Evaluation of the Optical Laser Scanning System for Facial Identification

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ABSTRACT

Facial reconstruction is applied when there is no information available with regard to the possible identity of the deceased and no information such as antemortem records obtainable for comparison with the post-mortem records of the human remains in question. The aim of the techniques involved in facial reconstruction is to produce a face, which can be recognized as belonging to a specific person, by relatives or friends of the missing person. Once such a recognition has been made, then the specialist can apply other techniques to confirm or refute identity. The reconstructed face can be publicized in newspapers or other mass media, in order to facilitate recognition.

Facial reconstruction is based essentially on the data taken from measurements of soft tissue thickness, primarily on the cadaver head and face and on the relationships between facial features of the face and underlying bone. Recently measurements of soft tissue thickness have been carried out in living persons using ultrasound.

Facial reconstruction has until now been carried out by the sculpting technique. There are two methods or a combination of both that can be used to achieve the reconstruction of facial features from a skull. The first is to use soft tissue thickness tables available to reconstruct the contour of the face at selected classical points. The depths of soft tissue are represented by markers placed directly on the skull which are then connected using bands of clay or plasticine or similar materials. The facial features are then formed using the same material. The second method involves reconstruction of the anatomical features of the face, applying the observation and comparison of sites of muscle attachments and other features to sculpt the facial muscles onto the skull using their bony

attachments as indicators of size and extent, then applying more clay to the depths specified in tissue thickness tables to approximate the various structures, according to the anatomy of the face. The sculptor thus rebuilds the face anatomically as it would be found in life or from anatomical dissection. A combination of both methods can be used, as is the practice in Great Britain. These two major methods represent the two principal schools involved in the development of facial reconstruction; these are the American and Russian respectively.

Application of the current techniques of facial reconstruction to individual identification has proven successful in obtaining personal identification in many forensic cases. However, according to the literature, the techniques on their own are still a long way from being accepted as definitive methods for identification. The latest investigations all agree that much research remains to be carried out to produce improvement in the reconstruction techniques. Problems remain unsolved which have a great impact on the final results, especially the relationship between the details of the facial features such as the eyes, nose, lips and ears for which the underlying bone does not provide information. Recently studies have shown the importance of these features as "good indicators" of facial recognition.

This study presents a method of facial reconstruction using an optical surface laser scanner system with an evaluation of the system for facial identification. The comparative analysis was carried out using facial anthropometry. The study was performed on a sample of plaster casts of skulls exhumed from a mass grave from a south American country. Photographs of missing persons thought to be of persons from this grave were also supplied to the Facial Identification Centre. These samples were all examined in the Facial Identification Centre of the Department of Forensic Medicine and Science of Glasgow University. By collecting a set of measurements and calculation of proportion indices, using computerized facial anthropometry and photogrammetry, a comparison was made between the facial reconstructions and photographs and the results are presented in this study. The computer method involves initially digitising plaster casts of skulls using a laser scanner and video camera interfaced to a computer. An average male face from a databank, is then placed over the plaster casts of skulls as a mask and the soft tissue thicknesses are modified to conform with the underlying skull. The advantage of this technique is its speed and flexibility. Nevertheless the technique is not perfect. It shares the same problems when the reconstruction is performed by sculpting; i.e., the relationship between facial features such as eyes, nose, lips and ears.

Results from the study have assessed the reliability of facial reconstruction using an optical surface laser scanner system. The system has some limitations but was able to produce a good resemblance between the finished reconstructed faces and the photographs of the missing persons. The morphological assessment was supported by facial anthropometry. Results from facial anthropometry were in turn strongly supported by statistical methods. The optical surface laser scanner in fact played an important role in the positive identification of sixteen cases of the sample studied. The identification, acting as supporting evidence for more positive techniques. The technique has been shown to be useful in personal identification, acting as supporting evidence for positive techniques. The results of the present study support the reliability in the application of this new method for facial identification.

For a more comprehensive understanding, the study involves 5 separates experiments :

1. Anthropometric measurements of the face in the frontal plane in 100 Caucasian, adults, volunteers using an optical surface laser scanner system. 1993 study

2. Computerised facial reconstruction using an optical surface laser scanner.

3. Computerised facial anthropometry in the frontal plane of the reconstructed faces, using the same system used for facial reconstruction.

4. Photogrammetry of the face or indirect facial anthropometry from photos.

5. Comparison of proportion indices selected between three-dimensional reconstructed faces with two-dimensional missing persons′ photographs.

To my beloved family who have stood by me.
To the memory of my beloved parents Manuel and Mercedes for their unconditional support, encouragement, help and genuine love given to me through my life.
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"Caminante, son tus huellas
el camino, y nada más;
caminante, no hay camino,
se hace camino al andar.
Al andar se hace camino,
y al volver la vista atrás
se ve la senda que nunca
se ha de volver a pisar.
Caminante, no hay camino,
sino estelas en el mar"
(Antonio Machado, Campos de Castilla, 1912)

"The reconstruction from the skull of the head is a branch of science, which has of recent years made some progress, but while the facial expression does to some extent depend on the form of the skull, and the strength of the musculature which can be partially judged from the skull markings, we are left wholly in the dark as to those facial lines which leave no permanent traces on the skull itself, and which have so much to do with our judgement of character" (Pearson, 1926)

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INTRODUCTION

The identification of human skeletal remains is a critical matter. A qualified specialist in this area must be extremely well grounded in comparative osteology, human osteology, craniometry and osteometry, and racial morphology. Therefore, he must have had extensive experience with the study of large series of human skeletal material. The branch of forensic science that deals with skeletal remains is Forensic anthropology.

Forensic Anthropology is one of the disciplines of Forensic Sciences formally incorporated into the American Academy of Forensic Sciences. These disciplines have their own responsibilities and very often function independently in the analysis of specific evidence in several cases. The aim of forensic science is for the specialists in these areas to cooperate in a team effort with law enforcement agencies to interpret the facts and circumstances of each case as a whole for legal use. The other interrelated fields in the forensic sciences include criminalistics, questioned documents, pathology and biology, forensic psychiatry, forensic toxicology, forensic odontology, jurisprudence, engineering and forensic anthropology.

Forensic Anthropology is that branch of applied physical anthropology concerned with the identification of human remains in a legal context. This discipline focuses on the analysis of unknown human remains for the purposes of identifying the deceased and formulating opinions as to the circumstances surrounding death. Forensic anthropologists coordinate their efforts with those of other experts in other fields in the resolution of forensic cases.

Forensic Anthropology was defined by Stewart (1979) as follows "is that branch of physical anthropology which, for forensic purposes, deals with the identification of more or less skeletonized remains known to be, or suspected of being, human.

Beyond the elimination of non-human elements, the identification process undertakes to provide opinions regarding sex, age, race, stature, and such other characteristics of each individual involved as may lead to his or her recognition."

Each forensic anthropological case is unique; the steps taken in an analysis depend on the type of materials recovered, the preservation of the remains, the skill and experience of the investigators, time limitations, technical equipment, financial restraint, etc.

One of the first problems that may confront the forensic anthropologist is the removal of both the biological and non-biological evidence from the death scene. Forensic anthropologists are called upon in both civil and criminal cases such as homicides, suicides, mass disasters (man made and natural), and the location of missing persons which present problems of personal identification. The past several decades have shown an increasing need for qualified specialists capable of processing unidentified human remains, and as result, forensic anthropology has emerged as a distinct subspecialty within physical anthropology. Through the years the value of forensic anthropology has been recognized by both law enforcement agencies and forensic pathologists.

Generally, the cases brought to the attention of the forensic anthropologist fall into one of two categories. One type involves the recovery of completely unknown remains. Case reports in these instances are largely descriptive and involve a "narrowing process" with regard to the broad biological categories of age, sex, race, and stature. Matching of missing persons' records may then attempted and a possible identification may be suggested. Thus the case has been converted to one of the second type, a tentative identification.

Remains may be tentatively identified through the process above mentioned, due to material associated at the death scene, or due to informant reports.

In such cases it is the task of the forensic anthropologist to confirm or excluded the suggested identity. In this task of exclusion or confirmation of identity the anthropologist very often is supported by the expert opinion of a forensic odontologist who analyses all antemortem dental records and/or radiographs of the case in question. The experts in this field of forensic odontology deal with all aspects of dental evidence associated with a death scene. Their analyses may include identifying unknown individuals by comparison of their dentition with antemortem dental records, evaluating injuries to the oral tissues resulting from violence, or analysing bite marks. Because of the frequent occurrence of teeth in unrecognisable human remains, the odontologist and the forensic anthropologist often have much to contribute to each other's analyses, particularly when the subjects under investigation were victims of a mass disaster.

Any forensic investigation involves three fundamental steps. Step one is the recovery of the remains. Step two is the laboratory analysis of the remains and step three is the reporting of one's findings. After the recovery of remains, the study proceeds by addressing certain questions. It must first be determined that the remains are human; this task is always a priority for the forensic anthropologist. The investigator's knowledge, experience and familiarity with human and non-human osteology is a crucial factor in this judgement. If the remains are human, a sorting process is initiated to determine how many individuals are represented in the sample.

