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Mobile Images in the visualisation of characteristic dental features

By

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DECLARATION

I declare that the dissertation, which I hereby submit for the degree in Master of Science (Odontology) at the University of Pretoria, is my own work and has not been previously submitted by me for a degree at this or any other tertiary institution.

Vimbai Manyukwi

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Date

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ABSTRACT

Identification in forensic odontology requires that a known characteristic of an individual's dentition be compared with the same characteristic of the unknown decedent. A vast number of bodies remain unidentified at medico-legal laboratory facilities in South Africa (SA). Determining the extent of this occurrence in SA is important, as these unidentified bodies have many social and economic consequences. When a positive identification has been established, investigations into the circumstances surrounding the death can begin. The positive identification of a body allows for closure to be obtained by that individual's family and friends.

In SA a number of factors render forensic identification of unknown individuals challenging. Many South Africans do not have access to modern dentistry, and consequently do not have ante-mortem dental records. In low socioeconomic areas of SA, where individuals might not have access to oral healthcare, studies show that 1 in 3 of those individuals has access to a smart phone. This study aimed at investigating mobile images, hereafter referred to as selfies, as a source of dental information in the form of characteristic dental features. Results of this study were disappointing as identifiable dental features could only be seen in 61 (5.6%) of the collected images (N=1098). The low number of useable selfies collected in this study could be the result of a lack of smiles and the poor quality of the images received. Individuals with poor dental aesthetics would commonly choose to take a selfie with a closed mouth where their teeth would not be visible. The most commonly identified dental features included: diastemas (49.2%), dental jewellery (37.7%), crowding (16.4%), difference in tooth height (16.4%) discoloured (8.2%) and missing teeth (8.2%). The importance of good oral health and an aesthetic smile cannot be over emphasised. Awareness of the importance of selfies in forensic identification should be increased.

Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ANNEXURES

LIST OF ABBREVIATIONS

Abbreviation	Description
SA	South Africa
AM	Ante mortem
PM	Post mortem
DNA	deoxyribonucleic acid
mtDNA	Mitochondrial DNA
DVI	Disaster victim identification
MMD	Maxillary midline diastema
Jpeg	Joint Photographic Experts Group

CHAPTER 1: General Introduction

1.1 Background and scope

Rapid and accurate identification of non-natural deaths is an important component of a good forensic service.(1) It is important for ethical, criminal and civil reasons. Post mortem identification requires that a known characteristic of an individual be compared with the same characteristic of the unknown decedent. If a positive match is found, the individual may be identified and a death certificate can be issued.

The high number of unidentified decedents at medico-legal laboratory facilities in South Africa (SA) is a source of great concern.(2) Often there is an absence of medical and dental records which renders forensic identification of unknown individuals a challenge.(2) It is not a rare occurrence to have to identify a person where there is little ante mortem data, as in the case of asylum seekers and individuals living in rural areas.

Increased unemployment rates and deepening poverty due to the current worldwide Covid-19 pandemic have resulted in a rise in the number of human trafficking cases.(3) Recent statistics reveal that less than 1% of these victims are ever rescued, and that they often have no identification documents which would aid in their identification.(4)

The techniques currently used for identification within forensic odontology in SA are more suitable for countries where dental records are generally available throughout all socioeconomic spaces.(5) Within SA, alternative methods of identification need to be investigated.

1.2 Study Aim and Objectives

This study aimed at investigating the use of mobile images in the visualisation of characteristic dental features.

The objectives of this study were

- To determine the number of selfies where the dentition of the individual could be visualised.
- To assess whether any characteristic dental features used in forensic dental identification could be visualised on the selfies.

1.3 Study Approvals

This study was approved by the Research Committee of the School of Dentistry (Annexure 1) and the Faculty of Health Sciences Research and Ethics Committee (Ethics number 740/2019) (Annexure 2 & 3) of the University of Pretoria in terms of the National Health Act (Act 61 of 2003) and the Code of Ethics for Research of the University of Pretoria. Participation in the study was voluntary. Approval was further obtained from the chief executive officer of the hospital at which the study was conducted (Annexure 4) and written consent was obtained by each study participant (Annexure 5).

CHAPTER 2: Literature Review

Forensic odontology involves the identification, analysis and evaluation of dental information in criminal or civil investigations.(6) The forensic odontologist assists legal authorities by interpreting dental evidence in different scenarios. This includes the identification of unknown individuals, performing bite mark analyses and age estimations.(6-8) Routine identifications make up the largest proportion of a forensic dentist's work.(9) Identifications are often required following natural and manmade disasters, for victims of violent crimes and for those involved in motor vehicle accidents. In many of these instances, individuals can be disfigured to such an extent that identification by a family member is neither reliable nor desirable. Persons who have been deceased for some time prior to discovery and those found in bodies of water present unpleasant and difficult identifications.(10)

During the identification process, forensic comparison of ante mortem (AM) and post mortem (PM) dental data is used to establish, with a high degree of certainty, that an unidentified body and a suspected individual are the same person.(11) In mass disaster scenarios, the identification of these individuals is known as disaster victim identification (DVI). There are a number of different methods in which DVI can be performed, the simplest being visual recognition. This involves distinguishing an individual based on their clothing, body markings, tattoos or piercings. In mass disasters however, this method is considered to have a high error rate and more accurate methods of identification such as fingerprinting, DNA matching and dental identification should ideally be performed.(12)

Fingerprint analysis relates to the identification of an individual by the friction ridges of the fingertips.(13) These friction ridges are raised portions of the epidermis which form distinctive patterns. The patterns are formed prenatally and remain unaltered throughout one's life. Human identification by fingerprint analysis is based on the principle that ridge patterns are unique and a fingerprint pattern does not change over time.(14) Permanence of fingerprints is based on the histology of the skin. Specifically, how the epidermal cells connect to one another, how the basal epidermal cells attach to the underlying basement membrane and how the basement membrane attaches to the dermis.(15) Modification or destruction of these patterns are said to only occur when there is destruction of the underlying dermis. Fingerprint recognition is considered to be a reliable means for human identification and is used in a number of different applications. This ranges from everyday uses such as utilising one's fingerprint to unlock their mobile phone, to having a database to identify and convict criminals by linking them to crime scenes.(14, 16, 17)

Fingerprints are valuable for the identification of individuals; however, a positive identification requires matching a fingerprint on a national database with the fingerprint of an already known individual. In SA, a national fingerprint database does exist but two factors need consideration: if there is any damage to the fingers, or if the fingers are lost. In these instances, fingerprint identification cannot be performed.(10) Furthermore, there is no guarantee that an individual in question would have their fingerprints captured on this database, such as in the case of street children or undocumented foreign nationals.

A highly accurate form of identification is DNA profiling and analysis. DNA analysis reveals the unique genetic makeup of a person.(18) Two sources of DNA are available: nuclear or mitochondrial DNA (mtDNA) (15). Additionally, the Y chromosome can also be used for identification as this chromosome is passed to the son from his father, which can help in the identification of the sex of an individual.(19) Teeth provide an excellent source of DNA as they remain virtually unaffected by environmental insults.(20) When isolating DNA samples, single nucleotide polymorphisms can be analysed.

These are variations that occur when a nucleotide sequence is altered.(21) Their advantage is that they can be used for identifications in which there are highly degraded DNA fragments.(21) While DNA and fingerprint analyses are highly accurate, they are not always viable. Both these methods are time consuming to perform and expensive.(22) In a developing country such as SA, these are not always feasible methods to use in routine forensic identification cases.

Over 4 000 bodies were reported to be unidentified and unclaimed in Gauteng state mortuaries in the three years prior to 2015.(23) Although the number of unidentified bodies in Gauteng mortuaries has reduced, there were still 1173 unidentified bodies in 2021.(24) This number remains high with many families still not knowing the fate of their loved ones.(25) There are numerous contributors to this dilemma. One of the biggest factors for bodies remaining unidentified in mortuaries is a lack of identification of the deceased.

Dental records can provide an alternate source of information for identification purposes, especially when other means of identification such as visual recognition, fingerprint matching and DNA analysis are not possible.(26) The accuracy and completeness of the AM and PM dental profiles will affect the outcome of any dental comparison. When good quality AM data is available, forensic odontology contributes to approximately 30% further identifications in collaboration with other identifying methods.(25, 27)

The purpose of keeping good medical and dental records is to ensure continuity of care as well as to share relevant information with other members of the multidisciplinary team.(25, 28) A South African study found that details of past medical and dental history were not entered into the records of between 20 and 25% of patients.(28) Bernitz and Van Niekerk investigated 40 identification cases in which AM information was required. They found that many South African dentists did not comply with the requirements pertaining to dental charting and record keeping, making forensic identification challenging.(29) In developing countries such as SA, a large majority of the population does not have access to dental

services further intensifying the shortage of dental records. Individuals living in the rural, socially disadvantaged areas of SA are particularly affected.

Ante mortem dental data can include treatment records, radiographic images, clinical photographs and physical casts of the teeth.(27, 30) Comparison of PM and AM dental information relies on the fact that teeth resist decomposition and extreme environmental conditions and that every person has a set of teeth which is recognisably unique.(27) It is easier to confirm identity when there has been significant dental intervention as there are more dental features to compare and match.(30)

Many regions of the body have been used for identification purposes but the teeth remain one of the most ideal sources.(31) The unique and highly characteristic nature of the dentition enables dental identification to be made with a high degree of certainty.(6) The forensic dentist pinpoints characteristics of the individual's teeth which are likely to narrow the search for the identification. The list of dental features which can be examined includes amongst others: variations in tooth shape and size, diastema, crowding, missing teeth, dental jewellery and restorations.(6, 27) These features give an individual their unique dental identity.

Variations in tooth shape and size include congenital causes such as microdontia (smaller teeth than normal) and macrodontia (larger teeth than normal). Congenital anomalies are inherited through genetics whereas acquired anomalies are caused by the changes occurring during tooth formation.(32)

A diastema is a gap or space between two or more consecutive teeth.(33, 34) It occurs more frequently in the midline of the maxillary teeth, hence the common term, maxillary midline diastema (MMD). Naturally occurring MMD may result from a wide range of causes. Possible aetiologies include genetics, a missing tooth, mesiodens and peg shaped laterals.(35, 36)

A high labial frenum attachment is considered one of the most common causes of MMD.(37) A study by Huang et al., which looked at the mandibular midline diastema, found that it is not a normal growth characteristic. They found that the primary etiologic factor in mandibular diastemas is tongue thrust in a low rest position.(38) No epidemiologic data have been published on the prevalence of mandibular diastemas. A Nigerian study found that prevalence of artificially created maxillary midline diastemas was common in their population at 34%.(35) The authors stated that MMD is generally regarded as a symbol of beauty; especially in women, and that 70% of their respondents desired to have a MMD.

The use of dental jewellery dates back centuries to the Mayans who were known to have used carved stones to prepare the labial surfaces of anterior teeth.(39) These markings were placed on specific teeth according to the different tribes and regions for religious and aesthetic reasons. Similar instances of dental modification have been seen in modern dentistry where ornamental gold crowns are placed on the anterior teeth.(39) Another form of dental jewellery is the dental grill. Grills can be composed of gold, platinum, or other metals and are often worn on the anterior teeth.(40) The demand for aesthetic dentistry has noticed a rise in the demand for gold inlays, followed by silver inlays and dental grills.(41)

An individual's dental pattern is considered as unique and identifiable as their mtDNA sequences. Different combination patterns of missing, filled, and unrestored teeth were found to be distinctive and appropriate for use in forensic identification.(42) Furthermore, dental patterns have been validated as an excellent means of forensic identification, especially when AM radiographic evidence is available. Dental restorations can be distinctive as they have unique sizes, shapes and wear patterns.(42) Dental interventions are not limited to restorations alone, and may include extractions, placement of prostheses such as full or partial dentures, and a range of surgical treatments. Teeth may also be missing because they failed to develop. Unique features within dental prostheses could be as simple as the exposed metal in a ceramo-metal crown.

Treatments such as dental implants or dentures can be beneficial in the identification process. Implants placed into an individual's body are often labelled with identification or serial numbers.(43) Dental implants vary in morphology according to the type, system and manufacturer. They are marked according to serial or batch numbers. Recently, innovations in implantology led to laser labelling of batch numbers directly onto dental implants.(44) When an unidentified body is found with one or more implants in the jaws, and no dental record is available, clues gleaned from the type of implants used could give direction to the investigation.(45-47) However, the large number of implant systems with different designs makes this a difficult task when no records are available.

Radiographic identification is one method by which an implant can be identified by clinical features such as connection type, length and diameter of the implant.(48) Several studies have looked at the identification of dental implants however currently no international dental implant database exists. Due to their physical properties, implants resist thermal insult. However, since they are mass produced, their lack of uniqueness limits the use of implants in identification and exposure to high temperatures could affect any batch or serial number etched onto their surface. A study by Berketa et al. indicated that batch numbers within Straumann™ implants survived heating to 1125 °C where an abutment was attached.(49) The insertion of serial numbers on each implant could help establish a new approach to identify unknown persons. An international dental implant database or improved methods for accurate implant recognition are important as they would aid in the identification of unknown individuals where implants are found.

