemed the perfect opportunity to have it designed and printed on a sturdy box frame at Pixel Frog (http://pixelfrogink.co.za); a wonderful eMalahleni based designing company.

Upon arriving at the festivities, I was impressed to see the scope of the organization – the program included a prayer opening by a local pastor, speeches by the community leaders, drama and traditional music routines by local youth performers and a meal for all involved. This provided me a very official and public opportunity to hand over the Mthimkhulu average face and thank Patience and the other staff. Further awareness of my research was raised during the official speeches. To my surprise, during the course of further data collection I managed to do on that day, I was approached by reporters from the local radio station and an impromptu tape recorded interview ensued. Images of the Mthimkhulu average face, as well as official presentation are included.



Figure A: *(left to right) Printed Mthimkhulu average face and its presentation by me to social worker, Patience.*

3. General data collection observations

By now I am sure that it is clear to the reader both what an invaluable assistant Patience proved to be, and what a wonderful experience collecting data at Mthimkhulu was. Of course, over the course of several months many other memorable experiences ensued. Not the least of which included an extended conversation on facial images with a retired photographer, as well as philosophising on the merits of further education with a site manager. He went on to express regret at having multiple children early in life (financial drain) and receiving a tertiary education only at a later stage in life.

I also vividly recall an encounter with a participant born in Zimbabwe, who had been working in South Africa for the past two decades. Upon further enquiry, it came to light that he actually had four various degrees and diplomas, but was working as a gardener at the time of our encounter. He assured me that despite his seemingly less than stimulating job considering his skillset, being in South Africa was worth any apparent sacrifices. This led me to contemplate the economic woes of our neighbour to the north, especially given the recent elections that had occurred at the time of writing this essay (Mahr, 2018).

Aside from the many unique individuals who, by dint of their willing participation crawled into my heart, I couldn't help but notice two overall trends that ran true for the vast majority of the individuals who participated.

Younger individuals in their 20's and 30's seemed uniformly well versed in social media and its privacy pitfalls we are all grappling with on a daily basis. After all, it seems that social media participation and privacy are two opposing forces that are constantly vying for supremacy. The ramifications of this dilemma has not yet been comprehensively discussed by us as a society (Qi and Edgar-Nevill, 2011). As such, the majority of younger individuals had many pertinent, well-informed questions on how our use of their facial images may impact them. This was such a theme, that when dealing with youngsters, I started paying a lot of attention to the privacy protections we built into this project from the moment I broached the topic of study participation with them. The older individuals on the other hand were slightly overwhelmed by all the privacy protections, and in some cases gave the distinct impression that the different protections we guarantee participants seemed

like repetitions of the same point. Various middle aged gentlemen, in fact, had no problem at all with us using their facial image in any way we see fit! To explain that we would not print their photo as is in a relatable example, we referred to not putting it on a billboard on the street. Some seemed quite taken with the idea of their faces emblazoned life size and larger on social media and any other surface we would desire! Of course the parameters within which this study was conducted do not allow for free use of recognizable images, yet their lack of concern over misuse was refreshing.

The second general trend was a rather interesting observation on generational differences. Individuals 60 years and older nearly uniformly preferred to be presented with the research participation information in Afrikaans. However, for individuals below 40 years of age I struggle to recall a single example of a request to discuss the research project in Afrikaans. English was definitely the language choice at the order of the day! I myself, as main researcher, unfortunately only speak these two languages and could not address all participants in their respective home languages. Throughout, care was taken to provide interpreters for individuals in a language of their choice, when requested. This distinct generational language preference very likely reflects the demographic changes of South Africa. A country moving from a distinctly Afrikaans base to a multicultural hot-pot where many languages are celebrated, but where English is the central language connecting us all nationally and globally (BusinessTech, 2015).

4. Observations on individuals not participating

The long and winding road of data collection and all the wonderful, inspiring encounters throughout can simply not be fully recounted within the limited frame of a single essay. However, despite the multitude of heartfelt experiences, there were certain shadow moments.

One that springs to mind was a certain location (not named for privacy purposes) where all individuals who were invited to participate declined! Whereas throughout the data collection process there were individuals who declined, such unanimous refusal was most definitely not the norm. Upon further inquiry, I was told that these individuals were currently in a work dispute. As we approached them at their place of work, one can only surmise that their refusal may have had some root in their dissatisfaction with their employers, leading to a general disinterest in cooperating with any requests at all.

On the lighter side of things, at a different location I was informed by a participant on the cause of his friend's refusal to participate. Said refusal was rooted in the maintenance of a certain Marijuana field, coupled with fear of recognition by authorities! While flouting the law is certainly no less serious than a workers' dispute, the fact that the participant so freely and in such a humorous tone confided in us provided a certain comical relief.

Memorable, but somewhat disturbing to my peace of mind, were the encounters I had with women during the data collection process. The ladies often were more interested in the project than the men. Despite being told it concerned men only, women stuck around to hear more about the research in information sessions and even sometimes approached us during data collection with more questions. The interest intellectually in scientific endeavours was wonderful to observe.

What was distinctly uncomfortable to me personally, was having to explain to these wonderful ladies that they were being excluded from participating. Of course any project requires parameters to

ensure that the execution is possible, and knowing that the majority of unidentified individuals in South Africa are males (Evert, 2011; Wild, 2017) provided motivation to focus on males first. However, seeing the women's faces fall and transform into resigned looks were quite hard emotionally. As a patriarchal society, too often ladies in our society are marginalised, passed over or excluded (Coetzee, 2001; Gerber, 2018; Mkhize, 2017; Noge, 2014). As a member of the fairer sex, I am familiar with the experience despite any cultural or socio-economic class differences there may be between my sisters and I – it is decidedly unpleasant and abhorrent! It is my firm wish to, at a later stage, conduct a similar study on women and to make a concerted effort to revisit all data collection places where ladies were present and expressed such interest in this research.