While preliminary answers to these questions may be formulated at the scene of death, final answers are best left until the laboratory analysis, where a detailed investigation may be carried out. The next stage for each individual is the determination of the general identification such as age, sex, race, stature.

This process requires a solid knowledge of osteology and also a familiarity with the variability present in the human skeleton.

The success of any forensic identification depends to a large extent on what is recovered for analysis. Evidence recovered at the scene of death is in some cases vital for the recognition of the deceased.

The accuracy with which postnatal age can be determined using traditional methods is inversely correlated with the age of the individual at death. In the younger age ranges, where estimates are based on developmental processes, more precise evaluation is possible whilst in older individuals degenerative changes are observed which "assist" with that evaluation process.

Techniques for the determination of sex fall into two categories metric and observational.

Categorisation of an individual according to race or ancestry is perhaps the most difficult and least precise assessment in any forensic analysis. These natural difficulties are due to problems of inconsistency between social and biological definitions of racial categories, intermixture between groups, and the important factor of the skeletal variation between populations.

The determination of stature in life from adult human remains can be made in one of two ways. The first involves laying out the skeleton in anatomical order, measuring the stature given by the bones, and then adding numerical correction factors to account for the soft tissue components.

This method has limited value since it cannot be used in incomplete skeletons and the correction factors may not be accurate for any individual.

The second method involves taking maximum bone lengths and applying them to special formulae such as The Trotter and Glesse regression formulae, that have been derived for various populations of adults.

Following the determination and estimation of the general features of individuality mentioned above, the forensic anthropologist, then seeks to ascertain the specific individuality or personal identification of the case in question.

Individualisation is the process whereby a set of remains is matched with a specific personal identity.

Methods of establishing or verifying a personal identification from skeletonized human remains depend entirely on the characteristics of individuality that can be determined from both the biological and non-biological evidence, and the availability of appropriate social records or biological samples for a specific individual that can be used for comparison. Individualisation is accomplished by the analysis of radiographs, medical or dental records, photographs, facial reconstruction, personal records or associated of death scene materials.

In cases of tentative identification, radiographs may be consulted for evidence of anomalies, abnormalities, fractures, surgery or unique structural properties such as sinus or trabecular patterns.

In cases in which no radiographs are available, photographic comparison may be attempted.

With the remains of a person whose identity is a complete mystery, or to further substantiate a possible identification, facial reconstruction may be considered.

In many cases, it is likely that using the conclusions reached in the determination of the general identification in combination with the application of the specific facial identification methods to reach a specific personal identification, unknown skeletal or semi-skeletal human remains can be identified with the accuracy given by scientific methods.

The last stage is the production of the final report of the case to be presented as evidence in the court.

Reports are generally submitted to the medical examiner or coroner and any local law enforcement agencies involved in the case.

Finally, in my opinion, forensic anthropologists should always be aware of the enormous natural variations in the human, and that perhaps a particular variation may be the clue or key for achieving a personal identification.

Topics related to facial identification techniques will be discussed in the following chapters.

HISTORICAL BACKGROUND OF FACIAL IDENTIFICATION

The forensic specialist very often as part of his/her duties, has to work with unknown deceased persons, who need to be identified. These cases are commonly encountered in routine practice. Indeed at the present time, the number is increasing with the discovery of mass graves in various parts of the world and in the investigation of mass disasters. The specialist must be equipped to resolve these types of case, and must therefore be aware of modern facial identification techniques involved in achieving successful identifications. The identification process is essential for both legal and social reasons, as well as in medico-legal matters, because an identified body is much more likely to lead to be successfully resolved by a police investigation.

In many cases, forensic specialists are able to make a positive identification of a deceased by visual examination of the face, or by the presence of marks or tattoos, personal effects, fingerprints or dental records.

If matching records are unavailable or if there are no individual identifying markers, identification becomes extremely difficult, if not impossible.

When the specialist is confronted with severe fire cases, advanced decomposition, mutilation or skeletalised human remains, the first stage is to carry out a general identification to determine sex, race, stature, and age. Only once this general identification has been established, can an attempt be made to establish personal identity of the individual. It is at this stage, that the face becomes importance.

Many specialists working in different fields, but with a common interest in identification, have been attracted to the idea of developing techniques to enable facial identification to be made from such remains.

Before going on to discuss facial identification techniques, it is necessary to mention an investigator in the nineteenth century who was interested in identification methods using anthropometry of the head. Bertillon (1889), a pioneer in this field developed a method for identification based on a system of description, referred to as "Bertillonage" after his name. This method consisted of measuring the length of the head (from the deepest point of the bridge of the nose, the nasion, to the farthest point of the occiput). This system could be used with photographs. The Bertillon method gradually fell out of use, being superseded by fingerprints, and was completely abandoned in the thirties. (Gloor, 1980).

Through the years facial identification techniques have gained importance and credibility and are regarded at the present time as useful adjuncts to other techniques as well as powerful tools in their own right.

The techniques used have undergone almost a century of development, but since the rapid progression of high technology, facial identification methods have changed dramatically. The benefit to the specialist of such progress will be to make the investigation much less tedious and hopefully improve the accuracy at the same time.

The following methods of facial identification are different in each case, and depend upon the type of remains available as well as other post mortem information and whether or not antemortem information is also available.

A **superimposition technique is** considered when there is a presumption of identity, in other words there is someone suspected of being the deceased person.

This technique is commonly used on deceased persons and its aim is to achieve an identification or support evidence of identity made by other established techniques such as comparison with dental or medical records.

On the other hand a **facial reconstruction technique** may be considered when there is no information available regarding the possible identity of the deceased person and no information such as antemortem records obtainable for comparison with the post-mortem records of human remains in question.

This technique should be used after a general identification has been carried out. The aim of the techniques involved in facial reconstruction are to produce a face, which can be recognised as belonging to a specific person, by relatives or friends of the missing person. Once such a recognition has been made, then the specialist can apply other techniques to confirm or refute the identity. The reconstructed face can be publicized in newspapers or other mass media, in order to facilitate recognition.

Forensic anthropologists may use a number of methods of physiognomic identification, based on the physical characteristics of the skull, as itemised below.

1.Cranio-Facial superimposition technique:

Comparison of the skull with photographs of the assumed deceased may be made :

a) Manually

b) Video-Superimposition

2.Facial Restoration:

Restoration of facial tissues severely damaged, but still present on the deceased. Such injuries can interfere with the recognition of the deceased by relatives or persons who are familiar with the deceased person.

3. Facial Reconstruction: (Syn. Facial approximation; Facial reproduction)

Reconstruction of a head from a skull.

The techniques used may be either two or three dimensional.

a) Two- Dimensional

- Artist drawing a face based on the outlines of the skull.
- Face imaging Reconstructive Morphography. This method allows the creation of facial features based on exact cephalometric measurements.

b) Three- Dimensional

- Manual modelling or Sculpting:

The modelling of a face onto a skull or plaster cast of skull using clay or plasticine.

- Computer aided Three-dimensional Reconstruction.

Computer aided three-dimensional Reconstruction using an optical surface laser scanner.

Facial reconstruction, whether two or three dimensional has its basis very much in the relationship of the face to the underlying skull. The specialist aims to reconstruct the facial features of the unknown human, based on the underlying shape of the skull, using reference statistical tables of soft tissue thicknesses, validated and published by several authors as well as other anthropometric data from the skull.

CRANIO-FACIAL SUPERIMPOSITION TECHNIQUE

The technique to date involves the comparison of human skeletal remains (dried skull) with photographs of the assumed deceased person.

It is a method based on comparing the characteristic features of a skull with photographs of a person whose identity is known.

This technique has been widely used in forensic anthropology in order to achieve the personal identification of unknown human remains or to support a personal identification made using other objective parameters. It is considered when no established means of positive identification are available.

Before superimposition is applied, there must be a presumption of identity already established by other traditional methods.

Basically this technique consists in positioning the skull in the same orientation as that of the face in the antemortem photograph and enlarging the antemortem photograph to correspond to the same size of the skull, prior to superimposition.

Craniofacial superimposition is now recognised as a valid method for assisting or achieving personal identification. Since it was first applied there have been a number of methods used and attempts to improve equipment and other parameters such as orientation of the skull in the same angle of the photographs, and enlargement of photographs to life size, using objective parameters to produce the correct scale. Despite the use of video technology in this field, the most critical issues still remain the positioning of the skull in the same identical position as the antemortem photograph.

There are some cases reported in the literature, where slight misalignments have produced false identification. (Dorion, 1981; Lan, 1992).

The key to successful superimposition lies in assessing the correct size and angulation of the skull or head when the two dimensional antemortem photographs were taken. The enlargement of photographs has also been an important consideration for experts working in this field.

One to one enlargements must be accomplished to achieve scientific objectivity. Without knowledge of the enlargement and angulation of an antemortem photograph, it is possible for two faces with similar skeletal features of different sizes to result in a false positive or wrong identification. (DeVore, 1977).

As a technique to aid the personal identification of unknown human remains, it is not new. It was used in the latter half of the last century by anatomists and physical anthropologists who had a special interest in confirming the identities of historical and well-known figures, based on comparison of the characteristic features of the known skull with the respective available portrait, bust or death mask.