Identification of a body can be more challenging if most or all of the teeth are missing, a situation which is commonly seen in older individuals. In such cases, the individual's dentures could be useful tools in identification. Complete dentures as well as acrylic based partial dentures are not ideal tools to use in identification as they do not fit with the same precision as dentures made with metal frames. Of all the removable dental appliances, metal-framed partial dentures provide the most distinctive information. These are precision-made to fit a

single mouth so they may provide a good method of identification. However, if there is no AM information about the identity of the person to whom they belonged in life, their presence is not helpful. Nevertheless, they are occasionally found in the home of a missing person in which case the identity of the owner may be inferred.(50) Dentures may be marked with identifying information, allowing one to trace the individual.(50, 51) Numerous methods have been proposed for marking dentures either with the patient's identity number or with a QR code. Marking of dentures could aid in the identification of individuals where dental treatment is visible however this is not general practice.(52) These identifying markings can either be surface markings or inclusion markings.(53)

Surface markers are economical but can be easily removed by denture cleansers, abrasives, or antiseptic mouthwash. Surface inclusion techniques consist of the incorporation of a marker, which includes metallic or nonmetallic materials, microchips and barcodes which vary widely in relation to the inclusion technique and reading. (54) Although, inclusion techniques using metallic and nonmetallic labels they are cost effective and easily available, they carry very little information. Microchips, barcodes, and radiofrequency identification tags permit rapid identification through the storage of a large amount of information, but these techniques are costly and require sophisticated equipment to read and access the information.(54) Ideal requisites of a denture marker include: that it should be biologically inert, easy to apply, aesthetically acceptable and inexpensive. They should also be acid-resistant, durable, resistant to everyday disinfecting agents and able to survive elevated temperatures.(55) Mouth guards and orthodontic appliances can also be utilised for identification in a similar manner as dentures. Untouched dentitions on the other hand represent more of a challenge to forensic odontologists, as there are no acquired dental characteristics to be used for comparison.(56)

Dental identification is one of the most reliable methods of identification as teeth and dental structures survive PM. Human teeth have a number of distinctive features and are able to withstand many chemical and physical insults that would destroy other bodily tissues.(31)

Because teeth are heavily calcified, they resist fire as well as a great majority of traumas. The identification of dental remains is therefore of prime importance when the deceased person is skeletonised, decomposed, burned or dismembered.(50)

Dental identification is a quick, cost effective, easy and accurate method of human identification to be used within the South African context.(30, 57) Furthermore, the status of a person's teeth changes throughout their life and the combination of decayed, missing and filled teeth is measurable and comparable.(58) However, this form of identification is dependent on the availability, adequacy and accuracy of AM dental records that can be compared with the PM dental findings.

In a routine dental examination, a thorough clinical and radiological examination is carried out on each tooth as well as the surrounding oral tissues. Observations such as distinctive shapes of restorations, root canal treatments and buried root remnants can be identified by examination of these radiographs.(58) In some instances a single tooth may be all that remains, and upon comparison of radiographs, a positive identification can be made. Radiographs taken at the time of autopsy should as closely replicate the angles at which the existing radiographs of the deceased were taken. The use of digital radiographs in modern dentistry has made this possible.(59) Findings such as damaged dental restorations, disintegration of dental tissues and failure to recover all teeth PM make identification difficult in some cases.(60) If an individual's AM dental records are matched with the PM dental findings seen in the body, a positive identification can be made. This is referred to as having "concordant dental features".(61)

Bernitz at al. defined concordant dental features as those features of an individual's dentition that could not possibly be confused with any other individual's dentition. They are the features that make an individual's dentition unique to them. Enough concordant dental features, and no inconsistencies, will aid in determining a positive identification of the individual.(61) Even a single tooth with unique concordant features and no discrepancies may

be considered adequate for a conclusive identification. Conversely, a single discrepancy would cast doubt and would require explanation, failing which an exclusion decision would have to be made. Dental charts are a proven valuable and useful tool in forensic human identification and can lead to the identification of unidentified human remains.(56, 62) However in instances where there is an absence of traditional methods of comparison such as clinical record charts and radiographs, new methods of forensic identification must be sought to accommodate our technological evolution.

With the rise of social media there has been a growing global trend toward using digital cameras to obtain selfie photographs. Social media use is increasingly widespread among young people and selfies have become a way of life.(63) One readily available resource that could be used to aid in forensic identification in SA, taking into account its socioeconomic standing, is a selfie. The main focus of a selfie is on an individual's facial attributes, including their smile.(64) Clear selfies showing multiple dental features can be used to positively identify decomposed, burned and mutilated bodies where the dentition remains untouched. Hinchliffe noted that when dental records are not available or are of poor quality, good quality smiling photographs showing the positions, angles and unique features of the anterior teeth might play a part in dental identification.(8, 65) Good quality dental records are an essential part of patient dental care, but not every country has rigorous standards for the documenting of dental treatment and the retention of dental records. Developing countries in particular, have a frequent absence of good dental records that pose a hindrance to a dental comparison in forensic identification.(27)

Technology has advanced exponentially, such that today about 2.5 billion people worldwide have smart phones.(66) The mobile phone distribution rate reflects that many South Africans have more than one smart phone and only 9% of South Africans do not have a phone at all.(67) The high incidence of smart phone users within our country's population supports this study's aim and objectives. The innovation of the camera phone, which was launched just 19 years ago, has made digital photography available to a vast

section of the population. According to a poll with 3,000 people, every third picture taken by an individual is a selfie.(68) The Oxford English Dictionary already in 2013 designated selfie as its International Word of the Year. Due to their growing popularity and functionality, smart phones are increasingly valuable tools for health and medical research.(66)

Middle and high income earners are not the sole purchasers of smart phones. Unemployed individuals as well as those with low income jobs also possess mobile phones. A United Nations report revealed that more people now have mobile phones around the world than have access to a flush toilet.(69) Considering that the flush toilet is several centuries old and the mobile phone only about 30 years old, there is a significant difference in the adoption of the two technologies.(70)

Gyathri et al. highlighted that with the advancement of electronic, telecommunication and social networking, selfie photographs are becoming more common.(71, 72) They proposed that using the smile line and superimposition of the images, selfies could be used for comparison with PM findings and could serve as a tool for human identification. A good quality AM smiling photograph may prove useful for the comparison process or as an aid in dental superimposition. Clinical photographs may record teeth of a patient in some detail. They can be useful for comparison with similar photographs of the teeth of a deceased person. Mehrotra et al. identified individuals by matching AM smiling photographs with PM dental casts.(73) He matched the shapes and forms of the individuals' teeth with the teeth in dental impression model casts and found that there was a positive correlation between the two. This means that the smiling photographs could be accurately matched with the dental cast models. This was achieved through the technique of photographic superimposition. Such a technique is more reliable than craniofacial superimposition where the comparison is carried out between facial soft tissues and cranium skeletal structures.(74) Reesu et al. aimed to increase the accuracy of dental identification using an 2D superimposition of a smile with a 3D dental cast as an alternative to PM photographs.(83) This study found that the inter- and

intra-rater reliability using the 3D superimposition was the highest. Their procedure intended to provide an alternative method for forensic odontologists.

There is a need for intra and extra oral photography in dentistry to be explored.(75, 76) Ferreira et al. stated that "the use of intraoral photographs for forensic purposes must be encouraged in medico-legal institutes."(77) These photographs are practical, easily attainable, cost effective in addition to being absent of radiation. The increased use of intraoral photographs for clinical purposes, along with the popularisation of digital cameras, is providing more material with potential value for forensic odontology. Selfies and photographs constitute a reliable source of information with the potential to help solve certain cases of human identification and have been described as reliable tools in the human identification process.(74)

When considering the use of selfies for forensic comparison, one must have an understanding of the possible changes that occur to the images once taken. When images are taken on a mobile phone, they are compressed for effective storing and ease of sharing. (78) As selfies are captured by front cameras with limited pixel resolution, the fine details are missed. Though the front camera is designed for video conferencing, it is often used to capture selfies.(71) Selfies usually undergo high compression; while this is an advantage in that it saves space on the device, the disadvantage is that it may not maintain the image quality. Joint photographic expert group is a lossy compression technique to store 24-bit photographic images. In lossy image compression there is some amount of information loss in the image resulting in an image of lower resolution or lower quality.(79)

The quality of these images that can be used for the identification of dental features is therefore in question. Selfies are widely shared as Joint Photographic Experts Group (Jpegs) of low resolution via social media.(80). There is a need to improve the quality of these images. For these reasons it is important to note that selfies should be used as supplementary dental AM evidence and not as a standalone tool in dental identification.(81) The use of selfies in

forensic identification should ideally be used in conjunction with other previously mentioned methods of identification.

Nuzzolese attempted to introduce a new application for smart phones called “Selfies in Forensic ID”. (82) This application aimed to employ selfies and facial photographs as an archive of dental data and dental features of the front teeth of missing persons.

As yet, no forensic mobile application exists with the aim of assisting the human identification process. There is also very little evidence in the literature of studies employing dental superimposition.

CHAPTER 3: Methodology

3.1 Study design

The study was an analytical observational, cross-sectional study.

The study was carried out at Pholosong Hospital Dental Clinic. This is a Provincial hospital which is located in Tsakane, in the Eastrand, Gauteng Province. The hospital serves a population of about 900,000 individuals a year from Tsakane, Kwa-Thema and Duduza. Pholosong's dental clinic deals mostly with trauma and surgical cases, and services mostly black South Africans. Consent from the hospital to carry out the study was obtained. (Annexure 4)

3.2 Participant selection

As part of a routine dental examination, patients were asked whether or not they own a smart phone. If they answered yes, they were asked if they were willing to provide a selfie photograph of themselves.

The inclusion criteria for the study population included patients who were above 18 years of age and who possessed a smart phone.

3.3 Research procedure

Data was collected from 20 November 2019 to 20 May 2020 from dental patients of the Pholosong Hospital Dental Clinic. A study period of six months yielded 1 098 cases which was sufficient for statistical purposes and allowed for the establishment of trends.

Patients were requested to provide a single selfie photograph of themselves, either alone or in a group. The participants who agreed to participate in the study were requested to sign a

consent form (Annexure 5) which explained that this was a study that was evaluating the feasibility of using mobile cellular phone images for the identification of individuals post mortem when one does not have access to fingerprint, DNA or dental records. The author did not instruct the participants to provide a smiling selfie; instead the participant was free to select any selfie of their choice. This was done to avoid any bias or influence from the investigator.

All selfies were assessed to identify whether the teeth were visible and displayed identifiable features. All collected images were stored on a database and given a unique study number which correlated with the patient's hospital file number.

3.3.1 Demographic and image information

Once the selfie photograph was provided, the photograph was assessed and data was recorded in a Data Collection Form (Annexure 6).

For each image the following details were recorded if available:

- Age;
- Gender;
- Ethnicity;
- Date photograph was taken;
- Dimensions of photograph;
- File type and size (ie. Jpeg)

3.3.2 Image usability

Usability of each of the selfie images was assessed and the images were classified as follows:

- Images where the dentition was visible and identifying dental features could be seen. These images were scored **1**.
- Images where the dentition was visible but identifying dental features could not be seen. These images were scored **2**.
- Images where the dentition was not visible or quality of the image was poor. These images were jointly scored **3**. (Scored separately as **3** and **4** on data capturing sheet)

3.3.3 Image analysis

Once the images were classified for usability, all images where the dentition was visible (**scored 1 and 2 usability classification**) were further analysed for the following dental features:

- Smile span
- Number of visible restorations and decay
- Diastemas
- Discoloured teeth
- Teeth with a difference in tooth height
- Number of visible dental crowns
- Crowding in the dentition
- Midline deviations
- Dental jewellery; such as gold inlays and onlays
- Visible dental anomalies and supernumerary teeth
- Number of missing teeth
- Other dental features such as chips, attrition, erosion

All captured data underwent intra- and inter-observer agreements and checks using Cohen's Kappa coefficient to ensure standardisation of all results. Intra-observer analysis was performed by the principal investigator. Of the collected selfies, 300 were re-analysed for a second time to ensure standardisation of the allocated scores to each selfie and to correlate the identifying dental features. This was performed 6 months after the initial analysis was done. For the inter-observer analysis, an independent expert analysed 300 random selfies.

3.4 Statistical analysis

The data analysis consisted of frequencies and descriptive statistics such as means, standard deviations and percentiles. Intra-observer reliability and inter-observer reliability was assessed on 300 of the collected images. Cohen's kappa coefficient was found to be statistically significant, with a p value of $p<0.001$.

3.5 Ethical considerations

This study was conducted following approval by the Faculty of Health Sciences Research and Ethics Committee (Ethics number 740/2019) in terms of the National Health Act (Act 61 of 2003) and the Code of Ethics for Research of the University of Pretoria. Participation in the study was undertaken on a voluntary basis. Consent was obtained from each participant after they had been informed about the study. The purpose of the study was explained to the participants on the consent form. Any individual who chose not to participate or opted out of the study was not disadvantaged in any way; they still received the usual standard of care. Participation in this study did not result in any undue costs to the participants. To maintain confidentiality, a research number was allocated to each sample case with only the researchers having access to the correlators. Any patient identifying data was removed prior to submission for statistical analysis. No case specific data was published in the findings of the study, and the participants' eyes were hidden after collection of the images.

The data collection sheets were in sole possession of the researcher, and were scanned and uploaded onto an external server in the department. All the original research documents and data will be stored in a locked cupboard in Room 6-16 at the Oral and Dental Hospital of University of Pretoria for a minimum of 10 years.