In conclusion, multiple challenges aside from disinterest in participation occurred and had to be solved. In addition to having to think creatively to overcome these issues in the field, the constant travelling also proved to be rather taxing. Personally, dealing with so many unique individuals also proved draining. Throughout, I attempted to connect to each participant on a personal level in addressing their concerns and questions. As someone who greatly values alone-time, reaching out consistently over the multiple weeks of data collection proved to be a personal challenge. Despite my reservations, given a chance at a do-over, I would gladly take on this journey each and every time. I was taught greater compassion and was provided a glimpse at the remarkable diversity of South Africans who are individuals in their own right and yet have so much in common. Through all my encounters with South Africans I could detect an underlying thread of hospitality, generosity and openness that both astounded and inspired me. I will carry this with me a lot longer than any academic achievements arising from this project.

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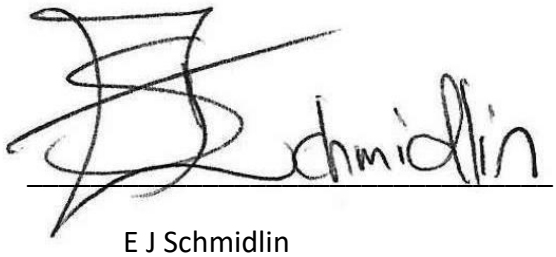
Appendix J

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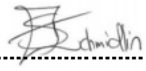
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Appendix K

Article and co-author agreement

Declaration: Student's contribution to article and agreement of co-authors

I, Estha J Schmidlin, student number 1253452, declare that this Dissertation is my own work and that I contributed adequately towards research findings published in the article stated below which are included in my Dissertation.

Signature of Student:  **Date**: 28/11/18

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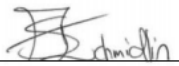
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Comments by primary supervisor:

Ms. E Schmidlin is the 1st author of this article and completed both the writing up of this article, as well as the research on which it is based. Myself and the other co-authors assisted on technical and statistical queries where needed, as well as working on the editing process. As such, Ms. Schmidlin is entitled to add the paper titled '*Facial ageing in South African adult males*' to this Dissertation in fulfillment of the requirements for her MSc (Med) degree.

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Facial ageing in South African adult males

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ABSTRACT

Knowledge of facial ageing is important in forensic facial approximation and photo identification. Previous studies mostly investigated facial ageing in European faces, and this research therefore aims to provide data on patterns of facial ageing in an African sample. One hundred eighty-nine black South African males aged 20 years and older were photographed in anterior and lateral views. Facial images were captured in a consistent position by using a Canon EOS 1300D camera and 18- to 55-mm EFS lens. Thirty individuals per decade were included, with the 80+ age category being limited to only nine participants. A facial ageing scoring system, based on previous research, was constructed for non-metric age changes such as appearance of wrinkles and sagging around the orbital area. Metric age changes such as ear lengthening and lip thinning were investigated separately. Results indicate that the ageing process in black South Africans has both similarities and differences to senescence described for European populations. Although most ageing features showed unidirectional change during time, these changes often occurred at a variable rate. Some features did not show a clear change with increasing age – these include mouth width increase, nasal elongation, nasal tip dropping, ear width increase and ear length increase. In addition to the age-feature correlations, an average face per decade was developed using Abrosoft FantaMorph Deluxe software. This provides a visual approximation of male South African faces captured at a single moment in time, as an aid for craniofacial depictions and facial image ageing in forensic practise.

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1. Introduction

As faces age, morphological changes can be observed. The rate of these changes is highly variable across sexes [1], ancestry groups [2,3] and individuals. With increasing age, senescence is regulated progressively less by genetics and more by environmental factors, which is unique for every individual. Environmental factors that likely play a role in ageing include sun exposure, general health, tobacco and alcohol use, socio-economic status and general stress [3,4].

In part owing to this large variability and the complicated nature of the intrinsic and extrinsic interactions in the ageing process, few studies that attempt to track these changes are available. The studies by Sforza et al. [5–8] and Albert et al. [4] are notable exceptions. The study by Albert et al. [4] provides one of the most comprehensive literature reviews of facial ageing research that could be found. This paper summarises descriptive morphological changes per age group in a clear and easy-to-follow table format, although some of the described changes that can be measured have been questioned [5–8]. Most of the research was conducted on North American and European populations.

The Sforza et al. [5–8] study focused on quantifiable ageing and sexual dimorphism changes at a specific facial region – the orbital, nasal, auricular and oral areas. Each paper analyses linear measurement data obtained from live participants using a three-dimensional computerised electromagnetic digitiser and cutaneous markings. Statistical analyses include descriptive data and factorial analyses of variance and are based on an Italian (European) population. Vashi et al. [2] considered an African American population but focused mainly on skin changes. It is widely accepted that environmental factors (such as sun exposure) play a significant role in ageing; therefore, the findings of the aforementioned studies [2,4–8] would likely not apply uniformly to all populations across all regions of the world.

Understanding age-related changes of the face is relevant in the field of forensics, amongst others, where ageing images of suspects/victims, for example, in cases of photo identification, need to be conducted. It is also relevant in facial approximations

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where an appropriate number of wrinkles, for example, need to be applied based on the estimated age of the individual. During their experience, the authors have found that forensic artists at times have to revert to Google Image references for photographs of people with vaguely age-appropriate skin textures. This strategy does not meet the standards set for good scientific practise [9], especially with regard to population differences in ageing.

