Chapter 3: Materials and methods

3.1. Introduction

In this study, crania and post-mortem photographs of individuals were used in order to carry out superimpositions. Crania were converted into 3D images with the use of a 3D scanner. Skull-photo superimposition was then carried out using 3D Studio Max software. This section will thus outline the materials and methods needed to achieve this.

3.2. Materials

The crania/ skulls that were used for this study were obtained from the Pretoria Bone Collection (PBC), Department of Anatomy, University of Pretoria.

3.2.1. The Pretoria Bone Collection

The PBC was started in 1943 initially as a teaching aid for medical, dental and health care students. In 2000, this collection was reorganized to include a student aid collection and a research collection. The research collection offers a wealth of information on physical traits and variations seen within skeletal material, such as "the physical characteristics of individuals originating from diverse geographic regions, sex differences, age and nutritional status" (39). It has been suggested that this collection can assist researchers with studies on contemporary remains.

The PBC sources the remains in one of two ways: donations and unclaimed bodies. In accordance with the *Human Tissue Act, 1983 (Act no. 65 of 1983)* (77), anyone in South Africa may donate his/her body or tissues for the purposes of medical training or therapy and research (39, 77). Under the act, the remains of a destitute individual which are unclaimed for burial by a spouse, relative or friend within 24 hours after the death may be donated to an institution such as a University for medical research, at the discretion of the inspector of Anatomy of that area. Between 50 and 100 bodies (unclaimed and donated) are received by the University of Pretoria each year, mainly from surrounding hospitals i.e. Kalafong or Mamelodi, and occasionally the Steve Biko Academic Hospital (previously the Pretoria Academic Hospital) (39). The benefit of this process is that the PBC has clear and accurate records of the individuals received from the various hospitals, such as the age of the individual, their sex and their ancestry. Therefore the research carried out using the PBC reflects standards for a South African population. A spouse, relative or known friend may later claim a previously unclaimed body with proof of relationship to the deceased or with an authorization order obtained from a magistrate (39, 77). Currently the collection consists of 1131 skulls, of which 812 are complete post-cranials and 399 are incomplete post-cranials (L'Abbe, pers. comm.).

The collection has cadaver photographs available, which are taken of the individuals on arrival at the Department of Anatomy, which thus include facial photographs reflecting the ancestry and sex of the deceased persons. In this way the demographics of each cadaver is documented for future use as white, black or coloured/mixed ancestry and male or female. The majority of the photographs were initially taken with an Olympus TRIP AF 30 normal 35 mm film camera and lens: DX Olympus 34mm 1:5.6. Some of the later photographs were taken digitally, with a Sony Cybershot, 2.8 megapixel, and Sony lens, f=6,9mm 1:2.8, digital camera. Photographs are taken at the time that the bodies are admitted to the University of Pretoria's mortuary, and thus are post mortem images of a deceased person; no ante mortem or ID book photographs are available for these individuals. All the photographs are catalogued for the purposes of research and these were the images used for this study.

Only anterior view photographs were included in this study. The photographs are taken by the technical staff in the Department of Anatomy, and not by a student or researcher, therefore there has been no standardization, i.e. the photographs are not always of good quality and don't repeat the identical positioning of the head for each photograph. The cadaver photographs are not "ideal" due to the lack of standardization when taking the photograph; however, it is believed that this may represent what could occur in real life where a photograph that is not of good quality is provided by the family of the suspected deceased.

It must be noted that the photographs are of deceased individuals, and therefore the superimposition involved superimposing a photograph of a deceased person over a skull. The superimposition could still be carried out however, where sufficient facial features were visible for the process to continue: i.e. photographs where facial features were poorly reflected were excluded from the study, based on the poor quality of the photograph.

3.2.2. Sample collection

The sample collection involved looking through the approximately 700 photographs available in the PBC. Of these, only 40 were included in the study due to the stringent exclusion criteria used. The final sample consisted of 20 black and 20 white males. Forty photographs of male persons, 20 of which were black and 20 white individuals, were randomly selected. Depending on the quality of the image, a photograph was accepted or rejected as part of the study. As stated above, many of the images could not be included due to their poor quality and some photographs had to be eliminated as the remains had been collected by the family

The catalogues of cadaver photographs were used to select skulls. For the photograph to be selected to be part of the study, specific criteria had to be met. Through a process of elimination using the criteria, 40 photographs were selected. The following criteria were used for selection:

- Only male individuals were selected for the study.
- The quality of the images: The photographs were chosen randomly and included depending on the clarity of the facial features seen in the photograph.
- For each of the 40 selected photographs, the skull matching that photograph had to be available.
- Black and white individuals were chosen.
- Nine skulls plus the skull of the individual in the photograph were selected for the sample. In order to perform blind testing, the nine further skulls together with the matching skull for each photograph were selected from the PBC. The skulls used in the blind testing were matched to the study sample with regards to ancestry and age. If two photographs were used that were of individuals of identical population affinity and similar age, some of the nine skulls that were used for the photograph were used for matching in the second similar photograph. This resulted in fewer skulls requiring scanning to make up the samples.
- This resulted in approximately 150-170 skulls being 3-dimensionally scanned to make up the scan sample for each photograph.