For a more comprehensive understanding of the development of the superimposition technique, we can divide our discussion into three stages:

Comparison with bust, portrait and death mask.
Skull to Photo superimposition.
Video-Superimposition

COMPARISON WITH BUST, PORTRAIT AND DEATH MASK.

According to the literature the first investigator who applied the principles of cranio-facial superimposition was Hermann Welcker, Professor of Anatomy at the Halle University in Germany (1883).
He used it to study the skulls thought to belong to Schiller and Kant with their available busts. In those early studies superimposition was not properly carried out. In the Immanuel Kant study, Welcker compared measurements taken from the skull and the available bust, and used the relationship of both sets of measurements rather than applying superimposition. His conclusion was that the skull was compatible with that individual. (Appendix 7,Figure 1a)
Nevertheless, when he studied Schiller's skull and the two existing busts, he carried out superimposition by drawing, using Lucae's apparatus (1873). This method involved producing outline drawings of the skull and the bust, with the two subjects held in an exactly corresponding positions, with allowance made for soft tissue thickness. The two drawings should hopefully then match. According to his conclusion in Schiller's case, because the measurements of the two busts varied significantly with the skull provided, no identity was confirmed. (Appendix 7, Figure1b)

In 1888, another skull was provided which was presumed to belong to Schiller. In that case he used drawing superimposition in the same way as stated above together with soft tissue thickness data he published in 1883. Welcker succeeded in proving the identity of Schiller's skull. (Appendix 7, Figure 1c). Another important case examined by Welcker's was that of the artist Raphael. Confirmation of his identity was made in 1884, using drawing superimposition and soft tissue thickness data.

Tandler an anatomist in 1909 used Welcker' technique when he examined a skull in the museum of the Vienna Society of the Friends of Music. With this method he succeeded in identifying Josef Haydn's skull.

During the 1920's and 1930's in the Biometric school of London University, some of the finest studies of superimposition were carried out. Investigators of this school used the superimposition technique in studies of skulls and available artistic impressions of historically important people.

The first was Tildesley (1923), who carried out comparison studies, between the existing portraits of Sir Thomas Browne and his skull which had been exhumed accidentally in August 1840. Sir Thomas Browne died in 1682 and he was buried at Saint Peter Mancroft Church, Norwich in the same year. Early in 1922 the skull was brought to the Museum of the Royal College of Surgeons from Norwich in order to make an exact and permanent record of its form and features, before it was to be restored to its ancient resting place. Later in 1922, the skull was re-interred after successful plaster casts of the skull were produced in the museum.

Sir Thomas Browne, who was a distinguished Physician of the seventeenth century and a man of high intellect, had a low forehead, not seen in the existing portraits. Evidence of the low forehead was reported to one of the newspapers by an eye-witness, Mr. Fitch, at the moment of the exhumation "It is true that no trace of the "features" remained, but the "beard" was in good preservation, and of a fine auburn colour; the forehead was remarkably small and depressed; the head unusually long." (Tildesley, 1923).

In addition to a detailed analysis of the existing portraits of Sir Thomas Browne, Tildesley made an elaborate anthropometric study of the skull and a comparative analysis with others from the same period.

She also described a complete genealogy of Browne, career, life, etc. She concluded her study as follows:

a) There are two original portraits of Sir Thomas Browne only, namely: the Buccleuch Miniature and the Norwich Painting. It is not certain, however, that they are absolutely independent. Of these the miniature is the later, and may be to some extent dependent on the painting.

b) The skull recently re-interred is undoubtedly the same as was seen and reported on by Mr Fitch in 1840. The skull is the same as that of which a cast was presented to the Norwich Museum in 1841 as Sir Thomas Browne's.

c) The Norwich painting and the Buccleuch miniature are as close to the form that in life draped the skull as we can reasonably expect such portraits to be. They indicate, if they do not stress, the markedly receding frontal of the skull. This not very flattering characteristic, apparently inherited from his father by Dr. Edward Browne, the son of Sir Thomas Browne, is wholly removed in the portraits in the Royal College of Physicians and at the Bodleian, but neither of these pictures is an original. (Tildesley, 1923)

Pearson (1926) criticised the portraits of Sir Thomas Browne, he said "we have a contrast between two portraits of Sir Thomas Browne fitted with the outline of his skull adjusted as closely as possible to the two representations. The earlier portrait agrees well with the skull, while the latter, almost certainly painted after his death for the Royal College of Physicians, exaggerates his low frontal into "high-brow" intellectuality. The artist was quite clearly an incorrigible idealiser." (Appendix 7, Figures 2a and 2b).

He earlier pointed out one of the problems in comparing skulls to portraits or bust, as opposed to photograph superimposition. Artists almost always tend to flatter their subjects, and uncomplimentary features are minimised as best as possible, because the artist wishes to please to his/her sitter and obviously sell the portrait. Another problem with portraits is that the features in some of them are so vague that a great deal of subjectivity is involved in locating the underlying bony landmarks so as to orientate the skull overlay properly.

One of the most important members of this school just mentioned above was K. Pearson who carried out relevant and remarkable investigations on the skulls of Robert the Bruce (1924 b), George Buchanan and Jeremy Bentham (1926), Henry Stewart, Lord Darnley (1928) and Oliver Cromwell (Pearson & Morant, 1934).

All the studies carried out by the Biometrics School had the same approach. Firstly, they took into consideration the individual's life; his career, relationships, circumstance and date of the death and the history of the human remains including the recovery. Secondly an anthropological assessment was performed, comparing the skull in question with other skulls belonging to conptemporary individuals.

Thus this comparison was represented by an illustration of the cranial contour drawing in different views, demonstrating whether they match or not.

Pearson (1926) also remarked upon some important anatomical characteristics of some of the aforementioned persons and their portraits based on his anthropological analysis as follows:

" Sir Thomas Browne compensated for his low frontal and small auricular height by a great skull length and an increased parietal breadth.

Buchanan's skull had a small skull capacity. "The height of the skull and its breadth are not small, they are simply mediocre, but the length is remarkably small."

Henry Stewart had a very disharmonic skull. The man who owned this skull was not therefore possessed of beautiful features, and with his low frontal uncompensated either in the parietals or by length of skull. He had a small cranial capacity.

The skull of Robert The Bruce suggests a man of most exceptional muscularity and strength."

Pearson according to his findings observed that:

a) There were many portraits of George Buchanan, but only a few could be considered as authentic. (Pearson, 1926) Superimposition drawing by Pearson as seen in (Appendix 7, Figures 3a, b, and c) which they have chosen from Pearson's total series. The author commented on these portraits as follows: Plate XXIX left (Appendix 7, Fig. 3a) "Earl of Buchanan's "Titian", St Andrews. I do not know whether it was worth the energy it has taken to dismiss this portrait of President Jeannin, but I have done so. The orbits are out of position, the alveolar margin absurd, and the forehead riculous for the skull"

Plate XXIX right (Appendix 7, Fig. 3b) " Mr. Sowersby's portrait fitted with the skull"

Plate XXX (Appendix 7, Fig. 3c)"The Royal Society's portrait. The orbits are reasonable, so is the nose. The alveolar margin is in the true position; the cheeks bones practically where they should be, and the frontals excellent. If the skull is to be our guide, this could hardly be bettered".

b) The last portrait of Jeremy Bentham was authentic as shown by a superimposition drawing with his mummified head. (Appendix 7, Figure 4)

c) The skull of Henry Stewart, Lord Darnley was genuine, as seen by a drawing of it superimposed on the five existing portraits of Lord Darnley. Pearson concluded "Taking the five pictures as a whole, and bearing in mind the varied methods of expression which different artists adopt, I think we may say that the skull passes the test as satisfactorily as we could hope for.

The historical evidence in favour of the skull is confirmed by portraits known to be genuine." (Pearson, 1928) (Appendix 7, Figures 5a, b, and c).

d) There were no valid artistic representations of Robert The Bruce, King of Scotland. Pearson concluded, "We have no valid portraits of Bruce; only our accurate knowledge of the physiognomy of the man is to be gained from his skull.". (Pearson, 1924 b) (Appendix 7, Figure 6).

e) The head of Oliver Cromwell was genuine as shown by a drawing of it superimposed on several portraits, bust, mask and death mask in existence. The authors concluded "We finish our inquiry with the conclusion that it is a "moral certainty" drawn from the circumstantial that the Wilkinson Head is the genuine head of Oliver Cromwell, Protector of the Commonwealth."

(Pearson and Morant, 1934). (Appendix 7, Figures 7a, b, and c).

Those early successful cases of personal identification or confirmation of identity and their researchers will be remembered as early milestones in facial identification.

SKULL TO PHOTO-SUPERIMPOSITION

The advent of photography, marked the beginning of a new era in forensic skull identification.

Before going on to discuss superimposition using photographs, it is necessary to cite the author and anatomist Stadtmüller, who in 1932 adapted Welcker's method, but used photographs instead of the bust or death mask. He used enlargements of photographic prints and tried to match those with skull photographs taken with a lens of the same focal length at the standard distance laid down according to the Bertillon technique (1895).

This technique cannot be applied when there is no profile or full frontal facial photograph available.