Some studies involved the construction of facial ageing maps (e.g. Ferrario et al. [10]). However, the sample is not based on Africans, and individuals only up to 40 years of age were included. This limitation is problematic, as many age-related changes progress and intensify after the age of 40 years [4]. One advantage of such facial maps is the consideration of the face as a whole, not focusing on specific smaller subunits such as the oral or orbital areas in isolation. Such a global approach using facial averaging software has long been utilised in psychology studies of face perception [11–13], with new research emphasising links between facial appearance and overall health [14]. Similar methods have been used to construct average faces in the craniofacial identification domain [15] and have contributed to the physical anthropology field through skull average morphology visualisation [16].

This study aimed to assess facial aging patterns in a sample of black South African males, especially with regard to the development of wrinkles and changes in the ear, mouth and nose. The approach included basic morphological scoring and measurements as well as facial morphing software to provide images of an average face per age decade.

2. Materials and methods

This research project on African faces was conducted in a developing country [17], in a fieldwork setting. The authors attempted throughout to attain the highest scientific standards while making use of limited resources, specifically regarding the available equipment. The research is therefore of practical relevance and can be reproduced in environments where availability of funding is often still a determining factor for the effectivity of both research and law enforcement [18,19].

The study sample included black South African males (n = 189), aged between 20 and 100 years, from the Gauteng region of South Africa. Thirty participants per age decade were recruited, with age groups starting from 20 to 29 years up to the age of 80+ years. Only nine participants could be found to be included in the 80+ age group. This reflects the life expectancy in South Africa, which is approximately 60 years of age [20]. All faces were anonymised, and images were stored at the Human Variation and Identification Research Unit at the University of the Witwatersrand, South Africa, using the REDCap secure database application. The Human Research Ethics Committee (Medical) of the University of the Witwatersrand approved this study (Approval No.: M161023).

Photographs of participants were taken in an upright position, while seated or standing. A Canon EOS 1300D standard digital SLR camera (18 MP) and 18- to 55-mm EFS lens set to a fixed focal length of 35 mm were used to acquire images of participants' faces, orientated in the Frankfurt horizontal plane [21]. The image aspect ratio was kept as 3:2 throughout the study, with negligible compression artefacts [22]. Both frontal and lateral views were photographed in high resolution (5184 × 3456 pixels). The camera tripod was set up 2 m away from the participant [23], with a photographic scale on a plane same as that of the face similar to that utilised by Briers [24].

Data were captured at various locations to ensure minimal effort for participants regarding travelling costs. Throughout the process, attempts were made to ensure sufficient and equal frontal lighting with the help of a Canon Aputure AHL-HC100 ring flash. Lightening was adjusted to ensure equal illumination across the face with no shadows present under or around the nose, eyes and chin. Owing to varying conditions at different data collection locations, camera shutter speed, frame rate and a fixed focus point for participants to normalise facial tilt were controlled as far as possible under field conditions. Participants with a pronounced cranial tilt/turn were asked to correct their faces to a more normalised position approximating the Frankfurt plane. Although the aforementioned attempts to maintain constant field conditions for image capture may not be comparable with the laboratory conditions of precision attained in literature such as the Stephan et al. [25] paper, in an African context with finite monetary resources, sufficient calibration has been attained to enable successful image analysis [24].

Observations from previous studies on facial aging in other populations were combined to establish a scoring system [2,4]. This was used to statistically assess the described age correlation for morphological, non-metric features. Owing to observed population differences, slight adjustments had to be made to better describe the South African sample. Two creases, namely, the lateral nose crease and mental pit [26], were not observed in the South African male sample. Instead of a mental pit, the chin in elderly individuals acquired an overall dimpled appearance. A separate table/scoring sheet for anterior (Table 1) and lateral (Table 2) views was created.

Features associated with measurements rather than descriptions were assessed separately, based on the Sforza et al. [5–7] measures: upper lip thickness measured from labiale superius to stomion; lower lip thickness from stomion to labiale inferius; mouth width from the cheilion at one end to the cheilion at the other end; nasal length from nasion to pronasale; nasal tip measured as the angle between nasion–pronasale–subnasale (°); ear width from preaurale to postaurale; and ear length from superaurale to subaurale. All measurements other than the nasal tip angle were taken using a millimetre scale. These measurements were used to assess the possible thinning of the lips, increase or decrease in mouth width, nasal elongation, dropping of the nasal tip and changes in the size of the ears. It should be noted that the landmark defined as 'nasion' by Sforza et al. [6] corresponds to the 'sellion' landmark described by Stephan and Caple [27]. From this point, the 'deepest midline point of the nasofrontal angle' [27] has been referred to as 'sellion' throughout this study for universal consensus and clarity. Measurements were recorded using the ruler tools in Adobe Photoshop image editing software once each image had been scaled to size using the reference scale included in each photo.

Many authors have questioned the validity of photoanthropometry [28,29]. One of the major issues in photoanthropometry techniques concerns the technical error of measurement (TEM), as described by Stephan et al. [25]. TEM relates to reproducibility of measurements under different conditions, as opposed to the repeatability from various assessors. To assess the validity of the method for image capture at varying locations, TEM values were calculated for each measurement. The calculations were performed for two participants using five images each captured at different times and locations. Relative TEM (rTEM) values were considered acceptable up to 7.5%, as for the inter-evaluation (accounting for the five different images) requirement for a skilful anthropometrist according to Perini et al. [30]. Standards ranging from 1% to 10% and more have been reported in literature [30,31], and for all measurements in this study, most of the image pairs scored far below 7.5%. Nasal angle measurements adhered closely to the 2% acceptance standards mentioned in Fancourt and Stephan [31]. It should be emphasised that according to Fancourt and Stephan, there is no universal level of acceptance. Rather, the percentage of acceptance is set on an individual basis by researchers. The pairwise TEM and rTEM values are provided in

Table 1
Facial ageing scoring system – anterior view.