Ethical clearance was obtained for this study (Ethics clearance number 32/ 2006), but in order to protect the identity of the individuals (cadavers) in the photographs, the ethics committee stipulated that only parts of faces may be revealed due to the sensitive nature of these images. For this reason, complete images of the individuals used in this study will not be shown anywhere. In the introduction section of this thesis, unedited South African Police Service case images (**) have been used without an attempt to protect the identity of the individual in the photographs, as this case has been finalized in the legal system. It was also agreed that the crime scene photographs would be used without editing in this thesis, but not used in any publications which may potentially arise from this study.

3.3. Methods

The study was carried out in three stages. In the first stage the technique of matching the skull to the photograph was developed. This involved scanning photographs to have digital copies of them as well as scanning skulls 3-dimensionally for the superimpositions technique. These were then matched/ overlaid using computer software. This process involved some practice and repetition. This newly developed technique was then used to carry out stages two and three. In the second stage a morphological matching of skulls and photograph was carried out and in the third stage a landmark-based computerized matching of skulls and photographs was carried out.

3.3.1. Stage 1

3.3.1.1. Photograph capturing procedure:

Photographs were uploaded using a Canon CanoScan LiDE 20 scanner. Photographs were digitally trimmed to remove unnecessary imagery- the images were cropped so that only the head and face could be seen. The cadaver number (which appears above the person in the photograph) was also digitally removed from the photograph. This was to ensure anonymity for the investigator during the study as well as to protect the identity of the individual. The new cropped image was saved separately with its original cadaver number to be used in 3D Studio Max software. The skulls were initially scanned according to the cadaver number assigned to the remains and were then later renamed in a new folder to be used in the 3D Studio Max program. This was done so that anonymity could be ensured.

3.3.1.2. Skull scanning procedure:

Once the 40 skulls of the individuals for which photographs were available, as well as the additional 150 skulls that would be used in the blind testing were selected, they were scanned using a Cyberware™ Model 3030 Colour 3D Scanhead scanner located at Ergotech in Centurion, Pretoria (Figure 3.1).

Skulls including articulated mandibles were scanned (making provision for the temporo-mandibular joint cartilage). Prestik™ was used to aid with the articulation of the mandible onto the skull and to represent the temporo-mandibular cartilage. The skulls of the white individuals proved problematic due to the fact that many of the mandibles and maxilla were edentulous. In cases such as these, the Prestik™ was used in the temporo-mandibular joint as well as a piece of Prestik™ (approximately 2 cm in thickness) between the maxilla and mandible to account for teeth (where dentures were probably worn). This 2 cm thickness was estimated based on measurements taken from skulls with teeth in the upper and lower jaw (Figure 3.2).