CHAPTER 4: Results

A total of 1098 selfie photographs were collected from 20 November 2019 to 20 May 2020 (N=1098). All the identified dental features which have been highlighted within this study were correlated with the clinical examination. This was done to ensure that dental features which might have been represented as mirror images in the selfies could be correctly identified and recorded.

4.1 Demographic and image information

4.1.1 Age

The minimum age of participant in this study was 18 years old and the maximum age was 66 years of age. The average age of participants in this study was relatively young at 30 years of age.

Table 1. Descriptive statistics for the age of the participants that provided selfie photographs

	Mean	Standard deviation	Range	Minimum	Maximum	Percentiles		
						25th	50th	75th
Age	30.5	6.9	48.0	18.0	66.0	26	29	35

4.1.2 Gender

Of the 1098 participants that provided selfie photographs, 805 (73.3%) were female, while 293 (26.7%) were male.

Table 2. Gender distribution of the participants that provided selfie photographs

	Frequency	Percentage
Female	805	73.3
Male	293	26.7
Total	**1098**	**100.0**

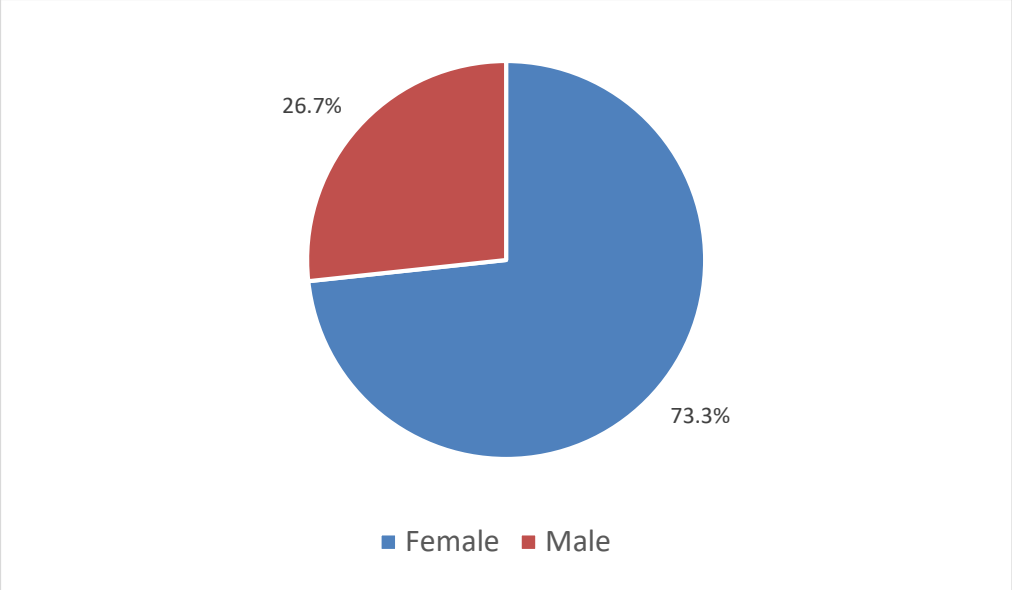

Figure 1. Gender distribution of the participants that provided selfie photographs

4.1.3 Ethnicity

Ethnicity of the participants was recorded by self-identification. One thousand and twenty-seven (93.5%) participants self-identified themselves as Black, 47 (4.3%) as Asian, 22 (2.0%) as white and 2 (0.2%) as coloured (Table 3). In the South African context, the term "coloured" refers to a person of mixed European (“white”) and African (“black”) or Asian ancestry.

Table 3. Ethnicity of the participants that provided a selfie photograph

	Frequency	Percentage
Black	1027	93.50
Asian	47	4.20
White	22	0.20
Coloured	2	0.18
Total	**1098**	**100**

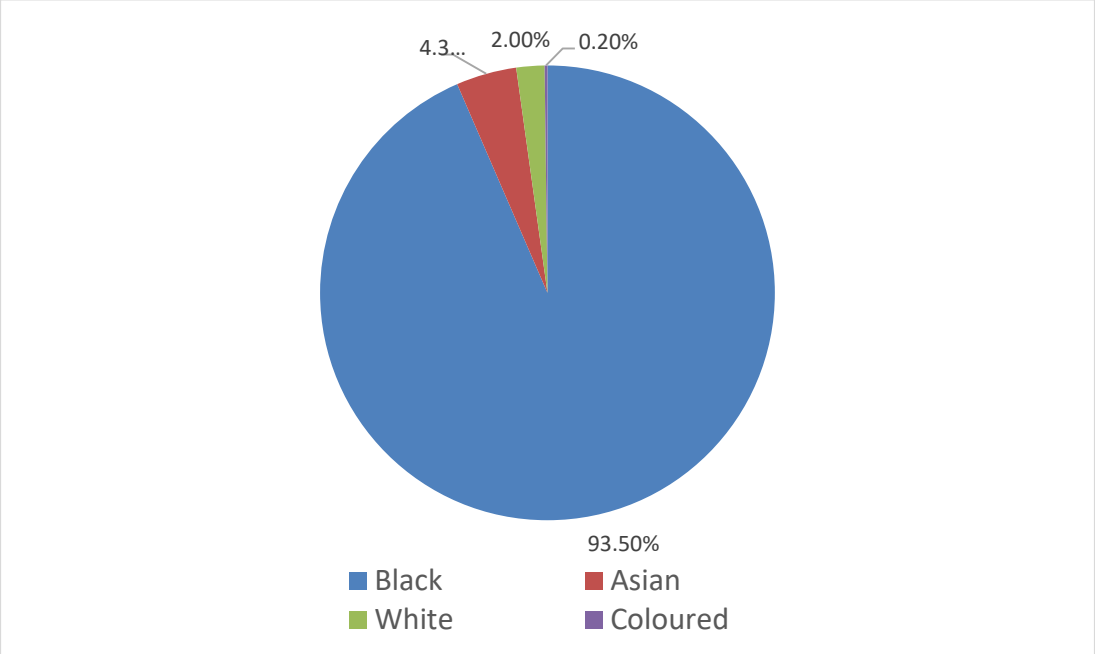

Figure 2. Ethnicity of the participants that provided a selfie photograph

4.2 Image usability

The quality of the images collected for this study played a role in how many teeth and identifiable features could be seen in the dentition. All the images received were Jpegs. Most of the study participants were in possession of basic smart phones that had a low quality camera. As a result of this, many of the received images were of insufficient quality to use for the identification of characteristic dental features.

Following demographic and image data collection, each image was classified according to whether the dentition was visible or not and the presence of identifying dental features (scored a 1, 2 or 3). In 61 (5.6%) of the 1098 images of the images the dentition was visible and identifiable dental features could be seen.

The dentition was visible, but no identifiable features could be seen in 34.2% (n=376) of the collected images. The individual's dentition was not visible in 638 (58.1%) of the collected images. The image quality was poor in 2.1% (n=23) of the collected images, therefore these images could not be analysed (Table 4).

Table 4: Extent to which features of individual's dentition were visible in the selfie photographs

	Frequency	Percentage
Dentition is not visible	638	58.1
Dentition is visible, but identifiable features cannot be seen	376	34.2
Identifiable features are seen in the mobile image	61	5.6
Quality of image is insufficient	23	2.1
Total	**1098**	**100.0**

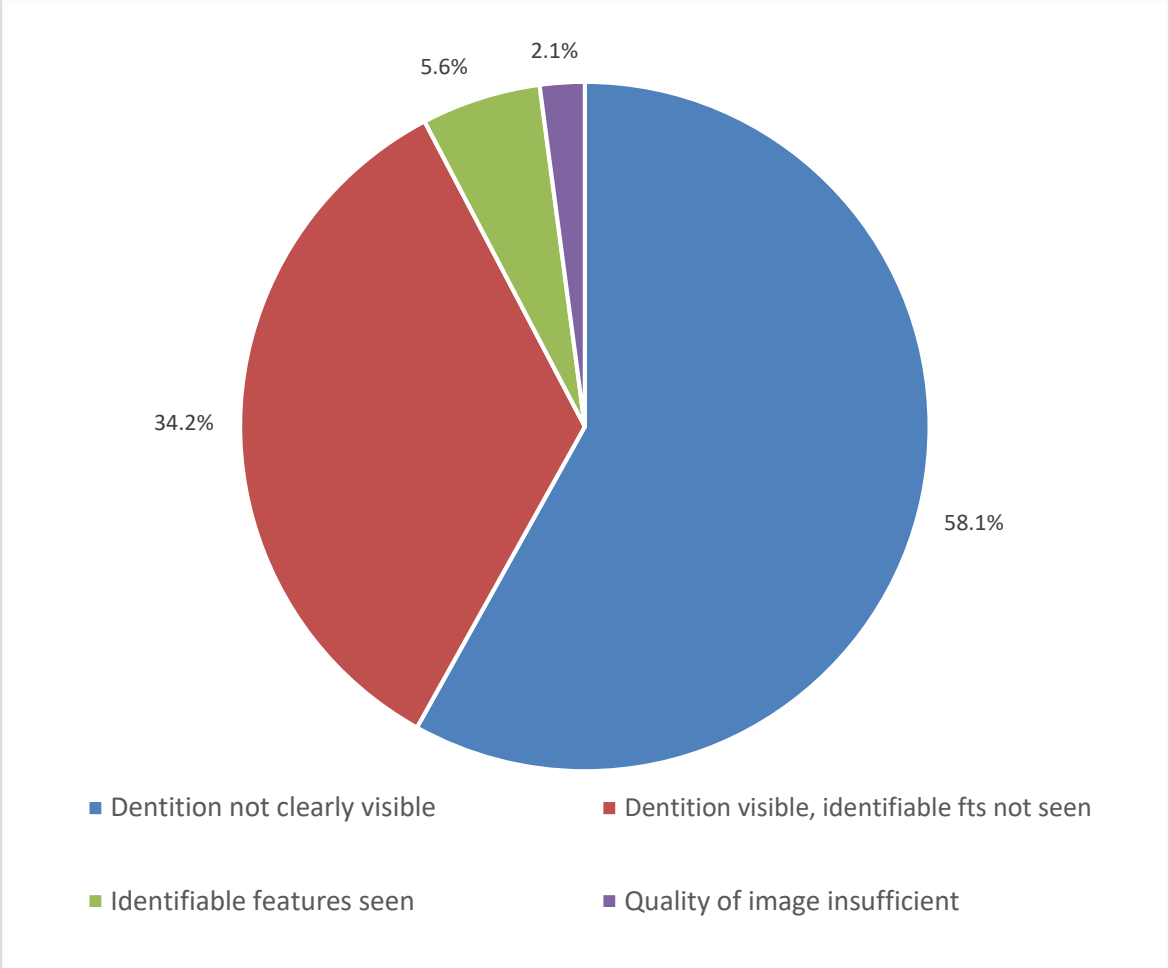

Figure 3: Distribution of visible features of individual's dentition

4.3 Identifiable dental features

The images where the dentition was visible (**scored 1 and 2 classification**) were further analysed for identifiable dental features. All identifiable dental features are summarised in Table 7.

4.3.1 Smile span

The smile span included the number of teeth clearly visible on the selfies (Table 5). In instances where the dentition could be observed but individual teeth could not be distinguished in number, these images were classified as 0 teeth in the smile span. This was performed as some selfies had visible dental features even though individual teeth could not be distinguished. These images were initially classified as 1 for image usability. There were 8 (13.1%) images that presented with this scenario (example can be seen in Figure 4) and the most common dental features seen in these images were diastemas and dental jewellery. Just under 60% of the images showed a broad smile with either 4 (27.9%) or 6 (29.5%) teeth visible.

Table 5. Smile span (Number of individual teeth visible in the selfie)

Smile Span Distinct no. of visible teeth	Frequency	Percentage
0	8	13.1
1	0	0
2	4	6.6
3	0	0
4	17	27.9
5	5	8.2
6	18	29.5
7	8	13.1
8	1	1.6
Total	**61**	**100**

Figure 4. Example when the dentition was visible but the number of teeth could not be distinguished. The smile span was therefore classified as 0 teeth.