Feature	Score				
	1	2	3	4	5
Orbital					
Wrinkles	No lines evident	Lateral orbital lines appear	Lateral orbital lines deepen	Vertical glabellar lines appear	Wrinkles increase in depth and number
Upper eyelid fold drooping	No drooping evident	Slight upper eyelid fold sagging	Obscures 1/3 of the upper eyelid crease	Obscures 2/3 of upper eyelid crease	Obscures the entire upper eyelid crease
Suborbital pouch formation	No skin sagging	Slight pouch formation	Definite pouch formation	Pouch formation with fine wrinkles	Pouch formation with defined wrinkles
Oral					
Wrinkles	No lines evident	Labiomental groove forms	Oromental lines form	Circumoral striae form	The chin has dimpled appearance
Nasal					
Wrinkles	No lines evident	Faint nasolabial lines form	Nasolabial lines deepen	Transverse nasal lines develop	Transverse nasal lines deepen
Forehead					
Wrinkles	No horizontal frontal lines evident	Faint horizontal lines appear	Clear horizontal line formation (1–3)	Horizontal lines increase and deepen (4–6)	Vertical superciliary arch lines form
Cheek					
Wrinkles	No lines evident	Inferior orbital grooves form	Buccomandibular grooves appear	Cheek folds appear	Lines deepen and increase
Overall					
Skin colouring	Homogeneous colour	≤25% of the skin shows heterogeneous pigmentation	26–50% heterogeneous pigmentation area	51–75% heterogeneous pigmentation area	>75% of the skin shows heterogeneous pigmentation

Table 2
Facial ageing scoring system – lateral view.

Feature	Score				
	1	2	3	4	5
Auricular					
Wrinkles	No lines evident	Faint periauricular line formation	1–2 clear periauricular lines	3–4 deep periauricular lines	≥5 deep periauricular lines
Cheek					
Hollowing	No hollowing evident	Slight indentation	Indentation enlarges	Indentation deepens	Sunken appearance
Overall					
Skin texture	Smooth skin with fine pores	≤25% of the skin has a roughened texture	26–50% roughened skin area	51–75% roughened skin area	>75% of the skin has a roughened texture

Supplementary Table S1. Given the overall positive TEM results, general trends can be evaluated using the photoanthropometry methodology as presented in this study.

Correlation analysis of both scored and measured features with age was performed using Microsoft Office Excel 2010 software. For the ordinal scores, Spearman's rank correlation coefficient was used. The advantage of using this correlation measure is that the sample spread need not be normal and that relationships other than linear correlation, such as an exponential trend, are indicated [32]. For features with numerical values, Pearson's correlation coefficient was used except in cases where one of the main assumptions, normally distributed data, was violated [32]. In these instances, Spearman's rank correlation coefficient was once again used. It should be noted that any correlation observed does not imply causation. Statistically significant correlations may still be due to chance.

Inter- and intra-observer reliability was tested for the scored and measured features. Stratified sampling was used to select five random participants from each age category for reassessment by the main author and for assessment by the third author. Three scores/measurements were therefore available for each of the five selected participants per age group. Inter-observer reliability was tested using Fleiss' kappa for scored features and intraclass correlation coefficient (ICC) for measured features [33,34]. The Fleiss' kappa test was selected specifically to account for cases where one of the observers chose not to score a characteristic due to constraints such as facial hair or a hearing aid, and the other did assign a score. The Fleiss' kappa is more robust in calculating agreement in such instances than Cohen's kappa [33,35]. Intra-observer reliability was assessed using Cohen's kappa for scored features and ICC for measured features [34,35]. In both instances, the ICC test used was a two-way, random effects, absolute agreement model. This was selected because of the more stringent statistical scrutiny provided by the absolute agreement as well as random effects selection [34]. The ICC analysis was completed using the PQStat statistical software package (https://pqstat.com/).

After each facial feature was investigated individually, a more global approach was followed by constructing an average face per age decade using Abrosoft FantaMorph version 5 Deluxe package facial averaging software (http://www.fantamorph.com/index.html). This facial averaging software uses landmarks placed on features to align and warp all faces to a common zero or set mesh. The layer morph function allows for instantaneous uploading of all 30 facial photographs per decade as well as morphing the various layers into one image. FantaMorph software rather than PsychoMorph software was used, as FantaMorph is slightly more user-friendly than PsychoMorph despite the lack of texture-preserving algorithms and slightly higher cost [36,37].

Both anterior and lateral views were averaged separately to make generalised comments on the expected ageing

characteristics within each broad, 10-year age grouping. FantaMorph automatically detects facial images and places 112 landmarks in a rough estimation of the anterior face, which can then be refined to each unique individual's image (Fig. 1A). These automatic landmarks are placed combining common facial landmarks and a fixed number of delineating landmarks. The lateral views, however, had to be landmarked manually by the main author. The mesh was partially constructed using the automated placement of anterior landmarks as a basic guide. Common facial landmarks in literature [27] were placed on a template, with a set number of landmarks placed at equidistance in between. Experimentation by trial and error provided the minimum set number of landmarks necessary to effectively outline the profile. A novel mesh was thus constructed using 152 points (Fig. 1B) and subsequently applied to all lateral images.

3. Results

General descriptive statistics were calculated for both the morphological and metric features, per 10-year age cohort. Density scatterplots indicating the scores obtained for each age-related morphological feature were constructed (Fig. 2). It is clear that all features assessed progress in a unidirectional positive manner. Three broad ageing trends can be identified from the average scores. First, suborbital pouch formation and upper eyelid fold drooping are the only features with a seemingly linear trend during time. Second, a plateau is seen in the ageing rate of approximately 70 years of age for nasal, auricular, cheek and oral wrinkles. Third, there is an unequal ageing pattern concerning forehead and orbital wrinkles, cheek hollowing, overall skin colour and texture, thereby suggesting that an ageing progression plateau is reached at approximately 50 years of age, coupled with a sharp increase in the average score of the older age groups.