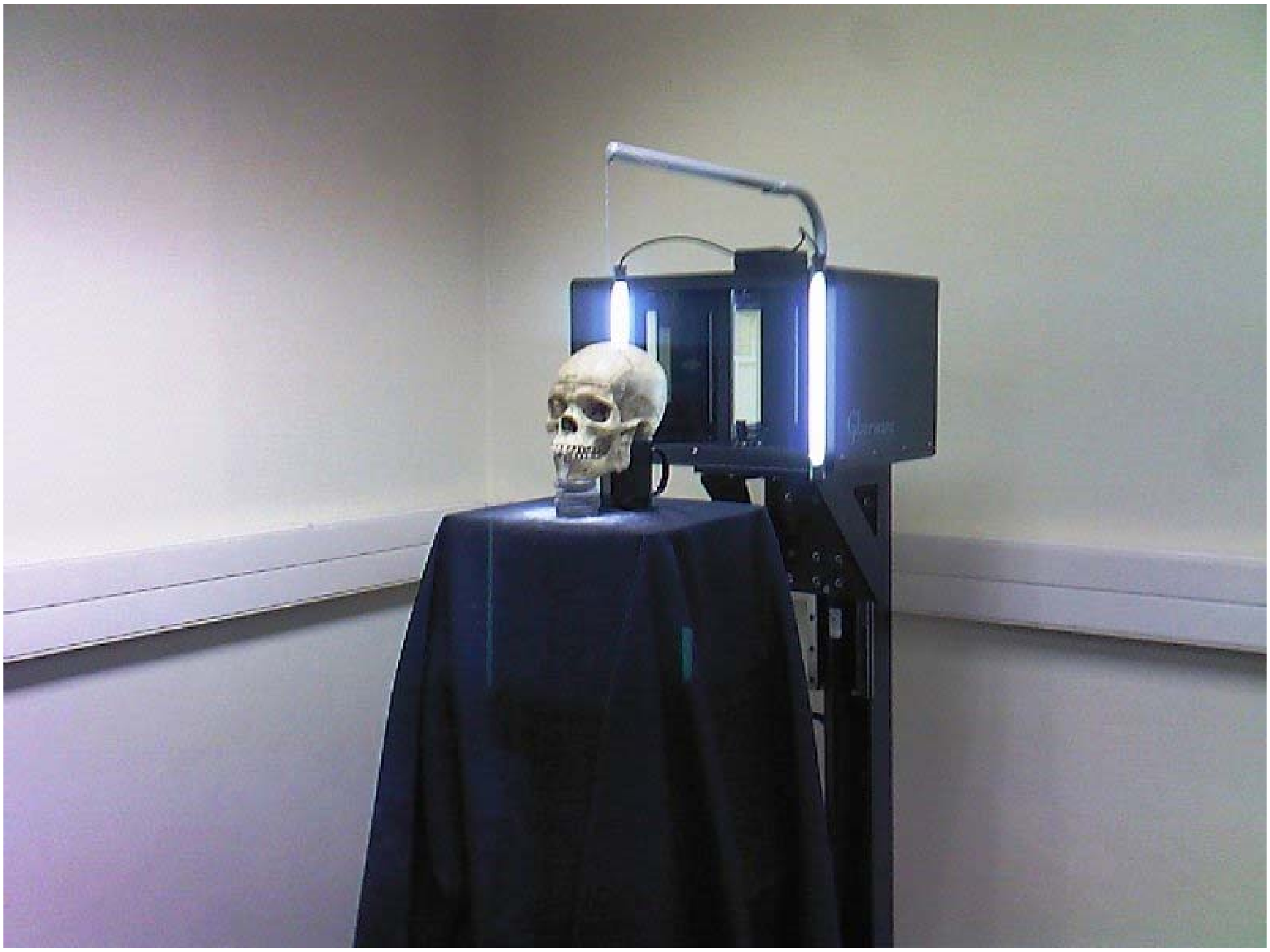

Figure 3.1. The process of 3D scanning a skull

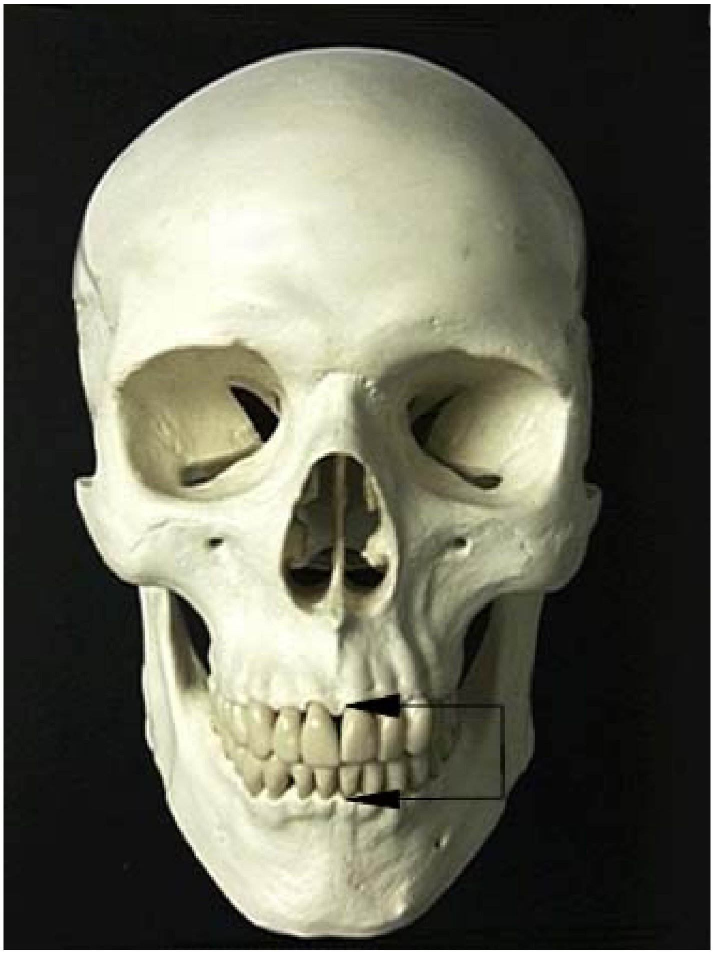

Figure 3.2. The measurement used to estimate the distance between the mandible and maxilla in an edentulous skull. The measurement is shown with the arrows.