One of the most celebrated cases, in which photographic superimposition was used for the first time was the Ruxton murder case. Superimposition was used to assist in the identification of Isabella Ruxton and her maid Mary Jane Rogerson in Scotland in 1935. The case is remembered for the highly sophisticated degree of medical and scientific teamwork and for the close cooperation between the medical experts and the police.

The team included John Glaister Jr (Glasgow University), Sydney Smith (Edinburgh University), James C. Brash (Edinburgh University) and their assistants, two dental experts, radiographers, an entomologist, and the photographic and fingerprints experts from both the Edinburgh and Glasgow police.

The details of the remains that were found are briefly described below:

On September 29, 1935, it was reported to the police at Moffat, a small town in Dumfriesshire, Scotland, that human remains were lying in the bed of

Gardenholme Linn, below the bridge on the Moffat-Edinburgh road. Gardenholme Bridge is situated two miles to the North of Moffat. In addition to four bundles which were found scattered below the bridge there were two heads, a thigh-bone, two forearms with hands attached and various pieces of flesh and skin. The first bundle was wrapped in a blouse and contained two upper arms and four pieces of flesh. The second one consisted of two thigh-bones, two legs from which most of the tissue had been removed, together with nine pieces of flesh, all enclosed in a pillow slip. The third one was covered with a piece of cotton sheet, and in it were seventeen pieces of flesh. The fourth bundle contained the chest portion of a human trunk and two legs which were tied together with what appeared to be a piece of hem from a cotton sheet. Adhering to the chest was some straw and cotton wool, and covering this bundle, from which the feet protruded, was a piece of cotton sheeting. In addition piece of newspaper were found.
One piece found in the first bundle was identified at once as a part of the Sunday Graphic and Sunday News, dated 15th September 1935. Each of the heads was wrapped in cotton wool; and a pair of child's rompers, held in position by a piece of twine, surrounded the head later designated as Head No. 1 (Glaister and Brash, 1937)

The Ruxton case involved parts of two dismembered bodies found in a stream near Moffat, about 50 miles south of Glasgow. The murderer was a medical practitioner called Buck Ruxton, who lived at Lancaster and killed his mistress and her maid and tried to remove parts of each body which might prove useful in identifying them. (Appendix 7, Figure 8)
He had removed eyes, noses, lips, and large portions of the skin of their faces and scalps, as well as teeth. So gross was the disfigurement, that Glaister and other doctors believed at first that the bodies were those of a man and a woman. Nevertheless despite his efforts to conceal the identity, Ruxton made a fatal mistake; he wrapped the parts of the bodies with clothes and pieces of newspapers just aforementioned which would play an important role in the identification of the bodies.
One of the most important pieces of evidence was from one of the newspapers, because it not only provided a clue to the possible date of the murder, but was a local edition limited to the Morecambe area.

Since the bodies were dismembered with a knife, and the teeth removed with an appropriate tool, the medical team immediately suspected that the murderer had some anatomical knowledge. The remains were removed to the University of Edinburgh, and labelled "Body No. 1 (Mary Rogerson) and "Body No. 2 (Mrs. Ruxton) and were reassembled by Professor Brash. This was not an easy task, because the remains were incomplete. He produced a satisfactory reconstruction of the bodies with careful articulation of bones recorded at all points with x-ray photographs. After the reconstruction Professor Brash realised that the bodies were those of two women.

The proportion of one head was within the statistical range between men and women, but was convincingly fitted to body No. 2, where the sex organs were intact. The other head with the attached neck had a small larynx which was obviously female; this meant that body No. 1 could also be identified as a woman, although the trunk was missing. In addition it was possible after microscopic examination to conclude that the three breasts found were female.

The age and height of the two females were estimated and matched together with other characteristics and with the antemortem records of the two victims. (Appendix 8, Tables 1 and 2) Because of the limited material for identification, a comparison of antemortem photographs of the two missing women with the partially macerated skulls was suggested and carried out by Glaister and Brash in 1935. Four photographs were supplied, two of them portraits of Mrs. Ruxton and two portraits of Mary Rogerson.

Brash labelled these photographs as follows: (Appendix 7, Figures 9a, b, and c)

Photograph A and B, Mrs. Ruxton.

Photograph C and D, Mary Rogerson.

The following procedure was used:

a) The portraits were enlarged to life size, and scaled by calculations based on the dimensions of a known object present in the photographs.

In the case of Mrs Ruxton, she had a diamond tiara that she wore in her head which was found later in her home; in the case of her maid a picket fence gate present in one of the photographs taken of her was used.

b) Each skull was photographed natural size and in the same orientation as the faces of both women in the photographs. Appendix 7 :(Figures 10a, and b) (Figures 11a, and b)

c)The outlines of the skulls and of the faces were traced on transparent overlays and compared by superimposing them on each other to determine the degree of correspondence.

d) Transparent negatives of the portraits and transparent positives of the skulls were made by using X-ray film.

e) After establishing the presumed identity, photo superimposition was carried out with the participation of a professional photographer who used the negatives from the skull photographs.

The transparent positive of each skull was then superimposed, over the transparent negative of each appropriate portrait and photographed on X-ray film by transmitted light, producing a transparent combination of the negative image of the skull with the positive image of the portrait. Appendix 7 : (Figures 12A1, A2, A3) (Figures 12B1, and B2) (Figures 12C1, C2, C3) (Figures12D1, D2) (Figures 12E1, E2, E3, E4).

The conclusion that they reached was that the comparison of the superimposed outlines of skulls and portraits demonstrated (1) that skull No. 1 could not possibly be the skull of Mrs. Ruxton and (2) that skull No. 2 could not possibly be the skull of Mary Rogerson.

Secondly, the opinion was given that skull No. 1 might be the skull of Mary Rogerson, and Skull No. 2, the skull of Mrs. Ruxton. This opinion was based on the correspondence of features of the skulls to features in the respective portraits with due allowance for the relative thickness of soft parts in different regions-the outline of cranium and face; the position and form of the orbits; the position, size, and outline of the nose; the position and size of the mouth; and the relation of the teeth to the empty sockets in the case of skull No. 2. In general the correspondence of all these features appeared to be as close as might be expected if the skull and portraits of a known person were dealt with in the same manner; nor did there appear to be any single point of discrepancy in any of the four comparisons which could not be explained by the inherent difficulties of the technique. Glaister and Brash, (1937)

The authors did not offer their technique as a method which proved identification, but rather one which could support other methods of identification.

Owing to the novelty of the method and the uncertainty of the reliability of the technique, a positive identification of the skulls, no matter how close a correspondence of skulls and portraits was obtained, would have been open to very grave objection.

Indeed, the Defence, knowing, that no evidence of positive identification would be given, objected to the admission of the superimposed outlines and photographs at all, on the grounds that it was "constructed evidence so liable to error.....that it ought not to be permitted" . Glaister and Brash, (1937)

The final conclusions about the personal identification of the two bodies were supported by non biological evidence such the comparison of the feet and the shoes. (Appendix 7, Figure 13 and Table N° 3)

Dr Ruxton, as well confirmed the personal identification. He was found guilty of murder on March 1936, after a trial lasting 12 days, sentenced to death and was hanged in May 1936. (Blundel and Wilson, 1937)

Glaister and Brash in order to test the validity of this technique, photographed a cadaver head and its skull after removal of its soft tissue, in the same position as Mrs Ruxton's photographs. They followed the same procedure used in the case, by tracing overlays before superimposition and found the technique worked, and the resulting fit was good enough.Appendix 7 : (Figures 14A1, A2, A3) (Figures 14B1, B2, B3).

Furuhata and Yamamoto (1967) described a slight modification of the method used in the Ruxton case. They placed a negative image of the skull over a negative image of the portrait. After superimposition was carried out and then printed, the resulting image was a positive image of the skull and portrait. They also used the placement of selected landmarks on a facial photograph and skull, to aligned them. These points were then checked for alignment by focusing the image on the screen.

The controversial issue regarding the correct method to produce life size photographic enlargements in the absence of objects visible in them, with known measurements has been discussed by several authors. (Simpson (1943); Reddy (1973); Prinsloo (1953); Sekharan, (1971); Janssens, 1978; Mc Kenna,1984; Maat, 1989).

In view of the fact that it is not always possible to find such objects for measurements in photographs, which are in the same plane as the individual's face, coupled with the inherent difficulty and tediousness of assessing measurements in the laboratory, it became necessary to find other objective parameters to generate accurate scaling of photographs.

Two procedures have been described which attempted to do this:

a) The first one employs facial proportions and distances between features to align a skull and enlarge the photograph, e.g., interorbital distance, interpupillary distance, size of dentition.

b) The second makes use of classical anatomical landmarks in both skull and photograph in order to obtain a correct enlargement for superimposition. (Appendix 7, Figure 21)

Some authors used the first procedure cited, where there were no objects in the photographs for comparison. Simpson (1943) and Reddy(1973), used interorbital distance; Prinsloo (1953), traced outlines of the skull and photograph and then superimposed them. This identification was supported by medical records which gave a history of a broken nose. In both former cases, the identification was supported by dental records.

The second method has been used by Russian researchers since 1935. The use of landmarks, attempts to evaluate objectively the superimposition technique and thus the accuracy of the identification.