The Spearman's rank correlation coefficients for the morphological features are summarised in Table 3. Hypothesis testing was executed under the Fisher paradigm to assess the statistical significance of each correlation [32,38]. The relationship noted in the correlation between age progression and each feature was assessed for significance under the null hypothesis (H_0) that zero correlation occurred (H_0: $r = 0$). If the p-value was less than 0.05, evidence is provided against the H_0, as it would not adequately explain the observed results. All the morphological features scored showed a clear positive correlation with age, ranging in strength from moderate to excellent. Significance testing indicated statistical significance for all morphological features at the $\alpha = 0.05$ level.

The descriptive statistics for the metric features, per age decade, are shown in Supplementary Table S2. Scatterplots of these features are given in Fig. 3. The averages reported in the Sforza et al. [5–7] papers are also indicated on these graphs. The convention used in this paper was the use of the lowest age per age range as a single value plotting point. As the age groups described in this study followed constant, discrete age intervals and those of the Sforza et al. [5–7] papers did not, the average age was calculated for each age range described in the Sforza et al. studies. The only two measurable features showing a clear trend are upper and lower lip thinning. Although a negative relationship can be observed between age and lip thinning, an unequal ageing progression is evident with a plateau appearing from 40 to 50 years of age, followed by a sharp decline from 60 years onwards. None of the other features show a clear trend with age. The described population values as found in Sforza *et al.* [5–7] cannot simply be extrapolated to the sample involving South African black males. This is especially clear for lower lip thinning, as the Sforza *et al.* [5] average trend line lies far below that of the South African sample. The South African group demonstrates thicker lips than the population described by Sforza *et al.* [5], and this increased value is maintained throughout progressing age decades.

The Pearson's correlation coefficient values for the measured features are summarised in Table 4. The statistical significance of each correlation was tested using the probability density function of the *t*-test under Fisher's hypothesis testing paradigm [32]. Upper lip thinning and lower lip thinning are the only measurable features with a distinct correlation with age. All the other features proved have little to no correlation with age and display a lack of evidence against H_0.

To test the repeatability and specificity of the scoring system and the measurements, inter- and intra-observer agreement was tested. Inter-observer agreement for the scored features was

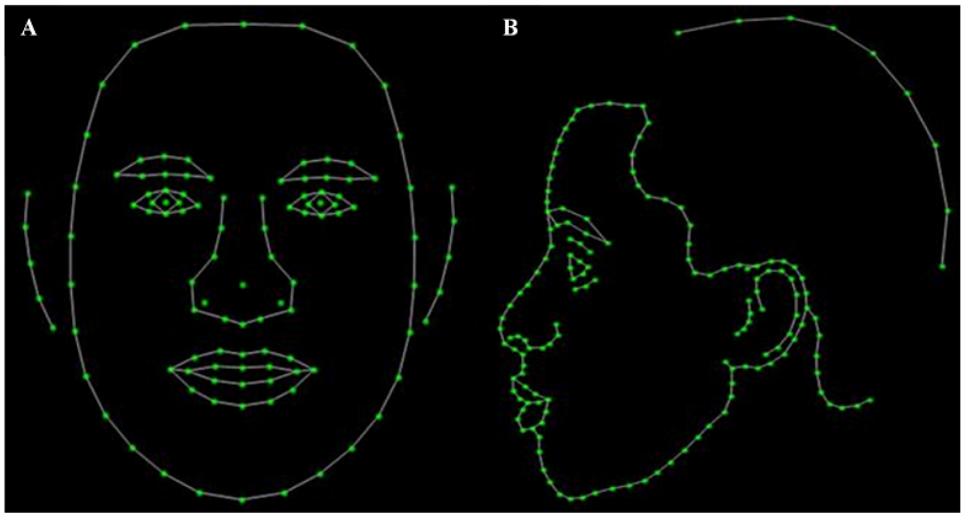


Fig. 1. (A) Automated anterior and (B) novel lateral facial view of the FantaMorph Deluxe mesh.