Once the skulls had been scanned, a three dimensional image was obtained. These images were then edited and reduced in size in the Cysurf™ software located on the computer at Ergotech. The editing involved opening the raw data image and "cleaning" it, using functions of the Cysurf™ program. This included de-spiking the image (i.e. removing areas of spiking on the image which is extra unnecessary data picked up by the scanner), voiding (or erasing) unnecessary areas that were picked up during the scanning process (i.e. areas within the orbits which were not needed); filling areas of the scan which were not picked up during the scanning process (some curved surfaces were not picked up properly) and finally smoothing the image. The cleaning process does not in any way alter the image or the original anatomy of the skull. This image was then reduced in size by 50% to be used in 3D Studio Max. No sections of the image or quality of the image are sacrificed in the decimation (size reduction) process. The decimation process is absolutely necessary in order for the image to be small enough to use in the 3D Studio Max program. These images were then further utilized in the 3D Studio Max program.

3.3.1.3. Development of skull-photo superimposition technique:

In this part of the study 10 photographs were matched to the 3D scans of their own skulls, in order to develop and refine the technique in 3D Studio Max- initially skulls and photographs were matched morphologically similar to the method used by the SAPS. Using this method, corresponding landmarks were then placed on the photographs and the 3D scans, and it was established how many of the dots representing primary and secondary landmarks should overlap exactly and/or touch in order for a match to be positive. Details of how this was carried out will be explained under 3.3.3.1. The aim for this stage was to "practice" the techniques that were necessary to carry out stages 2 and 3.

<u>3.3.2. Stage 2 of the skull-photo superimposition study:</u>

This stage analyzed how well the photographs matched the/a skull 3D scan based purely on morphology and whether one or more match between a photograph and skull (in effect 3D image of a skull) were obtained. Photographs of each of the 40 individuals were matched to 10 skulls each (the selection of which was explained previously). This stage was based on a visual morphological assessment of the goodness of the fit, and is similar to the current method used in photographic superimposition by the South African Police Service (Briers, pers. comm.) as well as the list of requirements of a frontal consistent fit between skull and face from Austin-Smith and Maples (24) as tabulated in Table 2.2.

3.3.2.1. Superimposition procedure:

Working in the 3D Studio Max program involved importing the photograph image (in .jpg format) as well as the skull image (in .obj format) into the program (Figure 3.3).

3D Studio Max is a software program that makes use of shapes and the manipulation thereof possible. The photograph itself is a flat image and had to be imported onto a shape to be viewed in 3D Studio Max.

Figure 3.3. The imported images in 3D Studio Max. The scanned image of the skull is shown on the left, and the photograph of the matching individual on the right.

The 3D Studio Max software program operates by providing a view of an image or object from four different perspectives/ views i.e. front, top, lateral and perspective. These four views enable the user to manipulate or rotate an image or object at random whilst at the same time being able to see the image or object from four different views at the same time (Figure 3.4).

For the purposes of this study, the "front" view was primarily used to ensure that the proportions of the photograph and skull were correctly maintained.

The stage 2 superimposition steps were as follows:

1. The skull and photograph were imported into the 3D Studio Max program.
2. The skull and photograph were adjusted to the same proportion and size.
3. The skull and photograph were moved over each other for the assessment to be carried out.
4. The morphological match was carried out based on the morphological features of the skull and photograph.