Although placing landmarks on the skull can be carried out satisfactorily, errors may occur in determining the correct position of some corresponding cephalometric points in a photograph, because of the interfering soft tissue thickness, angulation of the face, as well as the actual quality of the photograph.

The technology used by Russian researchers was described as follows:

1. Reproduce the missing person's photograph onto several photographic plates, 9 x12 cm, of different densities; using ink, mark the outline and marking points on the face as a reference for comparative points; print it to a glass slide; and place it on an imaging screen.
2. The skull should be fixed onto a freely moveable stand in front of the camera, so that the identification expert can observe the image-face superimposition while his/her assistant adjusts the photographic angle of the skull to completely align the projection of the skull and the marking points on the photograph.
3. Make several negatives of different densities of the skull, select the most suitable image to superimpose onto the photograph, and then produce a skull-image superimposed photo for identification.

Grüner and Reinhard (1959), developed of a new photographic method for skull identification. They discovered that the photographic angle of the skull influences the superimposition and also deduced that the most suitable photographic objective length of the skull was 1.75 m or greater. Grüner designed a special light stand, the optical bench, to achieve proper superimposition.
The optical bench is 3 m in length, the skull is fixed at one side, an aiming hole at the other, and the photographic angle can be adjusted through three rubber bands. A compact camera is fixed at the position of the aiming hole. (Appendix 7, Figure 15)
The researcher takes a negative of the skull, then enlarges it to the size of the image, and then prints it as a superimposed photo for identification.

The steps involved in Grüner's technique are listed as follows:

1. On an enlargement of a portrait (size 18 x 24 cm), the appropriate cephalometric measuring points (e.g., nasion, gnathion, gonion, etc) are found. These form the basis for a system of guide lines. **(Appendix, Figure 16)**
2. Mark the corresponding craniometric measuring points on the skull with India ink.
3. Adjust the rubber bands on the sighting device-taken off the optical bench for this purpose-so that they coincide with the guide lines on the photographs. (Appendix 7, Figure 17)
4. Take the perspex pane off the optical bench, drawing the outlines of the skull and the guide lines. **(Appendix, Figure 18)**
5. Position the skull:
   With the sighting device;
   With the sighting device and drawing on the
   perspex pane, taking into account the thickness of soft tissue. **(Appendix 7, Figure 19)**
6. Take the photograph:

a) Fasten the enlargement (without marker points and guide lines) onto the perspex pane, and take the portrait.

b) Remove the sighting device and perspex pane from the optical bench. Take a photograph of the positioned skull (double exposure).**(Appendix 7, Figure 20)**

Grüner concluded that "the help of outline drawing, marking points, and the system of lines, while taking soft tissue thickness into account, it is possible to precisely position the skull to correspond with the photographs without first determining its natural size". The same author and colleagues made variations of the same technique in order to simplify it. In 1964 Hiroshi Ishibashi improved Grüner's light stand by decreasing the size to 1.5 m, folded the stand, and added a strobe unit that continuously photographed the skull.

In 1978 Leopold modified Grüner's technique, using a large format camera and a projection screen between the skull and camera.

Others authors who have used landmarks or marker points in their investigation of personal identity were; Getvall (1974), Getvall and Johanson (1976/1977), Wadhera (1977), Sivaram and Madhera (1977), Iscan (1980). In these cases personal identities were supported by other parameters such as dental and medical records and hair comparison.

The superimposition technique was also applied by many other authors, e.g.,Webster and Basauri, Chandra Sekharan, McKenna, Dorion, Bastiaan, Dalitz, Woodward.

Chandra Sekharan has been interested in the positioning of the skull for superimposition since 1973. His studies have taken into account the atlanto-axial and atlanto-occipital joints, which are responsible of the range of the movements of the head which include flexion, extension and rotation. Sekharan states that the posture of the face in a photograph depends on the following factors:

a) Flexion or extension(forward to backward tilt). Appendix 7 : (Figures 22a, b; 23a, b; 24a, b)

b) Lateral flexion or extension right or left (sideways bent) of the head. (Appendix 7, Figure 25)

c) Rotation.

These factors must be carefully evaluated before positioning of the skull is attempted, and in his opinion flexion or extension (tilt) is the most important of these factors, for a successful superimposition technique. He applied landmarks for determination of the positioning of the skull.

Dorion (1983) designed an experimental superimposition unit and tested it with two forensic cases.

The equipment and methodology applied by Dorion were as follows:

1.The photograph was enlarged to 1:1 ratio using the reference standard points on the skull. A 1:1 transparency was created and mounted on a X-ray viewbox.

2.A Graflex 4 x 5 camera was mounted with a 135-mm lens at f-4.5, directly in front of the skull at a distance of 95.25 cm. (Appendix 7, Figure 26)

A beam splitter and front surface mirror were arranged so as to reflect the image of the subject's photographic transparency. (Appendix 7, Figure 27)

3. The skull was mounted in a tripod with a pivoting head, thus a similar angulation of the skull to the transparency could be achieved. The tripod was used to achieve all the movements of the head studied by Sekharan (1993).

4. The distance between the camera and the skull should be identical to the total distance between the camera and the reflected transparency. At the same time, the angle of the skull and lighting is adjusted until both the photograph of the skull and the projected image of the skull are superimposed.

5. The semitransparent reflector is then removed and the photograph of the skull superimposed with that of the deceased person.

Dorion's technique demonstrated with case studies the uncertainty of using photographic superimposition of the skull with antemortem photographs as the sole basis for positive identification. His first case was a partially decomposed body found in April of 1976. An identification was made in another jurisdiction using photographic superimposition as the basis for a positive identification (thus assuming a high degree of certainty).

His second case involved skeletal remains found in a wooden area, on November 2, 1979 at Millstream, Bonaventure, County in the province of Quebec, Canada.

Two skulls were found which were then superimposed with antemortem photographs of a particular missing person and one skull was identified as the individual in question, using this technique alone. This identification proved to be satisfactory.

However in the first case, the identification was mistaken; the correct identification was made later by fingerprints.

Dorion thus concluded that identification should rely on the recognised standard, reliable, and tested methods and was emphatic that photographic superimposition of skull and antemortem photographs should serve no basis as the sole method for positive identification.

In cases where the standard methods prove fruitless, and photographic superimposition shows a good match, then this technique should be used as corroboration with other available scientific findings and circumstantial evidence.

De Vore (1977), when describing the application of photography in Forensic dentistry, particularly after applied superimposition, concluded "It must be strongly emphasized that this method is for general information only and cannot be used for positive identification since the magnification and angulation of the original clinical photograph are unknown. This method of photographic superimposition is of value more in exclusion than identification".

McKenna et al, (1984) described a method of matching and identifying skulls to family snapshots or passport photographs, using landmarks and measurements of the dentition. He used this technique in a case study known as the "Jar Murders". The Royal Hong Kong Police requested identification of two skulls for three possible victims in August 1982.

Initially, the authors were able to identify two out three victims and then, four months later when a third skull was found, they were able to identify the third victim.

The method involved using selected dental landmarks to achieve an accurate factor of magnification.

They measured the distance between two teeth, (preferably the distance between two incisors) or the length of the incisal margin in a single, isolated, socketed tooth. The method is reliable, quick and relatively simple.

It is based on there being visible features of the dentition which are seen on photographs which must show a smiling face with the teeth visible. Scaling to corresponding size can thus be achieved with confidence, without using an object of known size as a parameter of magnification. A slide transparency or negative of the selected photographs is enlarged to bring the dimensions of the image of the visible dentition to the dimensions of the chosen measurements in the skull.

If the skull belongs to the individual in the photograph, then all other characteristics of the dentition and skull should correspond when life-sized transparencies from portrait and skull are superimposed.

This method was described as follows:

1. The life size transparencies were prepared with a blue sensitive, medium speed, high contrast radiographic film (Kodak X-omat RP).

2. The length of the exposure was adjusted to produce a transparency with good contrast and of a density that allowed light to be easily transmitted.

3. The transparency of the skull is prepared from a photograph taken from exacts the same viewpoint as that of the photograph selected for examination.

4. The skull was photographed with a Nikon F3 camera with a Nikkor Micro (120 mm) lens, and fine grained, black and white film (kodak Plus-X or Ilford FP4135) were used.

5. The negative of the photograph of the skull was enlarged and a positive transparency on radiographic film produced.

6. Features of the skull such nasal spine, orbits, zygomatic processes, and mandibular angles and body were traced on mate acetate from the transparency of the skull.

Similarly facial contours were traced from the transparency of the enlarged photograph selected.

7. The transparencies and tracings were then superimposed and illuminated from below on a radiographic viewing box.

8. Dental landmarks were verified and corresponding features of the facial skeleton and soft tissues of the face are noted.

9. The tracing mounted with the transparencies can be used for demonstration of the superimposition using a viewing box or an overhead projector.

The photographic superimposition and composite tracings that McKenna et al, prepared as evidence in the case were accepted as positive identifications by counsel for the defence and the prosecution in the High Court of Hong Kong. (Appendix 7, Figures 28, 29, 30 and 31) and (Appendix 8,Table N° 4). It was of equal importance that the identifications were also accepted by the families of the victims, particularly in the context of Chinese culture.

McKenna also noted some degree of difficulty in obtaining the correct angulation of the skull in the same direction as the photograph selected.