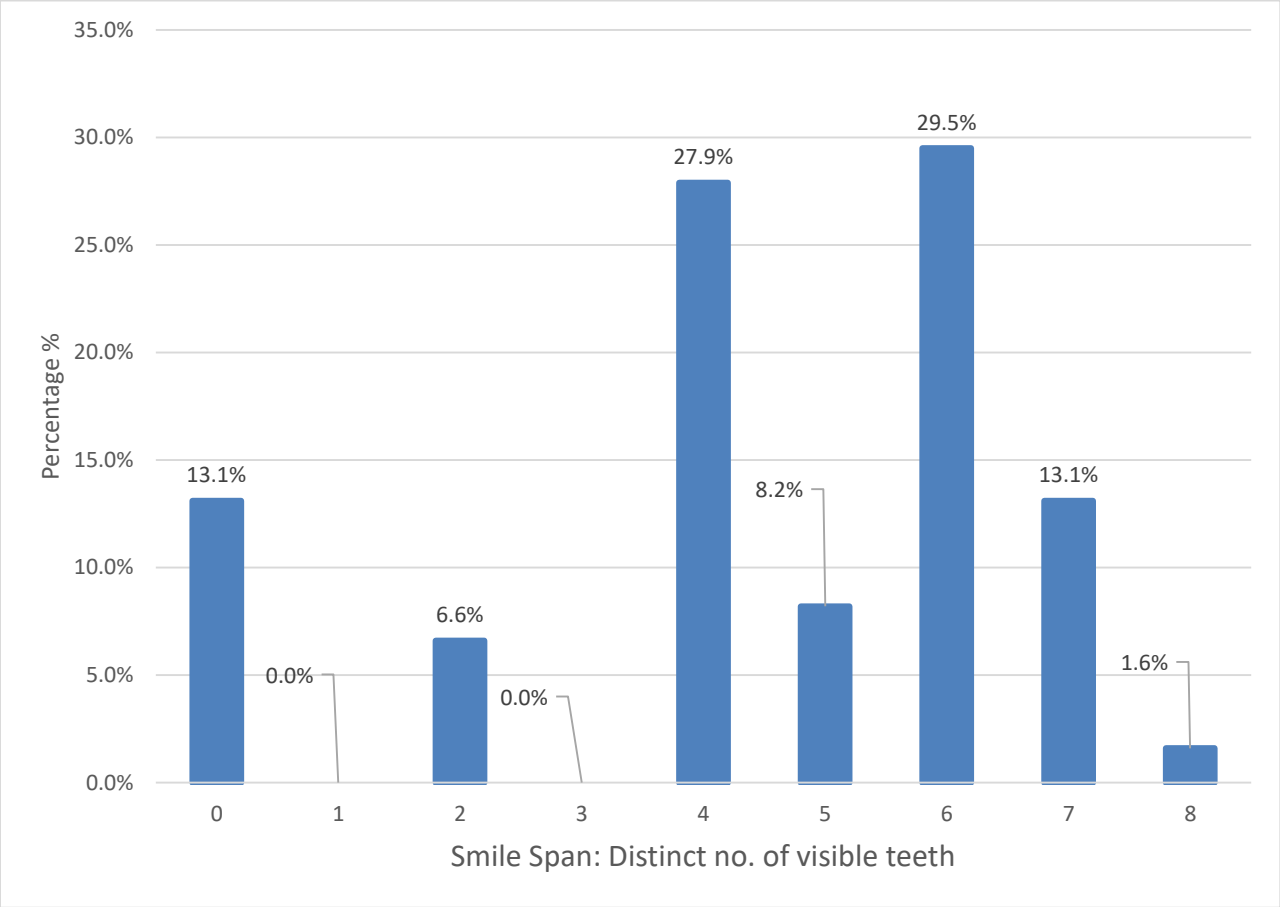

Figure 5. Distribution of Smile span (Distribution of individual teeth visible in the selfie)

4.3.2 Number of visible dental restorations or tooth decay

One (1.6%) of the collected selfies was identified as having visible dental decay. The decay was visible interproximally between the maxillary central incisors (between 11 and 21). It was noted that those individuals who displayed dental decay on the clinical oral examination, did not generally provide smiling selfies.

4.3.3 Diastemas

Selfies showing diastema in the dentitions was a relatively common finding. Diastemas were seen in 30 (49.2%) of the 61 selfies in which identifiable dental features could be seen. This made it the most common feature seen in this collection of images. All the selfies with diastemas were from self-identified black South Africans.

4.3.4 Discoloured teeth

A visibly discoloured tooth was noted in 5 (8.2%) of the 61 images which depicted identifiable dental features. The most common discoloured teeth were maxillary central incisors.

4.3.5 Teeth with a difference in tooth height

A difference in tooth height between the upper central incisors (11 and 21) was seen in 10 (16.4%) of the 61 images with identifiable dental features. The differences in tooth height within mandibular teeth was not observed as most of the selfies did not display the mandibular teeth.

4.3.6 Number of visible dental crowns

Tooth coloured dental crowns were not well visualised on the selfies, comparatively; full gold dental crowns were more easily observed. Two (3.2%) of the 61 selfies showing identifiable dental features exhibited a tooth coloured dental crowns. Gold crowns were analysed as part of dental jewellery.

4.3.7 Crowding in the dentition

Visible dental crowding was seen in 10 (16.4%) of the 61 images with identifiable dental features.

4.3.8 Midline deviations

Midline deviations were present in 4 of the 61 selfies with identifiable dental features. This represents 6.6% of the 61 selfies.

4.3.9 Dental jewellery; such as gold inlays and onlays

The second most commonly found feature in the 61 selfies was the presence of dental jewellery on the anterior teeth; these were either full gold crowns or gold inlays of either an L or U shape on the upper anterior teeth. Of the 61 images that exhibited identifiable dental features, 23 (37.7%) had teeth with dental jewellery. The majority of the dental jewellery was found on the anterior maxillary incisors 11, 21, 12 and 22.

The most common dental jewellery in the collected images was the gold slit/ inlay. Gold inlays constituted 17 of the 23 images where dental jewellery was seen, this translates to 73.9% of the dental jewellery seen.

4.3.10 Dental anomalies and supernumerary teeth

Only 1 selfie was found depicting a dentition with a dental anomaly. The individual in the image had peg shaped lateral maxillary incisor and this selfie constituted 1.6% of the 61 selfies with identifiable dental features. No selfies were collected which depicted supernumerary teeth.

Throughout the data collection, there were 6 dental features that were found to be the most common amongst all the other features (Table 6.)

4.3.11 Number of missing teeth

Four out of 61 images (6.6%) with identifiable dental features had dentitions where a tooth was missing. The most commonly observed missing tooth was the maxillary first premolar (tooth 14), which was missing in 3 of the 4 images which depicted missing teeth.

4.3.12 Dental features such as chips, attrition, erosion

These features were not commonly seen in the collected selfies. Only 5 (8.2%) selfies exhibited visible tooth chips. All the noted tooth chips were seen on anterior incisor tooth (on the maxillary central incisors, teeth 11 or 21). There were no selfies in which dental attrition or erosion could be seen.

Table 6. Summary of the most common identifiable dental features visualised on the 61 selfie photographs

Feature	Frequency	Percentage
Diastema	30	49.2
Dental jewellery	23	37.7
Difference in tooth height	10	16.4
Crowding	10	16.4
Discoloured tooth	5	8.2
Missing tooth	5	8.2
Tooth chips	5	8.2

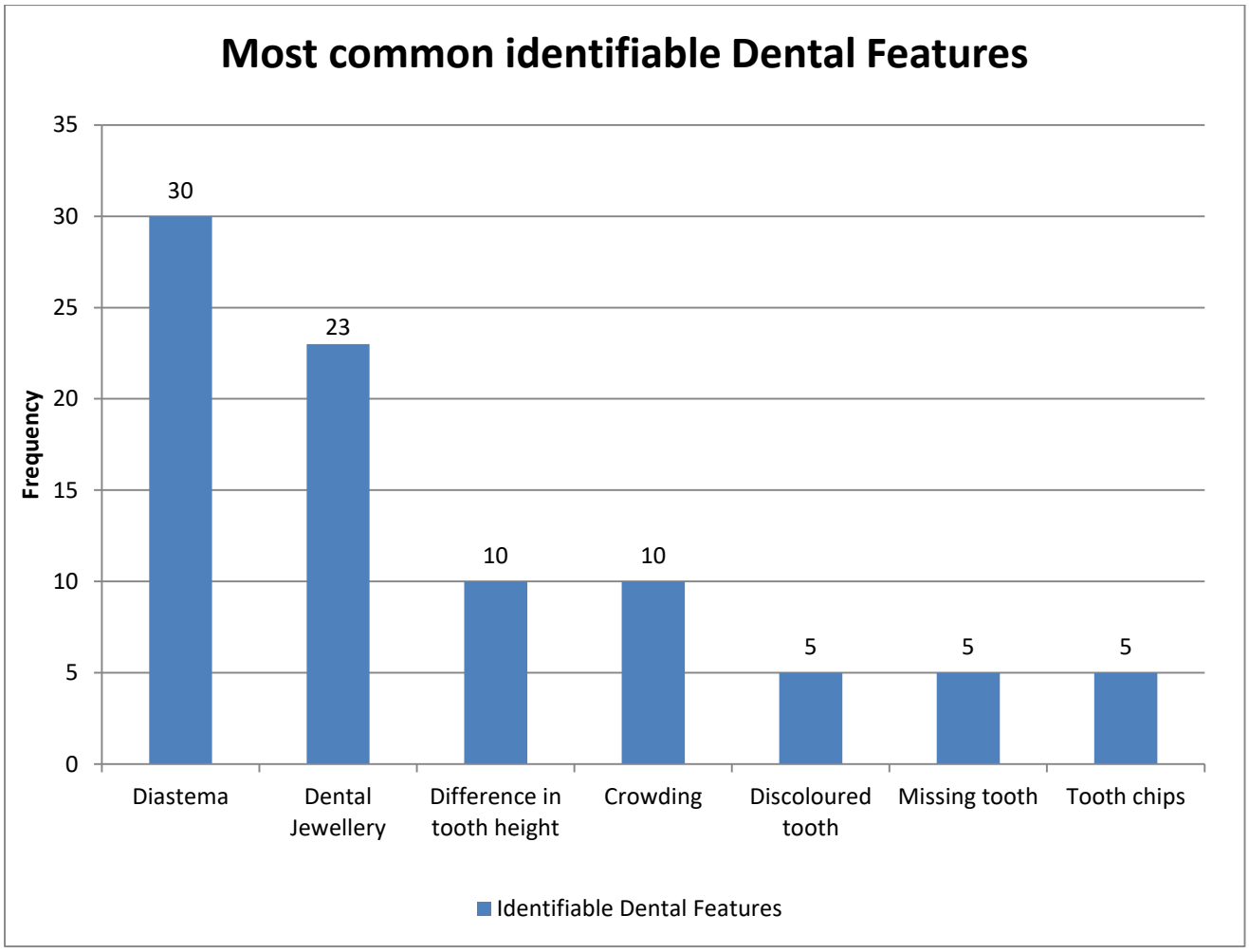

Figure 6. A summary of the most common identifiable dental features visualised on the 61 selfie photographs

Table7. Summary of all the dental features identified in 61 selfie photographs

Summary of the dental features identified in 61 selfie photographs				
Feature	**Present**	**Missing**	**% value**	**Total**
Visible dental restorations or tooth decay	1	60	1.6	61
Diastema	30	31	49.1	61
Supernumerary teeth	0	61	0	61
Discoloured teeth	5	56	8.1	61
Difference in tooth height	10	51	16.4	61
Visible dental crowns	2	59	3.2	61
Crowding	10	51	16.4	61
Midline deviations	4	57	6.5	61
Dental jewellery	23	38	37.7	61
Dental anomalies	1	60	1.6	61
Number of missing teeth	5	57	8.2	61
Number of tooth chips	5	56	8.2	61
Attrition, erosion	0	61	0	61

4.4 Intra- and Inter-observer reliability

Intra-observer reliability was assessed by the principal investigator. Of the collected selfies, 300 were analysed for a second time, 6 months after the initial analysis was done. It was found that the results for these selfies did not differ from the initial analysis results. Cohen's kappa coefficient was 0.972 and found to be statistically significant, with a p value of $p<0.001$.

Table 8. Intra-observer reliability

	Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Kappa agreement	0.972	0.012	21.991	<0.001
N of Valid Cases	300			

Inter-observer reliability was assessed by an independent expert analysing 300 random selfies of those collected. The results obtained by the two investigators were observed and assessed to find whether or not there were any discrepancies in the two data sets. Cohen's kappa coefficient was 0.966 and found to be statistically significant, with a p value of $p<0.001$.

Table 9. Inter-observer reliability

	Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Kappa agreement	0.972	0.012	21.991	<0.001
N of Valid Cases	300			

CHAPTER 5: Discussion

This study is the first in SA to investigate the possible use of selfies for the visualisation of characteristic dental features. Evaluating new methods for the identification of individuals is important, especially considering the challenges of access to health care and dental treatment in SA.

The unique and highly characteristic nature of the dentition enables dental identification to be made with a high degree of certainty.(83) It has been shown that as the number of recognisable dental features increases, the likelihood of a positive identification also increases.(83)

Selfie taking culture differs between age and gender groups.(84, 85) The mean age of the participants in this study was relatively young at 30.5 years. In the cases where older individuals had camera phones, most of them reported that they did not take selfies. The availability of selfies for identification is thus generally restricted to younger individuals and may become more difficult to source in older persons requiring identification. Studies have shown that there is a higher prevalence of use and ownership of mobile phones in adolescents than in adults.(86) In fact, in the past few years, phone usage rates have also considerably increased among school children aged 6–10 years.(86) This generational difference is an important aspect to consider. Where selfies are unavailable, smiling photographs, where the dentition is clearly visible, can also serve as an excellent source of dental information.(74)

In this study more female participants provided selfies (73.3%) than male participants (26.7%). This might simply be due to more females attending the dental clinic than men. Nonetheless, literature shows that women are more likely to schedule a dentist visit and are more proactive than men in maintaining healthy teeth and gums.(87) This may impact the gender profile of individuals attending the dental clinic for treatment. This study was conducted at one facility and the ethnicity of the participants was recorded by self-

identification and reflects the population demographics of the area. The majority of the participants in this study (93.5%) self-classified as Black South Africans.