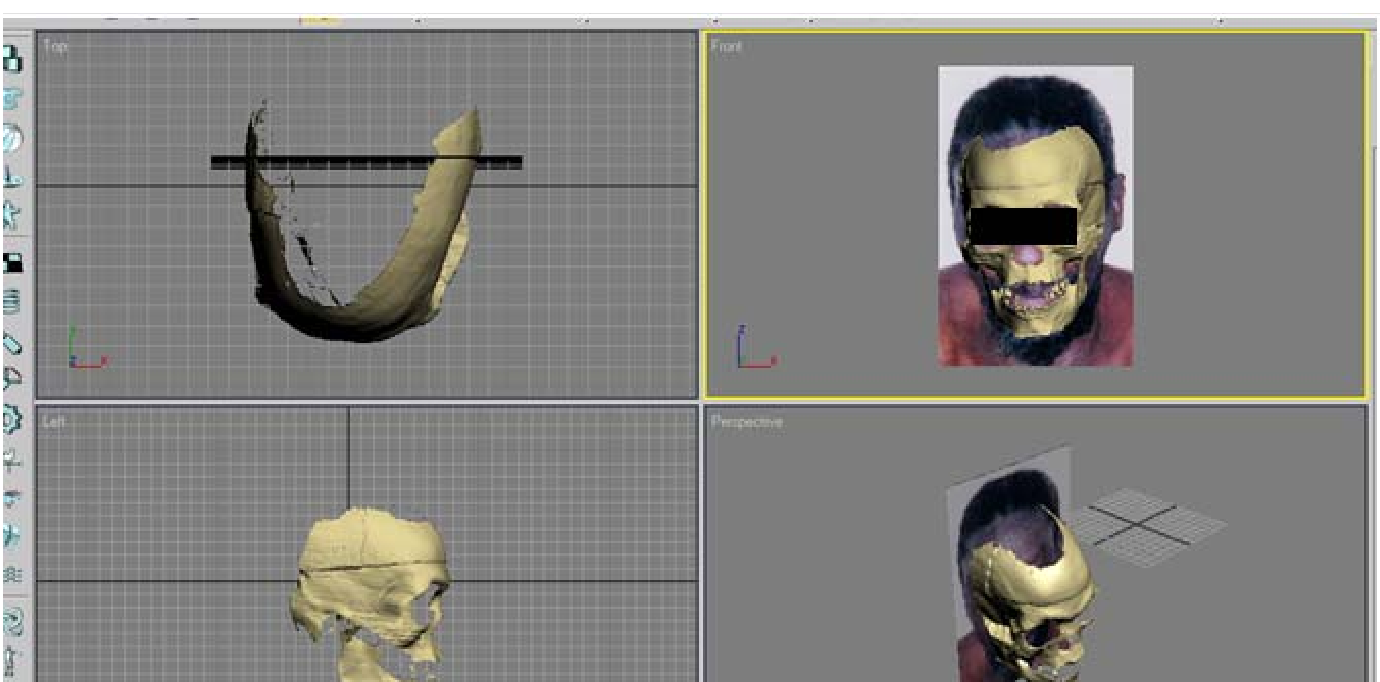

Figure 3.4. The four views seen in Studio Max. The top right view is the view used to carry out the superimposition. Whilst movements are made in the top right view, the same movements can be seen in the other views but from a different perspective i.e. from the top, or from the side (laterally).

For this stage a simple morphological match was carried out in order to determine whether the skull and its morphological features belong to the individual in the photograph. This was carried out using the list of requirements of a frontal consistent fit between skull and face from Austin-Smith and Maples (24) as shown in Table 2.2, for example did the morphological features of the face match with the features of the skull (Briers, pers. comm.). Dimensions such as nasal height, upper facial height and bizygomatic breadth were also considered when attempting to match the skull to the photograph. Each of the 10 skulls for one individual photograph were analyzed in this way following the above steps.

The only difference between this method and the current method used by the SAPS is the fact that an image of the skull in the form of a 3D scan was used, instead of a video image. This should make no real difference to the outcome of the superimposition.

3.3.3. Stage 3 of the skull-photo superimposition procedure:

In this stage 40 photographs were matched to 3D scans of 10 skulls each. This stage was firmly based on how well / exactly the craniofacial landmarks/points matched. No subjective judgments were made on whether the skull and photograph matched. The match between photograph and skull was made based on matching criteria for each landmark used as described fully in 3.3.3.3. The technique used here was similar to the technique used by Bajnóczky and Királyfalvi (22), where they made use of points and compared before and afterwards conditions when attempting to match two photographs to one skull as explained in the literature review.

3.3.3.1. The craniofacial landmarks:

Craniofacial landmarks have been used in this study in order to allow for objective assessment of a match between a photograph and a skull. Figures 3.5 and 3.6 show an anterior and lateral view of the skull with craniofacial landmarks, with full definitions of each of the landmarks in Tables 3.1 and 3.2 (78-80).

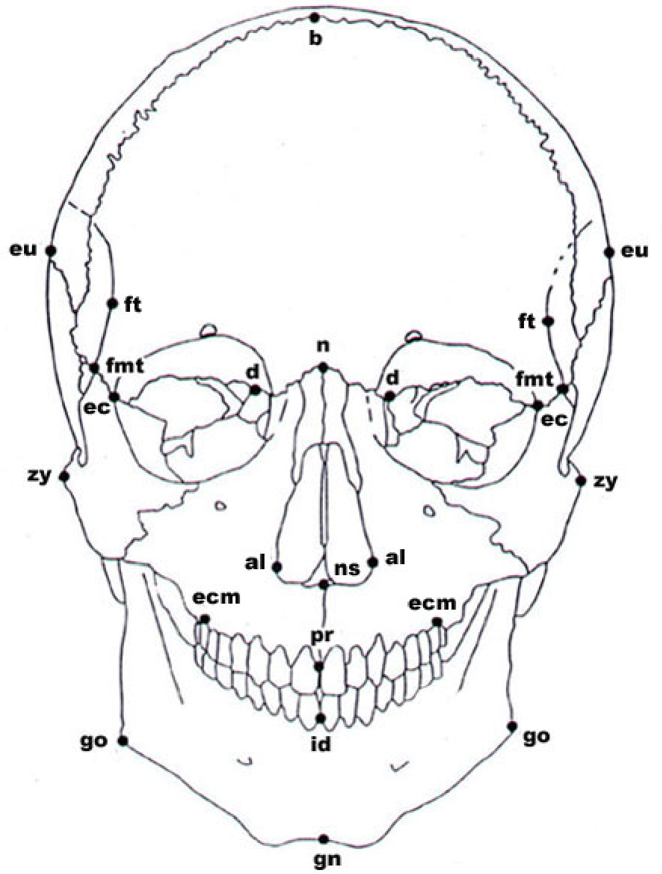

Figure 3.5. Anatomical landmarks of the skull/ craniometric landmarks (anterior view) (78-80). The landmark abbreviations and the full name of the landmark are explained in Table 3.1.