They overcame this using a special mounting device similar to a "phantom head-holder", used by dental students.

Maat (1987) was also interested in the problem of positioning and magnification of faces and skulls for photographic superimposition.

He defined the preconditions for its reliability as follows:

a) The principles of central projection

b) The posture of the head or skull should correspond to that of the original portrait.

c) The magnification of the laboratory image could be the same as that of the original portrait.

If these preconditions are met and the superimposition shows a good match, then the evidence for identity is strong.

Central projection:

The optimal result is obtained if the distance between the camera and the head or skull approximates most closely to the distance from which the original photograph was taken. In practice it is difficult to estimate that particular distance.

For such cases Grüner and Reinhard (1959) have shown that photographs may be matched if taken from distances of 1.5 m or more. Usually portraits are taken from a safe distance of at least 1.75 m.

Posture

The posture of the head in the subject' photograph is analysed based on the factors discussed by Chandra Sekharan (1988, 1993).

1. Turning on a horizontal axis parallel to the image, i.e., tilting the face down and up.

2. Turning on a vertical axis parallel to the image, i.e., turning the face sideways.

3. Turning on an axis perpendicular to the printed image, i.e., rolling the head sidewards. This component needs no analysis as it could be corrected by rotating the print. Points 1 and 2 are analysed by choosing landmarks and drawing parallel references lines through these landmarks.

This results in a grid-like set of reference lines which can be marked onto the ground glass of the laboratory camera. If the skull that is being matched is now viewed through this grid, it can be positioned according to the preconditions marked out by the reference framework.

For Sekharan the most important component is number 1, for a successful superimposition technique.

<u>Magnification</u>

This last step is required to achieve the best match with the original portrait. That enlargement is acceptable if all visible landmarks of the superimposed image cover their equivalents on the original portrait in the best possible way.

Video Superimposition

This is the most up to date method used by the forensic specialist, making use of the latest technology to carry out superimposition. Its principles and requirements are the same to those applied in static superimposition, as described earlier in this summary, to achieve a good match. The use of video technology has removed many of the technical problems of the superimposition process. It is a faster way of performing skull to photograph comparison, and is particular useful for allowing us to make a rapid exclusion when there is a mismatch.

It also enables the operator to readily obtain the required corresponding magnification of the two images by mixing and using a sweep technique with several wipes. By using mixing and wiping it enables the position of the landmarks and goodness of match to be checked.

This technique was first introduced and appears in the literature in the late 1970's, coinciding with rapid developments in video technology.

The technique has been adopted and tested by several authors, who have reported their findings.

Basically the equipment consists of two video cameras, and an electronic mixer, that allows to overlay a photograph over an image of a skull, and two or three monitors used for outputting the images from the cameras.

The system, thus described uses the following principles: a) Recording images with video camera. b) Freezing the image's frames. c) Correcting alignment and magnification of images. d) Mixing and performing various wipes to asses matching.

Helmer (1977) was one of the first, who experimented with video superimposition. He used two TV cameras, one video signal mixer, one monitor, and one photocamera. The two TV cameras separately took the images of the skull and photograph of the deceased. The signals output from the two TV cameras were mixed through the video signal mixer, and the superimposed images of the photograph and skull were displayed on the monitor. (Appendix 7, Figures 32 and 33)

The technique's steps were as follows:

1. The comparable position points representing soft tissue thickness were marked out on the tested skull. The skull was then secured onto a stand, and adjusted for angular correspondence in front of pickup camera 1.
2. The test photograph is fixed onto a stand that can slide in the track in front of pickup camera
3. Turn on pickup camera 1 and 2. The size of the photograph and the skull are separately adjusted to coincide with each other.
4. The gray scale and contrast of the skull and the photographic image on the monitor are adjusted, using the position points of the soft tissue (marked in advance) as the standard. Proper identification can be made only when all position points and the outline figure have been accurately superimposed.
5. Using a photo camera aimed at the monitor screen, the superimposed images are photographed for future use.

Helmer (1987) using the principles of this technique contributed to the identity of the remains of Adolf Hitler's former medical officer, Dr. Josef Mengele, the former "Medical Monster of Auschwitz" at Sao Paulo, Brazil in 1985.

In 1985 it was suspected that Dr Mengele might have died on 7/2/ 1979 and that he had been buried in the Cemetery of Embu/ Sao Paulo under the name of Wolfgang Gerhard. Helmer was part of a team of authorised international forensic experts officially representing the Governments of West Germany and the United States and the Simon Wiesenthal Center of Los Angeles with the collaboration of Brazilian scientists.

Helmer after his own investigation of identity concluded that "the osteometrical and osteological findings ascertained, correspond completely and consistently without contradiction with all the available personal data of Josef Mengele.

Through the superimposition technique, he determined that all the authentic photographs available which were used for comparison, corresponded with the exhumed skull. (Appendix 7, Figures 34, 35 and 36)

Helmer concluded that the electronic photocomparison of photographs of Mengele with the skull found "supplies an almost unassailable abundance of individual data which may be compared or combined with each other." By virtue of the clear evidence of all the findings taken together, there is no room for doubts that the exhumed skeletal parts are the remains of the corps of Josef Mengele."

Helmer (1989) with reference to the Mengele identification using his superimposition method, added that the technique played a decisive role. He concluded that "the published photographs of the examination are results of the direct comparison of skull and photographs. The identification of Mengele'skull was the result of complete congruity of all proportions and distinctive features of the skull and the photographs. At the same time there is not a single contradictory element.

This result was supplemented by the concurrence of numerous individual traits about Mengele with features of other part of the skeleton; e. g. body-height and peculiarities of teeth."

Helmer's superimposition results were refuted by Maurice E. Rogev in 1993, because of important damage in the structure of the reconstructed skull presumed to belong to Mengele, thus altering the position of the topographical reference points referred to by Dr Helmer.

Helmer's procedure used, was described by Rogev as follow:

1. The most probable outlines of the contours of the face consistent with the reconstructed skeleton of the face was determined. This was achieved by appying a white marker to the surface of the skull at 30 topographical points.
2. Each marker defined the estimated thickness of the soft tissue, including muscle, fat, and skin at each of the 30 topographical points. These estimates of soft tissue thickness were derived from published anthropological tables organized according to age, sex, and race.
3. The white markers were attached to the skull by dabs of clay.
4. Using two high resolution cameras hooked up to a video image processor, Dr. Helmer recorded separate photographs of the skull, on which the facial contours had been outlined, and a portrait photograph taken of Mengele in 1938.
5. Each camera was moved back and forth along a track until the two images seen in the video monitor matched, e.g., the facial contours as reconstructed on the facial skull corresponded with the same morphological outlines on the photograph.
6. There was a match between the contours of the face in each photograph examined, and the contours of the face as based on key points on the skull.

Rogev shared the conclusion reached by the U.S. Justice Department in October 1992, that defined the superimposition as probative and not of definitive value. In his opinion, the video skull- photo superimposition test carried out, was subjective and subject to the various problems associated with the technique as described in the literature.

Rogev concluded "The electronic video skull/photograph superimposition technique, as carried out in this case, does not prove that the 1938 photograph of Mengele matches the face and cranium of the Embu skull beyond a reasonable doubt".

He also suggested using the techniques designed by Ubelaker et al. (1992), Pesce Delfino et al.(1986), and Nickerson et al.(1989) to validate the results of superimposition of the Mengele skull.

He suggested carrying out a DNA analysis of the "fingerprints" of the skeletal remains, and comparing them with those of Rolf Jenkel (Mengele's son) and Irene Hackenjos (Mengele's ex-wife and mother of Rolf).

Professor Jeffreys from University of Leicester carried out this test. In March 1992 the following report was issued "P.C.R. analysis of microsatellitel loci in Rolf Jenkel, Irene Hackenjos and the skeletal remains exhumed from Embu Cemetery, has shown that the skeletal DNA has a consistent genotype compatible with the father of Rolf, and that 99% of Caucasians unrelated to Rolf would be excluded, and that the skeletal remains are beyond a reasonable doubt those of Josef Mengele."

Brown (1977), devised a craniofacial identification procedure using videotechnology. This procedure was as follows: (Appendix 7, Figure 37)

1. Two video cameras and a special effect's generator, were used to superimpose their images electronically onto a television monitor.

2. The skull was mounted through the foramen magnum by a clamp which allowed freedom of movement in three axes.

The advantages of Brown's technique, (cited by himself) were as follows:

a) The traditional photographic process was eliminated, with a considerable saving of time.

b) Adjustments in orientation of the skull and the determination of the relevant size of the photographs on the screen could be observed on the monitor screen.

c) The provision for fading the images into each other and wiping segments of one image over the other, allowed specific characteristics of the skull to be examined in greater details in relation to the corresponding features of the portrait.

d) Either image could be reversed to negative form as required to compensate for variations in contrast in the two images.

e) The entire procedure of adjusting, fading and wiping the images may be recorded on videotape.

This method was used in New Zealand by Koelmeyer (1982), Dalitz (1986)

Chandra Sekharan (1988), already cited, adopted Helmer's technique and improved on it. His version is called video imaging electronic skull identification unit (ESID). The apparatus he uses is comparable with that of Helmer and Brown. However, he emphasised that the exactitude between angles and image proportion must exist in order for the conclusion to be accepted. More than 140 cases have been identified since 1985 using his method.