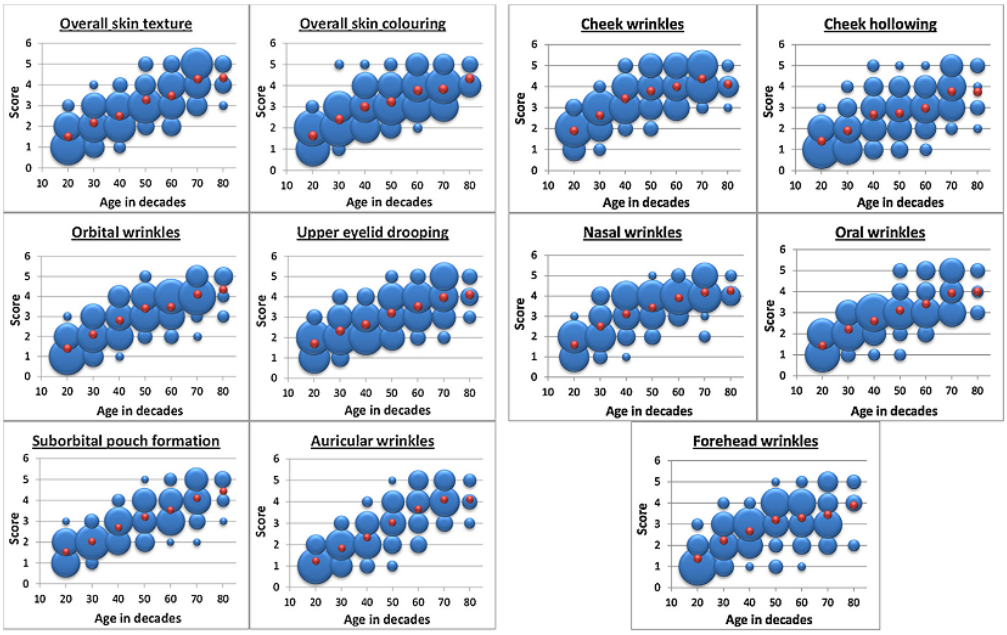


Fig. 2. Graphs of morphological feature score per age group. The red dots indicate the average score of the feature per age group. The blue dots indicate the scores obtained per age group, with the size of the dots indicative of the relative number of participants who were assigned a similar score. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 3
Correlation of scored morphological features, with age in decades.

Age-related scoring feature	Spearman's correlation coefficient (r_s)	Strength of correlation[a]	p-Value
Orbital wrinkles	0.784	Very good to excellent relationship	0.000*
Upper eyelid fold drooping.	0.697	Moderate to good relationship	0.000*
Suborbital pouch formation	0.806	Very good to excellent relationship	0.000*
Oral wrinkles	0.754	Very good to excellent relationship	0.000*
Nasal wrinkles	0.747	Moderate to good relationship	0.000*
Auricular wrinkles	0.801	Very good to excellent relationship	0.000*
Forehead wrinkles	0.620	Moderate to good relationship	0.000*
Cheek wrinkles	0.721	Very good to excellent relationship	0.000*
Cheek hollowing	0.632	Moderate to good relationship	0.000*
Overall skin colouring	0.724	Moderate to good relationship	0.000*
Overall skin texture	0.768	Very good to excellent relationship	0.000*

* $p < 0.05$, strong evidence against H_0: $r_s = 0$.
[a] Based on the Coulton rule of thumb as described by Dawson and Trapp [32].

calculated using Fleiss' kappa [33,39,40]. The standard error, 95% confidence interval (CI) and the p value were calculated to test for significance. Inter-observer agreement for metric features was calculated using ICC [34,41]. The significance of any observed agreement was assessed using Fisher's hypothesis testing [32,38]. The results are provided in Supplementary Table S3.

Intra-observer agreement was calculated using Cohen's kappa [35,40] for morphological features included in the scoring table. Once again, the standard error, 95% CI and the p value to test for significance were calculated. The metric features were assessed using ICC [34,41]. Intra-observer agreement results are also presented in Supplementary Table S3.

Assessment of categorical data such as morphological features is observer specific and therefore often considered problematic with high error rates [42,43]. Despite the relative fluidity in descriptions for morphological features, they are widely used in conjunction with metric-based approaches in biological anthropology [42]. Inter-observer assessment for morphological features ranged from −0.004 to 0.686, with metric features ranging between 0.340 and 0.957. Intra-observer agreement was overall higher, with morphological feature agreement ranging from 0.454 to 0.777 and metric feature agreement as high as 0.853 to 0.989 across features. As expected, morphological features displayed higher error rates than metric features. Given the descriptive nature of the morphological features, observer experience with population-specific standards would be beneficial. This is reflected in the comparatively higher intra-observer reproducibility than in the inter-observer repeatability scores obtained in this study.

Following the analyses as described above, an average face per decade was created using FantaMorph software. A visual assessment of the most observable changes can be made, although fine wrinkles