Table 3.1. Landmark abbreviation and landmark complete name which provide explanations to Figure 3.5.

Landmark abbreviation	*Landmark name*
Al	Alare
B	Bregma
D	Dacryon
Ec	Ectochonchion
Eu	Eurion
Fmt	Frontomalare temporale
Ft	Frontotemperale
Gn	Gnathion
Go	Gonion

Id	Infradentale
N	Nasion
Ns	Nasospinale
Pr	Prosthion
Zy	Zygion

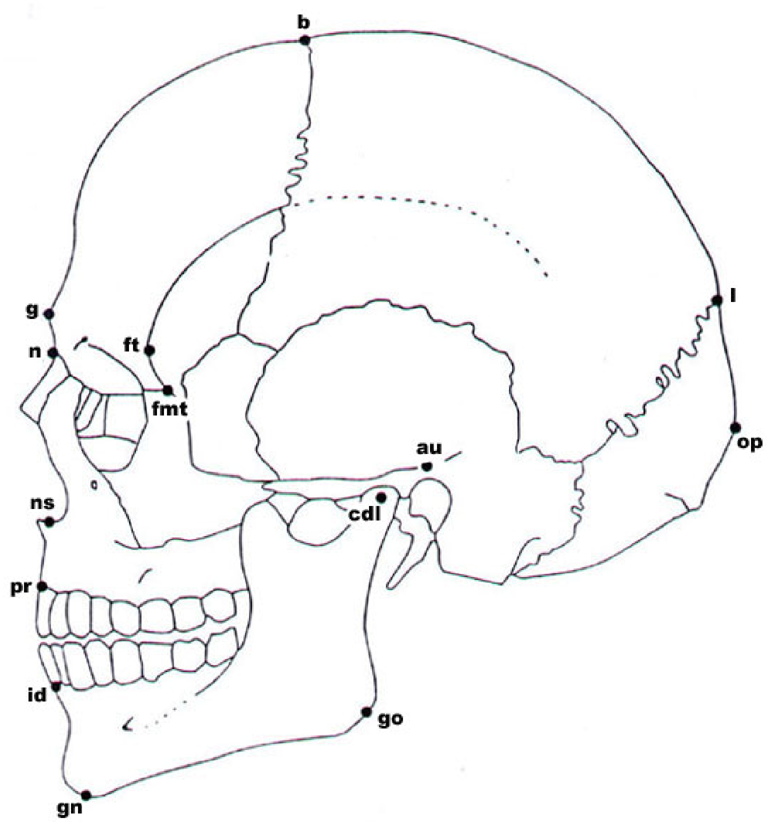

Figure 3.6. Anatomical landmarks of the skull/ craniometric landmarks (lateral view) (78-80). The landmark abbreviations and the full name of the landmark are explained in Table 3.2.

Table 3.2. Landmark abbreviation and landmark complete name which provide explanations to Figure 3.6.

Landmark abbreviation	*Landmark name*

Au	Auriculare
B	Bregma
Cdl	Condylion laterale
Fmt	Frontomalare temporale
Ft	Frontotemperale
G	Glabella
Gn	Gnathion
Go	Gonion
Id	Infradentale
L	Lambda
N	Nasion
Ns	Nasospinale
Op	Opisthocranion
Pr	Prosthion

It is important to take note that the craniofacial landmark on the surface of the skull may not have the same corresponding orientation as it would on the surface of the skin. As used by Farkas (62), for the purposes of this study, the cranial landmarks will be described as "bony" landmarks, and the skin surface landmarks will be described as "soft" landmarks henceforth. These are further described in Tables 3.3 – 3.5. The bony landmarks are accurately identified because the exact positioning of the landmark can be seen. The identification and placement of soft landmarks on the skin requires experience and so can be difficult for beginners. Raijion (81) has also had similar findings in his study where he explains that landmark identification on the face of an individual is more of an art than science and is often tedious and time consuming and the success thereof is based on one's previous experience. Some soft landmarks are easier to locate and place; however, the task is generally a challenge (62).

For this study, orientation landmarks, primary landmarks and secondary landmarks were selected from the list of available landmarks (Figures 3.5 and 3.6).

<u>Orientation Landmarks</u>

Orientation landmarks were selected to assist with the orientation of the skull to the photograph. These were selected as they were landmarks easily identified on both the face and the skull and therefore it was felt that these landmarks could be used to align photograph with skull with a high degree of accuracy. The orientation landmarks ensured that the skull was correctly aligned and sized with the photograph so that the process of determining a match could follow. These were thus used as a baseline. The orientation landmarks are described in Table 3.3. A total of four orientation landmarks were thus used, as the ectocanthion is a paired landmark.