Koelmeyer (1982) carried out the identification of unknown human remain, partially buried in sand dunes, found on a beach in the Muraiwai State Forest. To achieve this identification, he used video camera superimposition and facial reconstruction techniques. The video superimposition technique was similar to that described by Brown and Helmer (1977).

He used three video cameras to perform superimposition of a skull on which the facial features had been reconstructed on one side of the skull (left side)(Krogman, 1962); An X-ray of this skull and a photograph said to be that the deceased was utilised. The skull found was compared with two missing person' records provided by the police, and with information by a forensic specialist from the department of Forensic Pathology, School of Medicine, Auckland, giving information about general identification and some characteristic found on the clothes.

One of the missing persons was excluded by comparison of X-rays taken some months before the disappearance with X-rays of the skeletal remains. The facial reconstruction was carried out before the police were able to supply a photograph of the suspect.

The methodology used was as follows:

1. Three video cameras were used, one focused on the X-ray of the skull, one focused on the photograph, and one on the partially reconstructed skull.

2.The special effect generator used, enabled the comparisons to be performed relatively easily on the monitor, by mixing and wiping.

3. The X-ray picture and subsequently the skull image were progressively superimposed on the photographs in vertical and horizontal axes.

Before applying superimposition, an X-ray of the skull was taken in a position that would correspond with that of the photograph supplied. This involved simply linking a television camera to the X-ray apparatus.

In the opinion of Koelmeyer, the sweep technique permitted better comparison of bony points; despite the fact that the fade out produced a more pleasing image. The Auckland City Coroner, after viewing the evidence presented in the resulting video film, accepted the superimposition evidence as corroborative in order to establish identity.

Koelmeyer agreed with others that one of the main advantages of this technique, was that it was less time consuming. In a subsequent case the skull was incomplete, and video superimposition was carried out with photographs of adult males of same age group of the suspected missing person. Although a match was obtained with the photograph of the suspected, a good match was also obtained with another photograph of a person known to be alive. He therefore suggested that the complete facial skeleton is required for accurate assesment. He expressed the view that, in the absence of an assessment of the degree of accuracy, this method had only corroborative value.

Pesce Delfino and al.(1986) devised a technique called Computer-Aided Skull/Face Superimposition, in an effort to produce a new standard of digital identification, using the computer to process the video image.
His aims were to improve the objectivity and efficacy of the identification results. In this method, corresponding cranial segments of both the skull and antemortem photographs are compared, e.g., frontal segments, nasal profiles, in either lateral or oblique views of the face.
This is a method comparing profiles, and it evaluates the comparison between the two profiles. These profiles are treated as curves and compared with analytical mathematical procedure, such as the "kth-order polynomial equation" and Fourier Harmonic Analysis. The appropriate analytical morphometry software package is required. This method allows the determination of correspondence or "fit" between the two profiles by means of numerical evaluation.

The material and methods used were as follows: (Appendix 7, Figure 38)

1. An optic device for the superimposition- a prism made of semireflective glass, representing the hypotenuse of a right-angled prism. One side of the prism is totally reflective, the other transparent.

2. A B/W TV camera with a prism mounted on a standard lens.

3. A video monitor

4. A cross-hatch generator, which superimposes a network of vertical and horizontal lines onto the TV image displayed on the video monitor. These lines can be moved continuously and do not exhibit parallax with the TV image.

5. An Apple II Europlus computer, with 48 K. RAM, Apple soft language, two disk drives, and a graphic printer.

6. An A/D Microworks converter used as the interface between the telecamera and the computer.

7. Spotlights with lighting control.

8. Appropriate stands for the skulls and the photographs.

The skull was first fixed on the stand facing the pickup camera, the prism in the middle of the skull and pickup camera. The photograph and prism were placed vertically on another stand. The two images were then displayed simultaneously on the monitor by adjusting the intensity of the light; the images of both the skull and photograph must be adjusted to the same scale by varying the distance of one or the other to the TV camera.
The SAM (shape analytical morphometry) software package is then used to perform the following operation once the photograph and skull have been superimposed satisfactorily on the monitor:

1. Routine controlling of the system of coordinates and image luminosity.
2. The index using Fourier harmonic analysis is derived.

3. The outlines of the test skull and face and then processed to count out the differences of equal and unequal angles.

Delfino indicated that the purpose of the experiment was to get a volume of any number, which can be a reliable differential point in the presence of differing "true or false" characteristics. In evaluating the results of the experiment, Delfino stated that although correspondence was successfully obtained, the work was still in the preliminary stages of development and more studies were needed to establish an evaluation standard, to provide accurate identification.

Iten (1985) devised an experiment using the video superimposition technique and applied it to different cases.

The first case was the identification of a six year old missing girl; the second was the identification of human remains presumed to have belonged to the famous pedagogue Johann Heinrich Pestalozzi, who died about 160 years ago.

The method he used was as follows: (Appendix 7, Figure 39)

The apparatus should consist of two videotubes, 1 and 2 (preferably CCD cameras), electronic and mixer units, and three monitors.

The two video tubes (including optical lenses) must be adjusted by video test pictures. The skull in question was first captured with tube 1 and reproduced on the monitor 1. For comparison purposes, a photograph of the missing person was reproduced by tube 2 on monitor 2.

The picture-mixing unit not only allowed an infinitely variable mixing of the two pictures, but also allowed the creation of horizontal and vertical sections at any desired point. These sections and the mixed pictures were then appraised on the monitor

3. For future use, essential results of the investigation can be recorded on tape or photographed directly from the monitor with a camera.

Accurate and precise parameters such as the correct orientation of the skull, are very important. Assessment of inclination depends on the distance between the eye and the auditory canal axes. If the position of the

eye is not correct for an individual skull, for example reconstruction of a fractured zygomatic process can not replace the correct position of the eye, then accurate inclination of the skull may not be achievable.
Equally, the rotation of the skull depends on the ratio between the distance of the inner or medial angles of the eyes to the peripheral distance between the outer or lateral angles of the eyes. If there are anatomical distortions on the skull that can alter these parameters, and these alterations can not be reconstructed in an accurate way, the value of the skull photograph video superimposition method may be diminished. The author using this equipment was able to identify the persons involved in his two cases.
Video superimposition, has proven to be a success in the investigation of identity. Iten said: "Thanks to its versatility, this method presents enormous advantages over the usual photographic superimposition processes".

Chai, D et al. (1989) submitted a standard identification system consisting of 52 facial proportion indices in four groups for evaluation of superimposition results. This study was performed in 224 Chinese faces (100 males and 124 females). Thirty-four landmarks and eight determining or marking lines on face and skull were selected. (Appendix 7, Figures 40, 41) and (Appendix 8, Table N° 5.) According to the authors a marking line is formed by the connection of landmarks.
The cross lines are horizontally parallel while longitudinal lines are vertical to the cross lines. In their study the line between the two ectocanthions was used as a horizontal baseline and the front central line

was vertical to the bi-ectocanthion line while other marking lines, all running through respective landmarks, were parallel with or vertical to the bi-ectocanthion line. The first marking line fixed was the line between the two ectocanthions or ectoconchions. (Appendix 7, Figures 42a and b). They designed their study as following: In the first group there were eight determining lines; in the second group there were 22 proportion indices of interrelated relationships; in the third group there were 13 proportion indices for soft tissue thickness, and in the fourth group there were 9 proportion indices for profile morphological curves.

They stated that not all indexes aforementioned appeared in each case of identification. The index that appear at different deflection angles of the face may be called the observable index.

According to their research, if two of the observable indexes are not congruent with the data mentioned above, then the identity can be overruled. In the case that one of the observable index is not congruent, then a conclusion of suspicious identity may be drawn. A conclusion of identity can be drawn only when all the observable indexes completely superimpose. This method was the first to use data analysis to minimise subjectivity. Their study suggests that each face is metrically unique and therefore distinguishable in studies of photographic superimposition. Between 1980 to 1989, eighty-nine cases of unknown skulls have been identified with this method. From eighty-nine cases, eighty were classified as identical, 5 cases were rejected as not identical and 4 were not identified.

On the basis of this standard, Chinese researchers established "the directional superimposition unit" and Model TLGA-1 and Model TLGA-2

Skull Identification Apparatus, each of which combined the photographic angle and distance and the objective image proportion calculation as the prerequisite and laid a foundation for analysing and judging the superimposition using a computer.

Lan et al. (1989), developed an Image superimposition processing system which they called TLGA 213.

The system and methodology devised was as follows:

The equipment consists of an AST PC/486 computer, A CCD camera, a video-frequency synthesizer, a CGT colour monitor, a skull adjustment device, a stand and a stage, and 213 system software library. A TL image-processing card and a multimedium card are provided with the computer. **(Appendix 7, Figure 42 C)**

The computer is an AST PC/486 and works with MS-DOS 6.0 operating system. Using the image-processing card provided a digital image of 512 x 512 resolutions can be captured and passed through the video synthesizer and a superimposed image of the digital image and the analogue image from the camera, can be seen on the monitor. The resolution of the system is according to the requirements of image resolution in superimposition. The method used involved first processing the presumed person's photograph through the camera; the photograph is placed on the stage under the camera. Then an A/D converter, to convert it into a digital signal which is entered into the computer internal memory RAM which is processed through the 213 system software library. Finally, the image is displayed on the monitor. When this process is completed, the camera is aligned. The skull is fixed on the stand with six-directional-angle adjustment, in order to allow completely superimposition of the skull and photograph images under the program control.