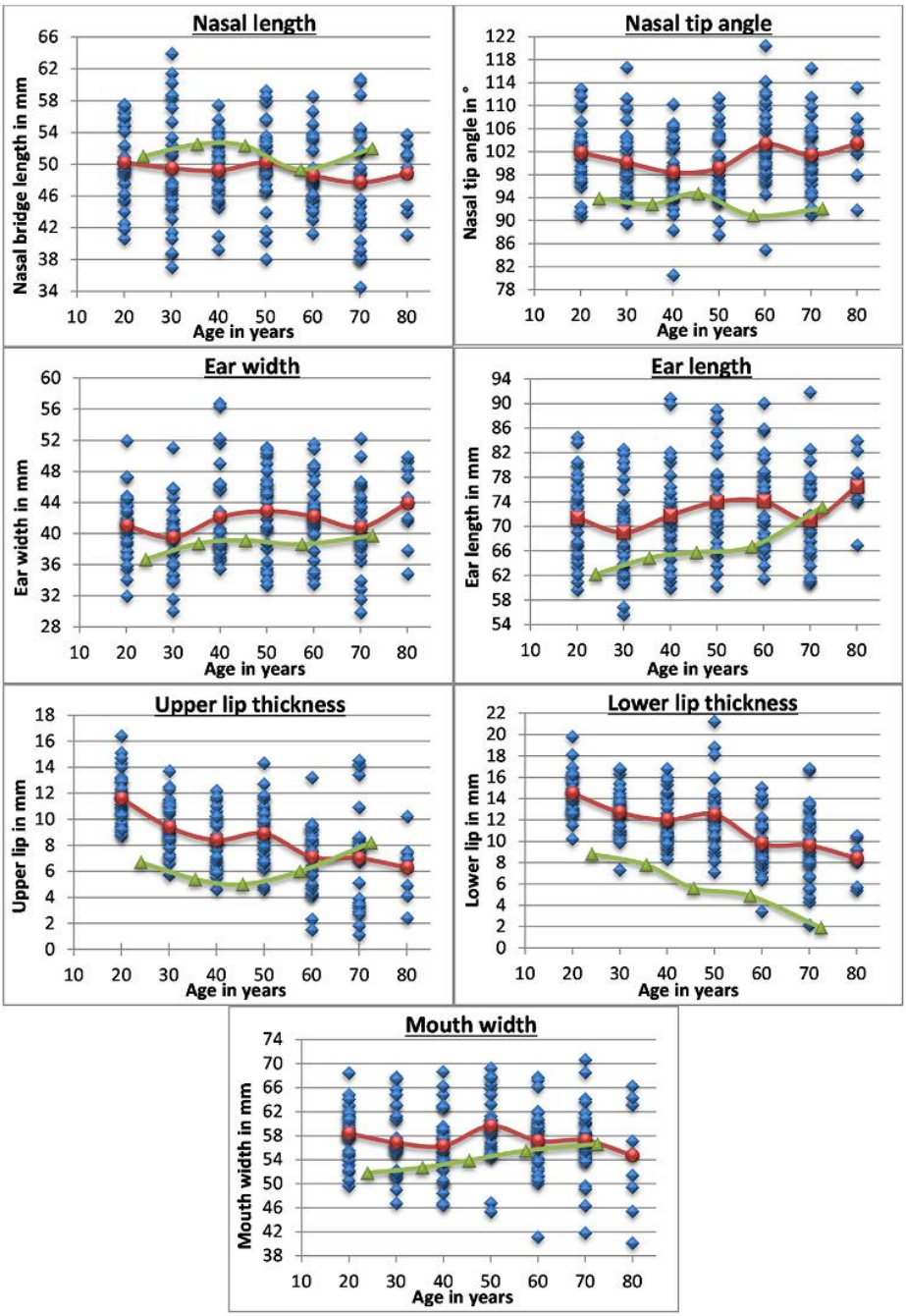


Fig. 3. Scatterplots of measured features per age group (blue diamonds) with trend lines indicated. The red line (connecting the circles) indicates the average measurement per decade from this study, whereas the green line (connecting the triangles) indicates the means obtained in Sforza et al. [5–7], respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
Correlation of measured features, with age in decades.

Age-related scoring feature	Pearson's correlation coefficient (r)	Strength of correlation[b]	p-Value
Upper lip thinning	−0.507	Moderate to good relationship	0.000*
Lower lip thinning	−0.561	Moderate to good relationship	0.000*
Mouth width increase	−0.021[a]	Little to no relationship	0,786
Nasal elongation	−0.120	Little to no relationship	0.100
Nasal tip dropping	0.087	Little to no relationship	0.241
Ear width increase	0.124[a]	Little to no relationship	0.093
Ear length increase	0.142[a]	Little to no relationship	0.054

*$p < 0.05$, strong evidence against H_0: $r = 0$.
[a] Spearman's rank correlation coefficient was used, as data did not follow a normal distribution.
[b] Based on the Coulton rule of thumb as described by Dawson and Trapp [32].

tend to be underrepresented owing to their variable location that subsequently becomes smoothed during the averaging process [36]. The results obtained using FantaMorph software are shown in Fig. 4.

4. Discussion

The results obtained indicate various differences and similarities from the ageing process described in existing literature based on European populations [2,4–8]. One of the first dissimilarities was encountered when setting up the scoring system based on descriptive features. No lateral nose creases were observed in the sample, and as such, this crease was removed from the scoring system (Tables 1 and 2). The lack of lateral nose creases may be accounted for when considering the underlying skeletal structure of the nasal bridge. In African populations, the nasal bridge tends to be broad and low, as opposed to sharp and pronounced like those of European populations [42]. Wrinkles form in part due to underlying collagen loss [1,2,4] that causes the skin to sag under the downward vector of gravity. Accompanied by adipose tissue redistribution, the pronounced angle formed by the high European nasal bridge likely contributes to the appearance of the lateral nose crease – which is in turn stymied by the more gradual nasal bridge slope in African populations.

Other unique aspects of South African ageing, involving forehead and orbital wrinkles, cheek hollowing, overall skin colour and texture as well as upper and lower lip thinning features, can be seen in the scatterplot graphs presented in Figs. 2 and 3. The unequal ageing pattern seems to be first characterised by a gradual increase/decrease in the specified feature with age, up to approximately 50 years. At this age, the increase/decrease slows dramatically, thus forming a plateau. Subsequently, the ageing seems to accelerate again in the 70 to 80 and upward groups. This trend may perhaps to some extent be explained by considering the average 60-year-old life expectancy of South African men [20]. It is suggested that a relatively linear age progression is observed until approximately 60 years of age, keeping in mind that the 50-year-old group includes individuals from 50 to 59 years of age. However, individuals that outlive this age might be either genetically inclined to longevity and/or healthier than average through chance and circumstance. Therefore, their faces may not show immediate age progression in a manner similar to their counterparts and as a result may seem to look younger. The plateau observed from the 50-year age group for some features seem to fit this trend, whereas normal age progression proceeded after the plateau. The trend as described here corresponds with the demographic composition of South Africans and may disappear during time because of the secular trend of increased life expectancy. However, owing to lack of specific evidence, this can only be speculated upon currently, and future studies should aim to address this aspect.

The measured features also showed some interesting results. Of the seven features assessed (Fig. 3 and Supplementary Table S2), only upper and lower lip thinning had a statistically significant correlation with age (Table 4). The difference between the mean upper lip thinning measurements according to Sforza et al. [5] and the averages obtained in this study are clearly illustrated in Fig. 3. The Sforza et al. [5] mean measurements for men aged 18–80 years range from 5.0 to 8.2 mm, whereas the South African mean measurements for men aged 20 years and older ranged between 6.3 and 11.6 mm (Table S2). Sforza et al. [5] state that the mean lower lip thinning values range from 1.9 to 8.8 mm. The South African values (Table S2), in contrast, range from 8.4 to 14.5 mm. We can clearly see that compared to their European counterparts, South African adult men tend to have broader lips across all ages. The Sforza et al. [5,6] studies also found a lack of nasal elongation and tip dropping in a European population. In a European population [5], upper lip thickness did not follow a linear progression with increasing age. For a South African population, upper lip thickness distinctly decreased during time. These results indicate another unique aspect in which facial ageing of South African men diverges from age progression in European populations.