The participants were requested to send the investigator a selfie of themselves or in a group which was not older than 1 year. The time frame was to ensure that the study participants' dentitions had not changed since the image was taken. The relatively poor quality of the majority of the images made it difficult to accurately identify subtle dental features. Had this study been conducted in a more affluent area where individuals firstly have better access to heath/ dental care and secondly better quality cellular phones, a different result could have been obtained.

Most of the study participants did not provide smiling selfies. The majority of selfies were of individuals with a short smile span or with their mouths fully or partially closed. The dentition was visible in 376 (34.2%) of the 1098 collected images and identifiable dental features could be seen in 5.6% (n=61) of these images. A large proportion of the images being unusable for the identification of dental features as there were no visible teeth in those selfies.

A contributing factor to the low number of smiling selfies collected in this study could be the oral health status of the participants. Individuals living in lower socio economic areas have poor access to oral healthcare and therefore oral health awareness is low. In this study, individuals with undesirable dentition would commonly choose to take a selfie with a closed mouth where their teeth would not be visible. There was only 1 selfie collected which showed dental caries in this study (1.6%), emphasising the fact that those with decayed teeth choose to not smile in their selfies. Considering that globally 2.3 billion people are estimated to suffer from caries of permanent teeth, it was surprising to note the low number of dental caries visualised in the collected images.(88, 89) The majority of individuals, who provided a selfie with a smile span of 6 or more teeth had good dentitions with no restorations or dental decay. Another reason for the low number of selfies depicting teeth with caries could be that caries prevalence has been found to be higher in posterior teeth as compared to anterior

teeth in both the sexes.(90, 91) Bhardwaj et al. found that mandibular central and maxillary lateral incisors were the teeth least affected by dental caries, while maxillary permanent first molars were the most affected by caries. (92) They stated that caries was 6 times more prevalent in posterior teeth than in the anterior teeth among boys and girls respectively. This can be attributed to the morphological nature of the posterior teeth which have deep pits and fissures.(93)

An example where a selfie was provided with a closed mouth can be seen in Fig.6A. This patient reported that she did not want to show her teeth while smiling due to embarrassment about the state of her dentition. After obtaining consent, the investigator took an intra-oral photograph of the individual's dentition which revealed multiple carious teeth and decayed root remnants (Fig.6B). In many of the non-smiling selfies provided in this study, the participants reported that they were self-conscious about their poor dentitions and therefore hid their smiles.

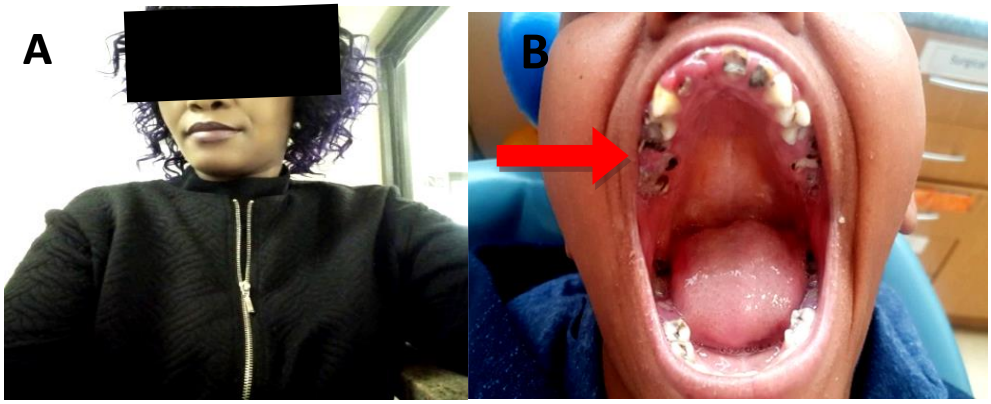

Figure.7A Selfie of an individual with a closed mouth**, B** Intra-oral image of the same patient's dentition.

Mckenna et al. investigated the role that anterior dentition visible in photographs can have in forensic identification.(94) In their study, 100 different photographs and dental models were studied. They found that 96% of the study participants had at least one feature in their dentitions which could be classified as unique. Their study was expanded in which they examined 1000 different photographs to identify the percentage of individuals who showed anterior teeth in these photographs. Their findings revealed that 60.9% of the photographs showed unique dental features and that 76.7% of their collected images were usable in the identification of unidentified persons. The results are in sharp contrast to the present study.

This research was carried out before the Covid-19 pandemic, and the effects of mask wearing were thus not reflected in the research sample. The pandemic has changed selfie culture resulting in more individuals taking selfies while wearing their masks (Fig.7). Mask wearing will reduce the number of visible dentitions in future selfie taking. In fact, the new term "maskie" has been coined to describe this phenomenon.(85)

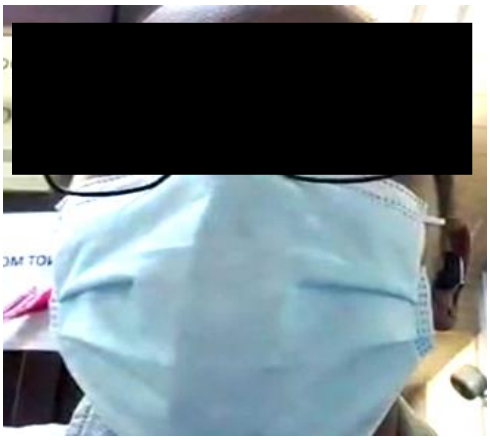

Figure.8 Selfie depicting an individual wearing a face mask concealing the dentition.

It must be stated that the prevalence of features observed in this study are not representative of the general population and are only relevant to this specific group of individuals who showed teeth in their respective selfies. Specific features observed in this

study can however be compared with other studies in which the prevalence was determined in their respective populations.

MMD was the most common dental feature identified in this study. Thirty (49.2%) of the 61 selfies in which identifiable dental features could be seen displayed a diastema. The literature confirms that midline diastemas are a common dental feature with a possible genetic component.(95) Alone this dental feature is not unique, but when considered with a second feature, can be of high forensic identification value. Three distinctive dental features were noted on the selfie in Fig.8; the first feature being a non-vital, discoloured left maxillary central incisor (tooth 21), the second being a gold inlay (tooth 21). The third feature was a large MMD. The more identifiable features visualised on a single selfie, the higher the likelihood of a positive identification.

There were 5 non-vital discoloured teeth (8.1%) noted among the collected selfies. Figure.8 shows a non-vital discoloured tooth 21. Two types of tooth discolorations can be distinguished: those caused by extrinsic factors and those caused by intrinsic congenital or systemic influence.(96) The intensity of stains may be worsened if there are enamel defects, such as fluorosis. The different aetiologies of the discolouration did not form part of this study.

Figure.9 Three dental features visible in one smile. A non-vital discoloured maxillary central incisor (tooth 21) with a gold inlay and large MMD.

The results from this study are similar to those of a study done by Abidia et al in 2017.(97) In their study, 98.3% of their respondents believed that their teeth determined their facial attractiveness and affected their quality of life.(97) Similarly, participants from this study who had poor oral health, tooth loss and untreated carious lesions tended not to take smiling photographs or were unwilling to share their selfies. In both studies, the participants reported that they tried to hide their smile in photographs due to embarrassment about the state of their teeth.

The clinical crown height of a tooth is the measure of the length between the gingival margin to the incisal edge of a tooth. There were 10 (16.3%) selfies which were found to have a difference in tooth height between the maxillary anterior incisors. Fig.9 depicts a difference in tooth height between teeth 11 and 21.

Figure.10 A poor quality image depicting difference in tooth height between teeth 11 and 21.

Dental crowns were observed in 3.2% of the collected selfies (n=2). Lighting and image quality may be contributing factors to the visualisation of the tooth coloured crowns. Gold crowns were more easily visible in the collected selfies than tooth coloured dental crowns. One of the tooth coloured crowns observed on the image was a conspicuous crown on the maxillary left canine (tooth 23). This crown was extremely white in colour and positioned

out of the dental arch (Fig.11). While this would not be an ideal crown for the patient's aesthetic needs, it provides good forensic identification value. It is highly unlikely that another individual would present with a crown showing similar features to those seen in this selfie.

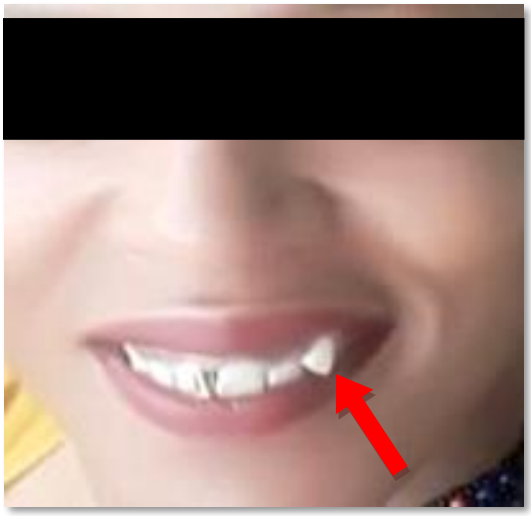

Figure.11 Highly characteristic dental crown on the individual's maxillary left canine (tooth 23).

In contrast to Fig.11, the other selfie showed an example of a more aesthetically pleasing crown on the left maxillary central incisor, tooth 21 (Fig.12). In this case, although a more clinically pleasing crown, it is of less forensic value as it is less conspicuous and more difficult to see on the image.

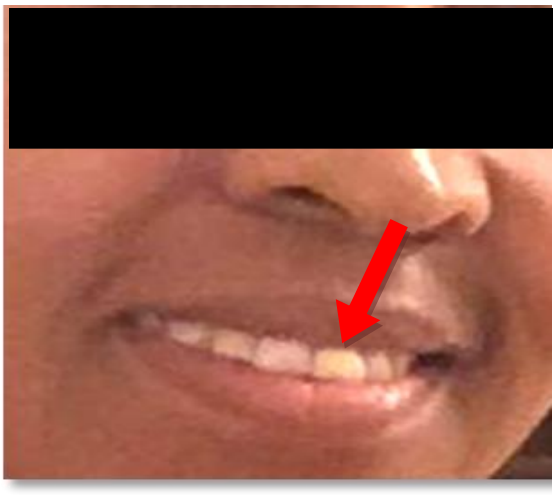

Figure.12 Dental crown on the left maxillary central incisor (tooth 21) with low forensic value.

A commonly observed feature in the collected selfies was dental crowding (Fig.13), which was observed in 10 of the selfies (16.3%). As oral health awareness has increased, there has been an increase in the number of parents who are concerned about dental crowding in their children's dentitions.(98) Dental crowding is defined as a discrepancy between tooth size and jaw size resulting in a misalignment of the teeth. Reasons for crowding can include physical trauma, discrepancies in the relationship between tooth size and arch size, emergence of the third molars and periodontitis.(99) A study by Bernitz et al. found that within the human dentition, anterior teeth have a specific numerical rotation value.(100) This means that even in dentitions of individuals with no crowding, no two smiles would have the exact same teeth alignment at a microscopic level. Crowding or misalignment of the teeth, specifically the anterior teeth, can be used as an identifying dental feature.

Figure.13 Dental crowing showing palatally positioned lateral incisors (teeth 12 and 22).

Midline deviations were present in 4 of the 61 selfies with identifiable dental features (Fig.14. This represents 6.6% of the 61 selfies. Khan et al. found that dental midline deviations are a relatively common finding.(101) They found that dental midlines were coincident with the facial midline in less than half of the sample (47.9%) in their study.

Figure.14 Visible deviation between maxillary and mandibular midlines.

The second most commonly found dental feature in this study was the presence of dental jewellery on the anterior teeth, which was seen on more than one third (37.7%) of the collected selfies. Numerous study participants who were identified as having dental jewellery during the clinical exam did not smile in their selfies, resulting in some of the dental jewellery data not being captured. Dental jewellery, especially gold inlays and onlays, are a common finding in different population groups.(102) In a study by Bhatia et al., 224 dentists in India reported that they practiced the application of tooth jewellery in their clinics.(102) Minimal literature exists on the prevalence of gold dental jewellery in SA, however, a recent South African study by Mtolo et al. reports that there has been a generalised upsurge in the request for gold inlays and dental jewellery within their region(41).

The most commonly seen dental jewellery in this study was the gold slit or inlay. For forensic purposes a gold inlay alone would be of little significance. However, if more than one gold inlay is found in one individual (Fig.15) or if two full gold crowns are found in one individual (Fig.16), the forensic significance is greater.

Figure.15 'U' shaped gold inlays on maxillary central incisors (teeth 11 + 21).

Figure.16 Two full gold crowns on both maxillary lateral incisors (teeth 12 and 22)**.**

A unique form of dental jewellery was observed in one of the collected selfies (Fig.17). Gold onlays with the letters "MRT" and a gold playboy bunny could clearly be seen on the maxillary anterior teeth. This is an example of a unique and characteristic dental feature that would not likely be found in another individual and could therefore be used for dental identification.

Figure.17 Mirror image of gold onlays with the letters "MRT" as well as a gold playboy bunny on the maxillary anterior teeth (11, 12, 21, 22).