Primary Landmarks

Primary landmarks were selected because they are easily identifiable, firm landmarks. They were described as "primary" because they are clearly visible on both a skull and face, should match completely and the soft tissue overlying the landmark does not vary much between individuals. These landmarks are described in Table 3.4. This totals five landmarks, as dacryon and frontotemperale are paired landmarks.

Table 3.3. Orientation landmarks. The description of the landmark on the skull (bony landmark) and the corresponding soft tissue landmark is given. The bony tissue landmarks are based on Martin and Saller (78) and Knussman (79) as translated in Moore-Jansen et al. (80).The soft tissue landmarks are based on descriptions from Farkas (62).

Landmark	Abbreviation	Description	
		Bony Landmark	Soft Landmark
Ectocanthion	Ec	The area where the palpebral ligament attaches (right and left).	The area on the orbit (lateral) where the top and bottom eyelid meet at the bony margin.
Subnasal point	Ns	The point where the lower margins of the nasal aperture meet to form the nasal spine.	The point where the nasal septum meets the skin of the upper lip.

Nasion	N	The intersection of the nasofrontal suture with the midsagittal plane.	The uppermost point of the nasal bridge where the nasal bridge meets the skin of the forehead.

Secondary Landmarks

The secondary landmarks are those which are somewhat more difficult to locate and may also be influenced by the amount of soft tissue overlying them. They are somewhat arbitrary, but are nevertheless helpful in matching a skull and a photograph- for example, the bony landmark of gnathion should always be inside/ above the soft tissue landmark, even though the exact soft tissue thickness may vary between individuals. Similarly, the bony nasal aperture should fall inside the alae etc. these landmarks are generally more challenging to position and interpret exactly, particularly with the soft landmark placement. These landmarks are described in Table 3.5 seen below. This totals seven landmarks, because gonion, zygion and alare are paired landmarks.

Table 3.4. Primary landmarks. The description of the landmark on the skull (bony landmark) and the corresponding soft tissue landmark is given. The bony tissue landmarks are based on Martin and Saller (78)and Knussman (79)as translated in Moore-Jansen et al. (80).The soft tissue landmarks are based on descriptions from Farkas (62).

Landmark	Abbreviation	Description	
		Bony Landmark	Soft Landmark
Glabella	G	The most forward projecting point in the midline of the forehead at the level of the supra-orbital ridges and above the nasofrontal suture.	The slightly protruding area between, but slightly above the supraciliary arches.
Dacryon	D	The point on the medial wall of the orbit, at the junction of the lacrimomaxillary suture and the frontal bone.	The point on the orbit (medial) just below nasion and to its right and left.

Fronto-temperale	Ft	The most medial point on the incurve of the temporal ridge.	The narrowest point on the temple (right and left) area when looking at the face anteriorly.

Table 3.5. Secondary landmarks. The description of the landmark on the skull (bony landmark) and the corresponding soft tissue landmark is given. The bony tissue landmarks are based on Martin and Saller (78)and Knussman (79) as translated in Moore-Jansen et al. (80).The soft tissue landmarks are based on descriptions from Farkas (62).

Landmark	Abbreviation	Description	
		Bony Landmark	Soft Landmark
Gonial angle	Go	The midpoint of the angle of the mandible between the body and the ramus- the angle of the mandible on the skull should be within the angle of the mandible on the photograph.	The area where the bony prominence of the angle of the mandible is visible (right and left).
Gnathion	Gn	The lowest median point on the lower border of the mandible.	The middle most and lowest point on the chin.
Zygion	Zy	The most lateral point on the zygomatic arch.	The most lateral point on the bony ridge of the cheek bone (right and left).
Nasal aperture width/ Alare	Al	The most lateral point on the nasal apertures.	The lateral point where each ala of the nose meets the skin of the philtrum and cheek.

Altogether 16 craniofacial landmarks were used to match the photograph to the/a skull.

3.3.3.2. Procedure for superimposition using landmarks:

The stage 3 superimposition procedure comprised of the same 40 photographs and 10 skulls used in stage 2 and proceeded as follows:

1. The skull and photograph were imported into the 3D Studio Max program.
2. The skull and photograph were adjusted to the same proportion and size without distorting it.
3. A rough morphological match was carried out so as to orient the skull and photograph. As a baseline, it was ascertained that the eyes fitted into the bony orbits. The skull and the photograph were then separated so that the landmarks could be placed on each of the photograph and skull.
4. The orientation, primary and secondary landmarks (Tables 3.3, 3.4 & 3.5) were then placed on the skull and photograph and grouped (i.e. landmarks on the skull move with the skull and landmarks on the photograph move with the photograph).
5. The skull and photograph were then moved over each other for the match. The match was made by ensuring the orientation landmarks from the photograph and from the skull all touched or overlapped, so as to make 100% sure that the orientation of the skull and the photograph are identical.
6. The relative positions of the other landmarks were then assessed. Specific criteria had to be met for there to be a match between the primary and secondary landmarks. These criteria are described below.
7. Skin tissue thicknesses were taken into account using skin tissues thicknesses developed from a South African sample (82). At the time of the study, skin tissue thicknesses were not available for a South African female sample; therefore only males were included in the study.