The morphological changes observed in this study for South Africans are broadly consistent with the those in existing literature [2,4] for other populations. South African men show initial wrinkle formation (Score 2 obtained for features; Table 1) at approximately a decade later on average than Europeans [4], with initial formation starting after 30 rather than 20 years of age. Circumoral striae (Oral wrinkles score 4; Table 1) around the mouth were only evident at approximately 70 years of age on average in South African men, whereas they became evident at 30 years onwards in Europeans [4]. Cheek hollowing (Table 1) was evident at an early age compared to that of Europeans, with individuals on average displaying considerable hollowing at approximately 40 years rather than 60 years of age. This is in contrast to many of the metric features that did not have a significant correlation to age.

Of special interest are the inter- and intra-observer agreement statistics, which indicate that the descriptive scoring system is not as replicable as would be hoped. In direct contrast, the metric features are all highly repeatable regardless of whether they actually show age progression or not (Supplementary Table S3). It is clear that the morphological descriptive assessment criteria for ageing are vague and difficult to accurately repeat without extensive experience at best. It is therefore recommended to create a population-specific visual database for each score, rather than rely on descriptions, for future use.

When considering each decade's average face (Fig. 4), general senescent changes can be described. Few obvious differences can be observed between the individuals who are 20–29 years and those who are 30–39 years. The infraorbital groove and nasolabial lines become more prominent, with a slight receding of the hairline – visible as an increased irregularity on the anterior image. From the 30–39- to 40–49-year groups, eyelid drooping and pouch formation start to become visible, with the infraorbital groove and



Fig. 4. Facial average image of black South African men from the top row, left to right: anterior view of individuals aged 20–29; 30–39 and 40–49 years old. Second row: lateral view of individuals aged 20–29; 30–39 and 40–49 years old. Third row: anterior view of individuals aged 50–59; 60–69 and 70–79 years old. Fourth row: lateral view of individuals aged 50–59; 60–69 and 70–79 years old. Last row: anterior and lateral views of individuals aged 80 years and above.

nasolabial line becoming clearly defined. The hairline recedes even more, and slight cheek hollowing becomes evident.

In the 50–59 years category, the lateral forehead and eye creases start to become visible. Lip thinning as well as oromental and labiomental grooves appear. From the 60–69 years category onwards, the overall appearance of the face becomes more rounded than elongated, with the jawline becoming more variable owing to jowl formation and possibly loss of bone

related to tooth loss. The hairline becomes difficult to distinguish because of the extent of its retreat, and buccomandibular as well as cheek folds begin to appear. During the age of 70–79 years, upper eyelid drooping and suborbital pouch formation become prominent. Visually, there does not appear to be many distinctive differences between the average face of 60–69- and 70–79-year olds, except that all ageing changes already observed are intensified.

By the age of 80 years and older, a greater protrusion of the ears occur. Cheek hollowing is pronounced, and the overall shape of the face seems almost completely round. This can likely be ascribed to age-related atrophy of the jaw, in which senescent dentoalveolar loss plays a prominent role [4,44]. All wrinkles are more pronounced, with auricular wrinkles clearly evident. When compared to the faces of individuals aged 20–29 years, the slight prognathic nature of the lower face seems to have receded into a near orthognathic lateral facial profile with increasing age.

Limitations to this study are as follows: it was based on cross-sectional data [32], facial averaging software without texture-preserving algorithms were used, and morphological progression scoring had a relatively low reliability. These limitations may be addressed in future research. Suggested research directions include an evaluation on how the face changes during the lifetime of a single individual, thus accounting for weight changes and life style factors. Investigation into the underlying skeletal changes affecting the face would also be beneficial because this study only focuses on the overall external surface of the face. In addition, an expanded sample from a broader region within South Africa should be assessed, ideally including other South African population groups from a variety of socio-economic backgrounds. Visual comparison of the obtained facial averaging results can be performed using facial averages constructed by PsychoMorph facial averaging software with texture-preserving algorithms. Population-specific morphological scoring guides including images of the typical progression indicated at each stage could likely address the subjectivity issue and reduce experience-based repeatability errors.

5. Conclusion

This paper provides the initial building block for facial ageing research in South Africa. It tests the presumed correlations between various facial features and ageing based on those observed in European population and reveals various aspects that did not correlate well with age in a statistically significant manner.

In general, all scored descriptive features (orbital, nasal, oral, auricular, forehead and cheek wrinkles, upper eyelid fold drooping, suborbital pouch formation, cheek hollowing and overall skin colour and texture) show correlation with age. Metric features such as mouth and ear width increase, ear length increase, nasal elongation and nasal tip dropping do not show any progression with age in a sample of South African black male. As ageing progresses, upper and lower lip thickness decrease. South African men can be said to have thicker lips throughout their lifetime, delayed wrinkle formation and advanced cheek hollowing when compared to a European population.

Both inter- and intra-observer measures of reliability for the measured features outperformed the repeatability of the descriptive, scored features. Cheek wrinkles and hollowing as well as overall skin colour and texture scoring could not be consistently replicated. Intra-observer agreement was comparatively higher than inter-observer agreement. The facial averages constructed per age decade in this study provide a visual and descriptive guide of overall facial senescence. It is envisioned that this guide will enable easier and more accurate depiction of facial ageing in a forensic, health or humanities practical context.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.forsciint.2018.05.006.

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