A dental anomaly seen in 1 of the collected selfies (0.9%) was a condition known as a peg shaped lateral incisors (Fig.18). Peg laterals are characterised by the maxillary lateral incisors being narrow and conical in shape. The prevalence of peg-shaped maxillary permanent lateral incisors was shown to vary by race, and gender.(103) Hua et al. found the global prevalence of peg-shaped maxillary permanent upper lateral incisors to be 1.8%.(103) To the author's knowledge there is no data available on the prevalence of peg shaped laterals in the South African population. No supernumerary teeth were observed on the collected selfies.

Figure.18 Peg shaped maxillary lateral incisor (tooth 12).

Four out of 61 images (6.6%) with identifiable dental features had dentitions where a tooth was missing. The most common reason provided by the study participants for having missing teeth was extraction subsequent to tooth decay. It was easier to identify a missing anterior tooth in the collected selfies than it was to identify a missing posterior tooth. The mean age of this study's participants was 30.5 years, which could explain why the number of selfies showing missing teeth was low. Complete and partial edentulism affects more elderly individuals than it does younger individuals.(104)

Figure.19 Selfie depicting two missing teeth; right maxillary lateral incisor and right maxillary first premolar (22, 24).

When analysing any study data it is important to consider the population demographics in which the study was conducted. The present study was conducted in the Gauteng province and the incidence of missing teeth was low at 6.5%. Had this study been conducted in Cape Town, an area known for individuals having a "passion gap" or "Cape Town smile", the incidence of missing teeth would have been higher.(105, 106)

In the Cape, it is a cultural practice for individuals to electively extract their maxillary central and lateral incisors (teeth 11, 12, 21 and 22) for aesthetic purposes. The main reason for the gap is dental decay with the front teeth being particularly susceptible and extraction being the frequent treatment.(106) A selfie from the Western Cape population where all 4 maxillary central incisors were missing would not be a significant finding.

A practical example of using a selfie showing characteristic dental features being used for a positive identification can be seen can be observed in Figures 20A and 20B. These images clearly show the absolute pattern match between the upper and lower dentition visualised on the AM selfie and the PM image of the victim. A conclusion of absolute certainty was made in this case.

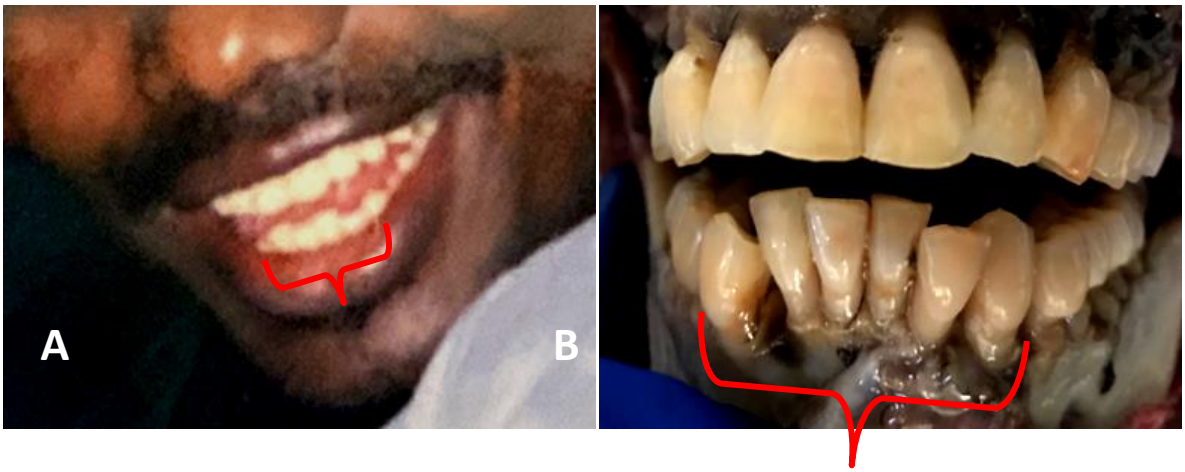

Figure.20A Smiling selfie with visible lower anterior crowding. **B** The same individual's dentition in a post mortem photograph. (Images courtesy of Prof H. Bernitz)

Comparison of a selfie to a deceased individual's dentition requires consideration of the orientation at which the selfie was taken. An AM photograph is crucial when taking PM photographs, as the angulation of the photograph must be reproduced for accurate comparison.(107) Mirror images, where the selfie was taken in a mirror, or where the front facing camera automatically reverses the image, need to be considered as these could be misleading when orientating the image.(107)

To avoid facing this issue, the investigator should thoroughly correlate the clinical PM examination notes with the photographs of the deceased's dentition. We recommend that during PM procedures multiple angled photographs of the deceased's dentition be taken to use for comparison with a provided selfie. Multiple angled PM photographs in the X, Y and Z (depth) axes should be taken for accurate comparison (Fig.21A and B).

Figure.21A, 20B Angled photographs taken during post mortem examination (Courtesy of Prof H. Bernitz).

This study highlighted the fact that many selfies collected in this study could not be used for identifying dental features either due to a lack of smiles or poor image quality. In some instances, highly characteristic dental characteristics could be visualised on selfies even if the smile span was small. The 6 most frequently observed dental features in this study were diastema, dental jewellery, crowding of the dentition, a difference in tooth height and discoloured and missing teeth. Selfies are easy to use, cost effective and accessible sources from which dental identification could be performed.

CHAPTER 6: Shortcomings and Recommendations

A key finding in this study was that the majority of participants with poor dentitions and identifiable dental features such as caries and dental jewellery did not smile in their selfies. Instead, they provided selfies in which their dentition could not be seen. Conversely, participants with good dentitions and no visible identifiable features in their smiles were more willing to provide the author with a selfie where their dentition was visible.

As stated in the signed consent forms, the aim of this study is to evaluate the feasibility of using mobile cellular phone images of individuals to identify them post mortem when one does not have access to fingerprint, DNA or dental records. While the purpose of the study was explained to each participant, they were not made aware of the reason why the author required a smiling selfie as opposed to a selfie where their smile was not visible. For this reason many may not have provided smiling selfies. Had individuals been asked for a smiling selfie from the onset, our sample where the dentition was visible could have been increased. We recommend further studies where individuals can be asked to provide selfies showing their teeth and this could possibly provide different results on the possibility of identifying dental features on selfies.

A selfie is a two-dimensional image of a three-dimensional structure. This makes it difficult to compare the dentition seen in a selfie to the actual smile of an unidentified individual. It is important to keep in mind that morphological and age related changes to the smile or dentition could have occurred since the selfie image was taken.

The usability of selfies during the Covid-19 pandemic where many individuals are wearing masks needs to be highlighted. The wearing of masks will impact the number of selfies being taken or the fact that selfies are now often taken with individuals wearing masks hiding the dentition. This will influence the use of selfies for identification purposes.

The sharing of selfies as a quick and easy means for obtaining medical or dental advice, dermatology triage or even postoperative wound assessment is growing. These images may be unsolicited and sent to clinicians with whom the patient may or may not have a prior doctor-patient relationship or on the instruction of the attending doctor or even on social media groups. Selfies often capture the happy lives of the individuals. The use of selfies offers a quick, cost effective and easy method of identification. However, having to compare happy, smiling selfies to PM bodies can have a psychological effect on the persons carrying out such tasks.

The ethical concerns over the exchange of health information and privacy needs to be explored in such issues and remains a challenge of a rapidly growing technological age. Sharing selfies electronically could create risks to privacy and consent.

CHAPTER 7: Conclusion

The results of this study were contrary to those that were expected and revealed that the application of selfies in dental identification in SA is limited. If a smiling selfie was acquired during data collection, the strength of this study would have increased. Only a small percentage of the collected selfies were usable. The author recommends that one method of human ID should not be relied upon. While selfies on their own cannot be used to identify an unknown individual, they can be used as an adjunct in the identification process.

The importance of good oral health and a beautiful smile cannot be over emphasised. A national drive to improve the general state of oral health in previously disadvantaged communities needs to be implemented with more urgency. The drive must include the importance of selfies.

Considering the growing trend towards selfie taking, the use of selfies in the forensic identification of individuals requires further exploration.

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CHAPTER 8: Addenda

8.1 Annexure 1: RESCOM Approval letter

Chairperson:
Prof LM Sykes
Members:
Prof SM Dawjee
Prof A Bhayat
Dr PD Brandt
Dr S Naidoo
Dr T Madiba
Dr C Davidson
Secretary:
Ms C Swart

RESCOM
School of Dentistry
Faculty of Health Sciences

UNIVERSITEIT VAN PRETORIA
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Dr V Manyukwi

2019-10-02

PROTOCOL APPROVAL: DENT 2019/22

We would like to inform you that your protocol, as recommended by the Research Committee, has been approved by the Chair of School.

Title: "Mobile Images in the Visualisation of Characteristic Dental Features".

Good luck with your research!

PROF L SYKES
CHAIRPERSON: RESEARCH COMMITTEE

8.2 Annexure 2: Faculty of Health Sciences Research and Ethics Committee approval letter

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.

21 November 2019

Approval Certificate
New Application

Ethics Reference No.: 740/2019
Title: Mobile Images in the Visualisation of Characteristic Dental features

Dear Dr V Manyukwi

The **New Application** as supported by documents received between 2019-10-17 and 2019-11-20 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 2019-11-20.

Please note the following about your ethics approval:

- Ethics Approval is valid for 1 year and needs to be renewed annually by 2020-11-21.
- Please remember to use your protocol number (740/2019) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers
MBChB MMed (Int) MPharmMed PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

8.3 Annexure 3: Faculty of Health Sciences Research and Ethics Committee completed approval letter

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IORG #: IORG0001762 OMB No. 0990-0279 Approved for use through February 28, 2022 and Expires: 03/04/2023.

Faculty of Health Sciences **Research Ethics Committee**

11 November 2021

Acknowledgement Certificate
Research Completed

Dear Dr V Manyukwi

Ethics Reference No.: 740/2019
Title: Mobile Images in the Visualisation of Characteristic Dental features

The **Research Completed Report** as supported by documents received between 2021-10-15 and 2021-11-10 for your research, was acknowledged by the Faculty of Health Sciences Research Ethics Committee on 2021-11-10 as resolved by its quorate meeting.

Yours sincerely

On behalf of the FHS REC, Dr R Sommers
MBChB, MMed (Int), MPharmMed, PhD
***Deputy Chairperson** of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria*

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2016 (Department of Health)

8.4 Annexure 4: Approval letter by Department to conduct research at the Hospital

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

EKURHULENI HEALTH DISTRICT
PUBLIC HEALTH UNIT

Enquiries: Mpho Manamela
Tel no: +27 11 878 8617
Fax no: +27 11 878 8587
E-mail: Mpho.Manamela@gauteng.gov.za

TO: UNIVERSITY OF PRETORIA ETHICS COMMITTEE

SUBJECT: PERMISSION TO CONDUCT RESEARCH BY DR V. MANYUKWI IN EKURHULENI DISTRICT, GAUTENG

In principle permission is granted to Dr V. Manyukwi, to conduct research in Ekurhuleni district (Pholosong Hospital) for the following research topic: Mobile Images in the Visualisation of Characteristic Dental features.

This study aims to investigate mobile images in the visualization of characteristic dental features.

The objectives of this study would be:

- Assess the percentage of mobile images where the dentition can be visualised
- Assess whether any characteristic dental features can be seen on the mobile images

The study will include 2000 participants and will take place at Pholosong Hospital Dental clinic, East rand Gauteng. As part of a routine dental examination, individuals will be asked whether they have a smart phone and whether they take photographs of themselves.
If the individual agrees to participate in the study, they will be requested to sign a consent form and send the author a random mobile image depicting themselves.

Ekurhuleni District Research Committee will review the proposal and will only give permission once we have received the final ethical clearance.

Yours sincerely,

Dr Ronel Kellerman
EKURHULENI DISTRICT RESEARCH COMMITTEE CHAIRPERSON
Date: 07 Oct 2019

8.5 Annexure 5: Patient consent form

PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT

STUDY TITLE: Mobile Images in visualilsation of charactteristic dental feaures

Sponsor: None

Principal Investigators: Dr. Vimbai Magagula

Institution: Pholosong Hospital

Ndaba street, Tsakane

Brakpan

DAYTIME AND AFTER HOURS TELEPHONE NUMBER:

Daytime number: (011) 812 5120

After hours number: 062 350 6645

date month / year Time:

DATE AND TIME OF FIRST INFORMED CONSENT DISCUSSION:

To the prospective participant

Dear Mr. / Mrs. .....

1) INTRODUCTION

You are invited to volunteer for a research study.

I am doing research for a Forensic Odontology Masters at the University of Pretoria. The information in this document is to help you to decide if you would like to participate. Before you agree to take part in this study you should fully understand what is involved.

If you have any questions, which are not fully explained in this document, do not hesitate to ask the researcher. You should not agree to take part unless you are completely happlicationy about all the procedures involved.

2) NATURE AND PURPOSE OF THIS STUDY

The aim of this study is to evaluate the feasibilty of using mobile cellphone images of individuals to identify them post mortem when one does not have access to fingerprint, DNA or dental records.

At the end of the study I aim to reveal whether using mobile cellphone images would be a scientifically valid method of comparing ante mortem and post mortem dental features of an unknown individual in the mortuary.

3) EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM PARTICIPANTS.

This study involves answering a few questions from a survey as well as providing the researcher with a mobile image of yourself, which could have been taken by you or someone else.