3.3.3.3. Criteria for matching of landmarks between the skull and photograph

The criteria for what defines a match between the bony landmark and the soft landmark for the primary and secondary landmarks are described in Tables 3.6 & 3.7.

In summary for stage 3 the match was carried out using only the craniofacial landmarks. The skull and photograph were first adjusted to be the same size. Orientation landmarks were then added to both photograph and skull and both were orientated using morphological features and the orientation landmarks. The skull and photograph were then separated and primary and secondary landmarks were added. Once all primary and secondary landmarks were added, the landmarks of the skull and photograph were then superimposed over each other. The orientation landmarks were forced to fit each other and the match of the primary and secondary landmarks were then assessed.

Table 3.6. Criteria for matching of primary landmarks (anterior view)

Landmark	Criteria for match
Glabella	Landmarks must touch or overlap on both the skull and photograph.
Dacryon	Landmarks must touch or overlap on both the skull and photograph.
Frontotemperale	Landmarks must touch or overlap or the landmark of the skull can be inside/ medial to the landmark of the photograph by a distance no greater than the width of a landmark*.

* The width of a landmark is approximately 1. 5 mm in diameter.

It was proposed that the primary and secondary landmarks should touch, overlap or one landmark could be medial to another for the photograph and skull to be determined a match.

Table 3.7. Criteria for matching of secondary landmarks (anterior view)

Landmark	Criteria for match
Gonial angle	Landmarks on both the skull and photograph must touch, overlap, or the landmark on the skull must be inside/ medial to the landmark on the photograph by a distance no greater than the width of a landmark.
Gnathion	Landmarks on both the skull and photograph must touch, overlap, or the landmark on the skull can be superior to the landmark on the photograph by a distance no greater than the width of a landmark.
Zygion:	Landmarks on both the skull and photograph must touch, overlap, or the landmark on the skull must be inside/ medial to the landmark on the photograph by a distance no greater than the width of a landmark.
Nasal aperture width/ Alare	Landmarks on both the skull and photograph must touch, overlap, or the landmark on the skull must be inside/ medial to the landmark on the photograph by a distance no greater than the width of a landmark.

Stages 2 and 3 were conducted blindly. Due to the number of skulls involved in the study, it was not possible that a skull from one stage could be memorized for matching a specific photograph in the next stage. The skulls were also renamed, further ensuring the blindness of the study.

Using the criteria described above, it was then assessed if none of the skulls, one of the skulls or more than one of the skulls matched with the photograph in question. Therefore a total of 10 superimpositions per photograph were carried out, totaling 400 superimpositions overall for each of stages 2 and 3. From the 800 superimpositions thus done, it was then calculated what the accuracy was, as well as the chances of making a false positive (skull and photograph incorrectly judged as being a match) or false negative (skull and photograph match, but was not matched during the procedure) diagnosis.

3.4. Repeatability study

A repeatability study was carried out to test whether the placement of the landmarks in the landmark based matching technique was accurate. For this study 10 photographs and their matching skulls were used as in stage 1 of the study. The landmarks on each particular skull were compared to the landmarks placed on that same skull, but these were allocated a few months later. This was done to ascertain to what degree of accuracy the positioning of the landmarks may differ if placed on separate occasions.

As mentioned previously, the investigator was aware that the placement of the landmarks on the skull would be more accurate than on the photograph. This procedure tests the investigator's ability to place landmarks accurately on the same position time and time again. The validity of the study was dependant on the investigator being able to reliably place landmarks. The same matching criteria used to match skull to photograph as used in stages 2 and 3 were used again to assess a match or non-match. Therefore no statistics could be used to assess the repeatability, as the descriptive matching criteria were used for assessment.

3.5. Statistical analysis

Using the data obtained from the 800 superimpositions, (40 photographs each superimposed on 10 skulls for both stages 2 and 3), the chances for obtaining false positives and false negatives were determined. This involved calculating the percentages of skulls correctly and incorrectly matched to their corresponding photograph. This was done separately for stages 2 and 3 of the study, in order to assess the accuracy of the two methods used. For each of the two stages, the following calculations were done:

1. Out of the 40 possible correct matches, how many were positively matched to their skull?
2. In how many cases were the correct skulls not matched to their photograph (i.e. a false negative)?
3. For each of the 40 photographs, how many of the nine remaining skulls (excluding the true positive) also matched particular skull i.e. “false” positives?
4. What was the success rate with the two techniques combined- how many skulls were positively matched overall using the two techniques combined?
5. Is there a difference between the reliability of the two techniques? A Fishers Exact Probability calculation was used to determine whether there is a statistically significant difference between the results from stage 2 and stage 3, in order to establish whether one method is better to use than the other.