Your eyes will be blurred out in this image and your personal information will not be revealed. The strictest confideniality will be maintained in this study.

4) POSSIBLE RISKS AND DISCOMFORTS INVOLVED

There are no medical risks associated with the study.

5) POSSIBLE BENEFITS OF THIS STUDY

Although you may not benefit directly. The study results may help us to improve the methods of identification of unknown individuals within South African mortuaries.

6) COMPENSATION

You will not be paid to take part in the study. There are no costs involved for you to be part of the study.

7) YOUR RIGHTS AS A RESEARCH PARTICIPANT

Your participation in this trial is entirely voluntary and you can refuse to participate or stop at any time without stating any reason. Your withdrawal will not affect your access to further medical care.

8) ETHICS APPLICATION

This Protocol will be submitted to the Faculty of Health Sciences Research and Ethics Committee, University of Pretoria, telephone numbers 012 356 3084 / 012 356 3085 and written applicationroval will be granted by that committee.

The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving human/subjects. A copy of the Declaration may be obtained from the investigator should you wish to review it.

9) INFORMATION

If I have any questions concerning this study, I should contact:

Dr V Magagula

Tell : (011) 812 5120

10) CONFIDENTIALITY

All information obtained during the course of this study will be regarded as strictly confidential.

Each participant who is taking part will be provided with an alphanumeric coded number e.g. A001. This will ensure confidentiality of information so collected.

Only the researcher will be able to identify you as participant. Results will be published or presented in such a fashion that patients remain unidentifiable. The hard copies of all your records will be kept in a locked facility at the Oral and Dental Hospital of the University of Pretoria.

CONSENT TO PARTICIPATE IN THIS STUDY

- I confirm that the person requesting my consent to take part in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
- I have also received, read and understood the above written information about the study.
- I have had adequate time to ask questions and I have no objections to participate in this study.
- I am aware that the information obtained in the study, including personal details, will be anonymously processed and presented in the reporting of results.
- I understand that I will not be penalised in any way should I wish to discontinue with the study and that withdrawal will not affect my further treatments.
- I am participating willingly.
- I have received a signed copy of this informed consent agreement.

_____	_____
Participant's name (Please print)	Date
_____	_____
Participant's signature	Date
_____	_____
Researcher's name (Please print)	Date
_____	_____
Researcher's signature	Date

AFFIRMATION OF INFORMED CONSENT BY AN ILLITERATE PARTICIPANT

(if suitable)

I, the undersigned, Dr. V Magagula, have read and have explained fully to the participant, named ..... , the informed consent document, which describes the nature and purpose of the study.

The explanation I have given has mentioned both the possible risks and benefits of the study. The participant indicated that he/she understands that he/she will be free to withdraw from the study at any time for any reason and without jeopardising the his/hers standard care.

I hereby certify that the patient has agreed to participate in this study.

_____	_____
Participant's name (Please print)	Date
_____	_____
Participant's signature	Date
_____	_____
Investigator's Name (Please print)	Date
_____	_____
Investigator's Signature	Date
_____	_____
Name of the person who witnessed the informed consent (Please print)	Date
_____	_____
Signature of the Witness	Date

COMMITMENTS AND RESPONSIBILITIES OF SUB- INVESTIGATORS REQUIRED FOR RESEARCH THROUGH THE FACULTY OF HEALTH SCIENCES RESEARCH ETHICS COMMITTEE, UNIVERSITY OF PRETORIA

DECLARATION BY INVESTIGATOR:

I agree to **personally** conduct or supervise the described investigation.

I understand as sub-investigator that I am **totally responsible** for aspects of the study delegated to me by the Principal Investigator and am legally bound by the contract signed with the sponsor and **will not inappropriately delegate my responsibilities** to the rest of my study team.

I have **read and understand the information in the investigator's brochure**.

I agree **to ensure** that all associates, colleagues, and employees assisting in the conduct of the study are informed about their obligations in meeting the above commitments, without relinquishing my total responsibility for the study.

I confirm that I am **suitably qualified and experienced** to perform and/or supervise the study proposed.

I agree to conduct the study in accordance with the relevant, current protocol and will only make changes in the protocol after approval by the sponsor and the Ethics Committee, except when urgently necessary to protect the safety, rights, or welfare of subjects.
I will ensure that the ICH GCP Guidelines and Ethics Committee requirements relating to obtaining informed consent are met.

I agree to timeously report to the Ethics Committee adverse experiences that occur in the course of the investigation according to the time requirements adopted by the Faculty of Health Sciences Research Ethics Committee, University of Pretoria.

I agree to maintain **adequate and accurate** records and to make those records available for inspection by the appropriate authorized agents, be it EC, FDA or sponsor agents.

I agree to comply with all other requirements regarding the obligations of clinical investigators and all other pertinent requirements in the Declaration of Helsinki and South African and ICH GCP Guidelines and am conversant with these guidelines
I agree to inform the Ethics Committee in advance should I go on leave together with an agreed plan of action regarding an alternate principal investigator or sub-investigator to take responsibility in my absence.

I understand that the study may be audited at any time and that deviation from the principles in this declaration will be put before the Ethics Committee for action, which may include disqualification as an investigator and rehabilitation before being accepted as an investigator in other studies.

I confirm that there is no conflict of interest whatsoever in my participation in this study. I have no shares in the sponsoring company and my participation and interests are as defined in the financial agreement.

---------- ----------

SIGNATURE OF PRINCIPAL INVESTIGATORNAME (Printed) DATE

8.6 Annexure 6: Statistical Data Collection Form

Data capturing sheet

For office use only

Questionnaire number — V0 ☐

1. Have I asked you for a picture within the last year?

Yes	1	No	2

V1 ☐

2. To what extent are the features of the individual's dentition visible in the mobile image?

Identifiable features are seen in the mobile image	1
Dentition is visible, but identifiable features cannot be seen	2
Dentition is not visible	3
Quality of image is insufficient	4

V2 ☐

A. Demographic information

1. Gender

Female	1	Male	2	Other	3

A1 ☐

2. Age .....years — A2 ☐

3. Ethnicity

African	1
Asian	2
Coloured	3
White	4
Other (please specify)	5

A3 ☐

B. Characteristics present

	Characteristic	Present	Absent	Comments	
1.	Difference in tooth height (11 & 21)	1	2		B1 ☐
2.	Dental jewelry	1	2		B2 ☐

3.	Discoloured teeth	1	2		B3	
4.	Diastema	1	2		B4	
5.	Tooth chips	1	2		B5	
6.	Supernumerary tooth	1	2		B6	
7.	Midline deviation	1	2		B7	
8.	Crowding	1	2		B8	
9.	Anomalies	1	2		B9	
10.	Attrition	1	2		B10	
11.	Abrasion	1	2		B11	
12.	Erosion	1	2		B12	
13.	Other	1	2		B13	

C. Number of …….

1.	Smile span (number of teeth visible):		C1	
2.	Number of dental crowns:		C2	
3.	Number of dental fillings:		C3	
4.	Number of missing teeth:		C4	
5.	Other(please specify)		C5	

D. Photograph file characteristics

1.	File type		D1	
2.	Date taken (dd/mm/yyyy)		D2	
3.	Dimension: Width		D3	
4.	Dimension: Height		D4	
5.	File size		D5	

8.7 Annexure 7: Published Article

Will "selfies" solve the identification crisis in lower socio-economic South Africans? A dental feature analysis of "selfies"

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Running Header: Dental identification using Selfies

Keywords: Forensic Odontology, identification, record keeping, mobile phones, selfies, dental features.

Abstract

Identification in forensic odontology requires that a known characteristic of an individual's dentition be compared with the same characteristic of the unknown decedent. In South Africa a number of factors render forensic identification of unknown individuals challenging. Many South Africans do not have access to modern dentistry, and consequently do not have ante-mortem dental records. In South Africa, 22 million people are said to own a smart phone, which accounts for close to 40% of the country's population. The aim of the study was to investigate selfies as a source of dental feature information in a government clinic catering to previously disadvantaged patients.

Identifiable dental features were observed in 61 (5.6%) of the collected images (N=1098). The low number of useable selfies collected in this study could be attributed to: a lack of smiles seen in the received images. Individuals with poor dental aesthetics would commonly choose to take a selfie with a closed mouth where their teeth would not be visible. The most commonly identified dental features included: diastemas (49.2%), dental jewellery (37.7%), crowding (16.4%), difference in tooth height (16.3%), discoloured (8.2%) and missing teeth (8.2%). This study found that selfies cannot solve the identification crisis in lower socio-economic South Africans. Awareness of the importance of selfies in forensic identification should be increased.

Introduction

Rapid and accurate identification of non-natural deaths is a key component of a good forensic service.[1] This is important for ethical, criminal and civil reasons.[1] Post mortem (PM) identification requires that a known characteristic of an individual be compared with the same characteristic of the unknown decedent. This forensic comparison plays a role in the identification of victims of violence, disasters or mass tragedies.[2] If a positive match is found, the individual may be identified and a death certificate can be issued. This provides some degree of closure for an individual's loved ones.

The high number of unidentified decedents at medico-legal laboratory facilities in South Africa (SA) is a source of great concern.[3] There are a number of legal consequences for families in cases where a loved one is missing but the death cannot be confirmed. Often there is an absence of medical and dental records especially in the black, previously disadvantaged rural populations of the country. This renders forensic identification of unknown individuals a challenge.[3] It is not a rare occurrence to have to identify a person where there is minimal ante mortem (AM) data, as in the case of street children, asylum seekers, undocumented foreign nationals and individuals living in remote rural areas.

A lack of DNA reference samples, the high cost of DNA analysis as well as the damage that occurs to fingerprints during the decomposition and carbonisation processes present challenges for the identification of unknown individuals.[3] An absence of medical and dental records, further hinders the identification process.[3] The Covid-19 pandemic has created large pools of vulnerable persons who, due to their worsened economic situation, were recruited for labour or sexual exploitation in their local area.[4] Loss of livelihoods and restrictions on movement have led to increased numbers of human traffickers recruiting victims in their local areas.[4] Recent statistics reveal that less than 1% of these victims are ever rescued, and that they often have no identification documents which would aid in their discovery.[4]

A 2016 study revealed that of the world's population, nearly 70% own a mobile phone.[5] Africa has shown phenomenal growth of mobile cellular ownership in recent years. The popularity of prepaid subscriptions and low-cost phones have made it possible for many of the country's youth living in poverty to own or use a phone themselves.[5] In SA, 22 million people are said to own a smart phone, which accounts for close to 40% of the country's population.[6]

Current techniques utilised in forensic identification in SA remain more suited for first world countries, where dental records are generally available throughout all socioeconomic groups.[9] Within SA, alternative methods of identification need to be investigated. Mobile phones are easily accessible and found in most sectors of our population, making selfies a possible source of dental information. Yet, there is minimal information regarding the use of selfies within forensic dentistry.

Aim

The aim of the study was to investigate selfies as a source of dental feature information in a government clinic catering to previously disadvantaged patients.

Materials and Methods

Patients older than 18 years that attended a Provincial Hospital dental clinic from November 2019 to May 2020 were requested to provide a single selfie photograph of themselves. The selfie could be any selfie of their choosing, of them either alone or in a group. Informed consent was obtained from each study participant. All the collected images were stored on a database and given a unique study number that correlated with their patient file number.

The following patient and selfie information was recorded: age of the individual, gender, ethnicity, date the photograph was taken, as well as the dimensions and size of image. Additionally, a clinical oral examination was performed for each patient as part of their routine dental treatment.

Usability of each of the provided selfie images was assessed and the images were classified as follows:

Images where the dentition was visible and identifying dental features could be seen. These images were scored **1**.

Images where the dentition was visible but identifying dental features could not be seen. These images were scored **2**.

Images where the dentition was not visible or quality of the image was poor. These images were scored **3**.

The images where the dentition was visible (scored a 1 and 2) were further analysed for a number of identifiable dental features.

Intra and inter observer reliability were carried out on 300 random selfies during the analysis period. The data analysis consisted of frequencies and descriptive statistics such as means, standard deviations and percentiles.

This study was approved by the Research Ethics Committee (Ethics number 740/2019) (Annexure 1) of the University of Pretoria in terms of the National Health Act (Act 61 of 2003) and the Code of Ethics for Research of the University of Pretoria. Participation in this study was voluntary.

Results

A total of 1 098 selfies were collected during the study period. The descriptive statistics for age of the patients that provided selfies was 30.5 years (Table I)

Table I. Age of the participants that provided selfie photographs

	Mean	SD	Range	Min	Max	Percentiles		
Age	30.5	6.9	48.0	18.0	66.0	25th	50th	75th
						26	29	35

The number of selfies received by females (F=805) was far more than those received by males (M=293) (Table II).

Table II. Gender distribution of the participants that provided selfie photographs

	Frequency (%)
Female	805 (73.3%)
Male	293 (26.7%)
Total	1098

The dentition was visible in 437 (39.8%) of the collected selfies. Of these images, 61 (5.6%) selfies showed identifiable dental features (Table III).

Table III: Usability of the collected selfies.

	Frequency	Percentage (%)
Dentition is not visible	638	58.1
Dentition is visible, but identifiable features cannot be seen	376	34.2
Identifiable features are seen in the mobile image	61	5.6
Quality of image is insufficient	23	2.1
Total	**1098**	**100.0**

The maxillary anterior teeth were most frequently visible in the collected selfies.

The highest frequency of anterior teeth seen was a smile span of 6 visible teeth (n=18).

Presented in the table below (Table IV) is a summary of the most common dental features seen on the 61 selfies where features could be identified.

Table IV. Most common identifiable dental features visualised on the 61 selfie photographs.

Feature	Frequency	Percentage of the 61 images where features were seen (%)
Diastema	30	49.2
Dental jewellery	23	37.7
Crowding	10	16.4
Difference in tooth height	10	16.4
Discoloured tooth	5	8.2
Missing Tooth	5	8.2
Number of tooth chips	5	8.2

The intra observer reliability was 0.972 and the inter observer reliability was 0.966 showing a good agreement and reproducibility in the methodology of identifying the dental features.

Discussion

The results of this research unfortunately showed that most of the study participants did not provide smiling selfies. The majority of the selfies that were collected were of individuals with their mouths fully or partially closed. The dentition was visible in 34.2% of the 1098 collected images (n=376) and identifiable dental features could only be seen in 5.6% of these images (n=61).

A possible contributing factor to the low number of smiling selfies collected in this study could be the dental /oral health status of the participants. Individuals with poor oral health, tooth loss and untreated carious lesions may be self-conscious and therefore may not take smiling photos or be willing to share such images.[10, 11] Individuals living in lower socio economic areas have poor access to oral healthcare and therefore oral health awareness is low.[12] The majority of individuals that provided a selfie where their dentition was visible had good oral health with no restorations or dental decay. In contrast, individuals with a poor state of their dentition frequently provided a selfie with a closed mouth where their teeth were not visible.

There was only one selfie collected which showed dental caries in this study (1.6%). In this image it was almost as if the individual was trying to conceal the visible dental decay in their smile line by not smiling widely. This finding emphasised the fact that those with decayed teeth chose to not smile in their selfies. Considering that globally 2.3 billion people are estimated to suffer from caries of permanent teeth, it was surprising to note the low number of dental caries seen in the collected selfies.[13]

An example where a selfie was provided with a closed mouth can be seen in Fig.1A. This patient reported that she did not want to show her teeth while smiling due to embarrassment about the state of her dentition. After obtaining consent, the investigator took an intra-oral photograph of the individual's dentition which revealed multiple carious teeth and decayed root remnants (Fig.1B). Weiser et al. reported that the recent substantial growth of social media has led to more individual self-promotion and competition.[14] This could explain why those individuals with undesirable dentition would choose to take a selfie with a closed mouth where their teeth would not be visible. In many of the non-smiling selfies provided in this study, the participants reported that they were self-conscious about their poor dentitions and therefore hid their smiles.

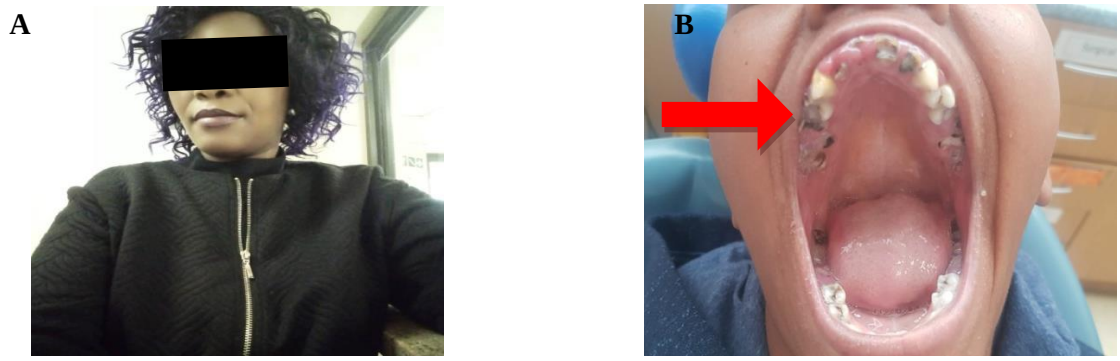

Figure.1A Selfie of an individual with a closed mouth, B Intra-oral image of the same patient's dentition.

The mean age of the participants in this study was relatively young at 30.5 years old. In the cases where older individuals had camera phones, most reported that they did not take selfies. The availability of selfies for identification is thus generally restricted to younger individuals and may become more difficult to source in older persons requiring identification. This is not an unusual finding as studies have shown that there is a higher prevalence of use and ownership of mobile phones in adolescents than in adults.[15] In fact, in the past few years, phone usage rates have also considerably increased among preschool children aged 6–10 years.[15]

There were more female participants (73.3%) who provided selfies than male participants. This might simply be due to more females attending the dental clinic than men. However, literature has shown that women are more likely to schedule a dentist visit and are more proactive than men in maintaining healthy teeth and gums.[16] Furuta et al. claimed that women have a better understanding of what oral health entails, as well as a more positive attitude towards dental visits.[16]

In 1986, Mckenna et al. investigated the role that anterior dentition visible in photographs can have in forensic identification.[17] In their study, 100 different photographs and dental models were studied. They found that 96% of the study participants had at least one feature in their dentitions which could be classified as unique.[17] Their study was expanded in which they examined 1000 different photographs to identify the percentage of individuals who showed

anterior teeth in their photographs. Their findings revealed that 60.9% of the photographs showed special attributes, or unique dental features and that 76.7% of their collected photographs were usable in the identification of missing and unidentified person. Their results are in sharp contrast to the present study.

There are a number of characteristic dental features that can be used for forensic identification.[18] These include the shape of the crown, morphological characteristics, dental anomalies, and alignment between the teeth.

Consideration of the population demographics in which a study is conducted is important when analysing any study data. This study was conducted in Gauteng and the incidence of missing teeth was low at 6.5% (n=5). The most common reason provided by the study participants for having missing teeth, was extraction subsequent to tooth decay. Had this study been conducted in Cape Town, an area known for individuals having a "passion gap" or "Cape Town smile", the incidence of missing teeth would have been higher.[19] In the Cape, it is a cultural practice for individuals to electively extract their maxillary central and lateral incisors (teeth 11, 12, 21 and 22) for aesthetic purposes. A selfie from the Western Cape population where all 4 maxillary central incisors were extracted would not be a significant finding.

The more dental features present in one's selfie, the more significant the findings are. Figure 2 is an example of a selfie that showed more than one visible dental feature. In this selfie a non-vital discoloured maxillary central incisor (tooth 21) with a large midline diastema was visible. Maxillary midline diastema was the most common finding in this study (49.2%). If this selfie portrayed an isolated midline diastema, this would not have been a significant finding in this study population. The fact that the individual also has a discoloured tooth 21 adds significance to the dental features. When combined, these 2 dental features are of more forensic significance compared to each feature being found in isolation.

Figure.2 An example of a good selfie with 2 identifiable dental features; midline diastema and non-vital 21.

A commonly found feature in this study was dental jewellery on the anterior teeth, which was seen on more than one third (37.7%) of the collected selfies (n=23). Dental jewellery, especially gold inlays and onlays, are a common finding in many different population groups.[20, 21] The gold slit/inlay was the most commonly seen dental jewellery in this study. For forensic purposes a gold inlay alone would be of little significance. However, if more than one gold inlay is found in one individual (Fig.3) or if two full gold crowns (Fig. 4) are found in one individual, the forensic significance is greater.

Figure.3 'U' shaped gold inlays on maxillary central incisors (teeth 11 + 21).

Figure 4. Two full gold crowns on both maxillary lateral incisors (teeth 12 and 22).

In one of the provided images, a conspicuous anaesthetic, tooth-coloured crown could be seen on the left maxillary canine (tooth 23). This crown was extremely white in colour and positioned out of the dental arch (Fig.5). While this would not be an ideal crown for the patient's aesthetic needs, it provides good forensic identification value. It is highly unlikely that another individual would present with a crown showing similar features to those seen in this selfie. Interestingly, a more clinically pleasing crown would be of less forensic value as it would be less conspicuous and more difficult to see on the image.

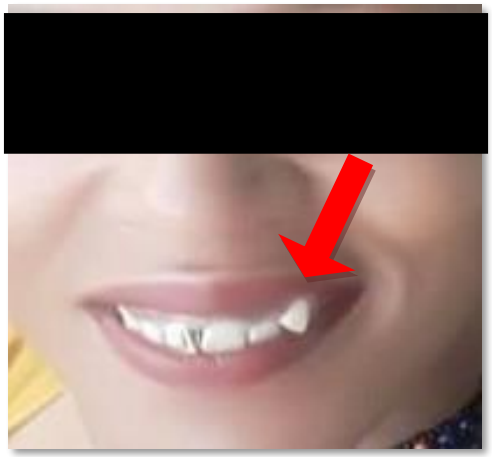

Figure 5. Unaesthetic dental crown with high forensic value.

Anterior teeth have been shown to have specific numerical rotational value and form part of an individual's unique identity.[22] Dental crowding is defined as a discrepancy between tooth

size and jaw size resulting in a misalignment of the teeth in the arch.[21] The aetiology can include physical trauma, discrepancies in the relationship between tooth size and arch size, emergence of the third molars and periodontitis.[21] Dental crowding was only observed in 10 of the selfies (16.4%) in this study. The last of the most observed dental features in this study was the presence of a difference in tooth height between the upper central incisors. Ten selfies (16.4%) were found to show a difference in tooth height between the maxillary anterior incisors.

A practical example of using a selfie showing characteristic dental features being used for a positive identification can be seen in Figures 6A and 6B. These images clearly show the absolute pattern match between the upper and lower dentition visualised on the AM selfie and the PM image of the victim. In this specific case, a conclusion of absolute certainty was made through the use of the AM and PM images.

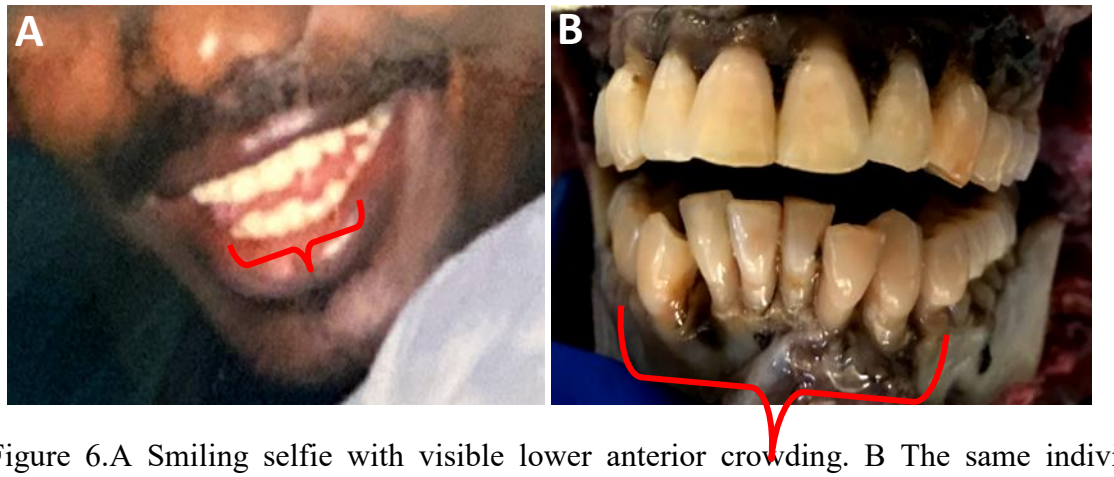

Figure 6.A Smiling selfie with visible lower anterior crowding. B The same individual's dentition in a post mortem photograph. (Images courtesy of Prof H. Bernitz)

When comparing a selfie to a deceased individual's dentition, the orientation of the selfie image and the PM image needs to be considered. An AM photograph is crucial when taking PM photographs, as the angulation of the PM photograph should be reproduced for accurate comparison.[23] Mirror images, where the selfie was taken in a mirror, need to be considered as these could be misleading when orientating the selfie.[24] A mirror image selfie is not only produced by an individual taking a selfie in the mirror, mobile cameras have the ability to flip a selfie and create the illusion of a mirror image. Additionally, to avoid any confusion, the investigator should thoroughly correlate the clinical. PM examination notes with the photographs of the deceased's dentition. We recommend that during PM procedures multiple

angled photographs of the deceased's dentition be taken to use for comparison with a provided selfie, see Figure.7A and B. The angulation of the photograph must be reproduced in the X, Y and Z (depth) axes for accurate comparison.[25]

Figure.7A and 7B Multiple-angled photographs taken during post mortem examination. (Courtesy of Prof H. Bernitz)

selfies are easy to use, low cost and accessible sources from which dental identification could be performed. From this study it was evident that the more teeth seen in a selfie, the higher the likelihood that the investigator would see identifiable dental features. The 6 most commonly seen dental features in this study were diastemas, dental jewellery, crowding, a difference in tooth height, discoloured and missing teeth.

Conclusion

The results of this study were contrary to those that were expected and revealed that selfies cannot solve the identification crisis in lower socio-economic South Africans. This study may not be a true reflection of identifying dental features on selfies as most of the images provided were where the dentition was not visible. Considering the growing trend of selfie taking and the availability of these images, the use of selfies in the forensic identification of individuals still requires further exploration.

Acknowledgements

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Conflict of interest

The author reports no conflict of interest. This article has not been previously published and is not currently being considered for publication elsewhere.

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