Lan (1989) stated that the introduction of the TLGA 213 system is an important advance. It makes direct testing and judgement of the superimposition result possible and reduces dependence on the expert's

experience. Since its adoption, the authors claim that the system has demonstrated practical value for improving the accuracy and objectivity of identification and that the science of skull image identification has been significantly advanced to a higher level. More than 300 skulls have been identified using this method since 1982, and none of these identifications have shown discrepancies with other forensic experts reports.
Lan, since 1982 has been developing his superimposition technique. He has also suggested that the anatomy and morphology differences between individuals of different races, nations, sexes, and ages render the study of the facial proportion indices more important than the use of advanced apparatus. He stated that these differences should be fully addressed while determining the proportion indices for identification; the accuracy of a determination can only be assured on the basis of these differences.

Nickerson et al. (1989) developed a methodology that computes a fast, near optimal fit between a three dimensional skull surface mesh and a two dimensional, digitized facial photograph. Photographs were digitized in pixels and the skull digitized in a three dimensional mesh that was transformed into two dimensions with perspective projection. Using four anatomical landmarks (ectocanthion, glabella, nasion and subnasal), and their determining lines, along the front central determining line, the computer visually depicted the superimposed results.
The final image was reviewed by a forensic specialist to ensure the sizing, correct positioning, and alignment of craniometric points of the skull in relation to the photograph.

Helmer et al. (1989) designed an experiment to prove the conclusiveness of skull identification using video superimposition. The principle of superimposition is based on the assumption that no skull is completely like another because of the variability of all biological forms.

The aim of this project was "to find out to what degree the individual form of a skull can be identified and what must be taken into account during the practical identification of the individual.".

They defined craniometric individuality of a human skull and calculated the probability of confounding different skulls because of measurements errors. They measured 52 Caucasian skulls with a measuring instrument designed by themselves. The coordinates of 35 points on the bone surface were measured with a tolerance of +/- 0.5 millimetre. The skulls were placed in the Frankfort horizontal, the frontal and the mediosaggital plane. The landmarks selected were the classical craniometric points. Age and sex were not take into account. Their conclusions were the individuality of the skulls in their collection, its statistical calculations showed that at worst there will be one skull in about 630 billion which is identical to a certain other skull in respect of the position of those eight selected points. On averaging the individuals, a probability of only one in 10.000 billion skulls would match.

They also added these figures were based on the relatively small number of 52 skulls and on the congruity of all selected coordinates within the tolerance of +/- 0.5 millimetre.

They remarked "the great individuality of human skulls is of decisive importance for the reliability of the video superimposition technique. The accuracy of videosuperimposition can only be achieved taking in account the following factors soft tissue thickness, a high quality video camera, good quality photographs and, if possible, several photographs at different angles."

Ubelaker et al. (1992) devised a new computer assisted video superimposition, using an IBM PC and a printed circuit board.
The method involved digitization and storage in the computer of images of the photograph and skull. The skull was aligned using a tracing of the important anatomical landmarks found in the photograph. The digitised images were superimposed and the software allowed for any mixing of bony and photographic images, including removal of soft tissue to view the skeletal structure underneath. The credibility of this method was enhanced through the study of collections of similar human crania and comparison with the available photographs.

The authors stated that: "the system can be used to demonstrate that a cranium and mandible could belong to a person in a photograph as long as positioning and size are correct. A slight mis-orientation of the bones precludes a successful match."

They also remarked that "success in identification depends upon the quality of the submitted photograph, proper articulation of the cranium and mandible, and proper orientation of the cranium and and mandible."

The latest technical advances in skull to photo superimposition reported in the literature, particularly with reference to the positioning of the skull and photographic magnification, have been by Lan and Chai (1993).
They devised a new technique that uses a microcomputer to correctly obtain the angle of superimposition, an approximation of natural head size, and maximum objective length.

Angle of craniofacial superimposition:

The method can calculate the deflection (rotation) and pitch (upward and downward tilt) angles of the head in the photograph according to the deflection and pitch indices. A study involving analysis of 100 Chinese Han males between 18 to 55 years photographed in 19 different angles was used for this purpose.

For calculating the deflection index, three landmarks on the face of the individual to be examined are important: left and right ectoconchions and glabella, (points A, B and C respectively).

The deflection index can be calculate as follows:

$$\text{Deflection Index} = \frac{\text{Distance from A to C (mm)}}{\text{Distance from B to C (mm)}}$$

They have found an inverse relationship between the deflection index and the deflection angle. The deflection index of each photograph was found to decrease, as the deflection angle increased.

For calculating the pitch index, three landmarks on the face of the individual were also examined. These were: glabella, subnasale and gnathion, considered as points E, F, and G respectively.

The pitch angle can be calculate as follows:

$$\text{Pitch index} = \frac{\text{Distance from E to F}}{\text{Distance from G to F}}$$

Their results indicated that the pitch index decreased as the pitch angle of the head increased.

Determination of natural head size:

Anthropometric measurements were carried out on 120 Chinese Han females to determine natural head size..

They measured the distance between the ectoconchions on both sides in the photograph and if the ectoconchion on one side disappeared due to an increase in the deflection angle, the remaining length should be used as the total measurement.

"Their results showed that the length of the line segment between the two ectoconchions in the photo shortened gradually as the deflection angle increased. The change in length was not linear if it was relatively small for deflection angles below 40°. However, if there was a substantial change (with an angle greater than 40°), the relationship was linear. At 90°, the length of the line segments was 15.02 mm (being the distance between the bridge of the nose and the ectoconchion opposite the one that was turned away from the camera).

The investigator using the formulae described is thus able to determine the distance between two ectoconchions. This length and the deflection angle of the test photograph, will allow one to extrapolate the natural head size from the photograph. This system converts all three dimensional data of the anatomical proportions of the face into two dimensional data.

Identification using this method is thus achieved through digitised measurements and calculations based on anthropological data and optical theory.

The accuracy of video-superimposition methods for identifying unknown human skulls has not been widely reported, but lately Austin-Smith et al.

(1994) carried out an experiment to test the reliability of the technique. Austin used the Dual video camera method, and compared three identified skulls with 97 lateral views and 98 frontal view photographs.

None of the skulls were from individuals represented by the photographs. The comparisons were carried out without using anterior dentition.

The system used consisted of two television cameras, an electronic signal mixer and a video monitor. (Appendix 7, Figure 44)

She found that 9.6% of the lateral view and 8.5% of the frontal view superimpositions were classified as a consistent fit based on the criteria established by authors for a good match between skull- photograph. (Appendix 7, Figure 45)

The incidence of false matches was reduced to 0.6% of the sample when a frontal view and lateral view photograph of the same individual were both compared with one skull. It was concluded that without anterior dentition, skull/photograph superimposition is reliable when two or more photographs, clearly depicting the facial features from different angles, are used in the comparison. When she used only one photograph, 9% offered close matches that could be classed as identifications; in others words there was a possibility of a false identification in 9% of the cases.

The above author also agrees that the correct positioning of the skull is still a critical issue and that the maximum and minimum tissue thicknesses measurements, over 34 landmarks of Caucasoid skulls by Helmer (1984), provided additional accuracy for positioning of the skull. She also suggested that those wishing to carry out such work should be experienced in determining the relationship between the skull and overlying soft tissue before attempting to make identifications.

As we know, slight misalignment can lead to a false superimposition and, thus a misidentification because of angle error. Lan (1992), used his apparatus to perform a test analysis of false superimposition caused by angle error. His results showed that the angle error must lie within the range of 3°, otherwise it is difficult to eliminate false superimposition. In addition it is also essential to accurately place landmarks and lines which will allow accurate angle determination. The most important landmarks in this respect are the glabella and subnasale.

The optimum objective length appears to be about 1 metre.

Although video technology has revolutionised and simplified the field of superimposition and furthemore is generally accepted by many specialists as a powerful tool to facilitate successful identification, some of the parameters involved are still being studied, particularly with respect to correct positioning of the skull, essential for achieving a correct match.
This method has made important advances since its invention in terms of equipment requirements and methodology, but in the final analysis a succesful and reliable identification relies on the experience of the assesor, their knowledge of the cranio-facial identification field and the specific knowledge of the relationships between skull and overlying soft tissue.

Although identification of a deceased person using video superimposition, in some cases is not taken as a proof of identity, it is however a useful tool for supporting other evidence of identity or certainly as an important preliminary step in the identification study. The technique at present used alone is not perfect; further research is required in order to achieve a solid standard of superimposition.

The most important factor which needs to be considered is the correct determination of the angle of the photograph and consequently the corresponding skull.

Summary and Current Status of Superimposition Techniques:

The old fashioned method of manual superimposition has been replaced with the development of video technology, a vast improvement on the manual photographic technique. The latter method was difficult to carry out and time consuming. The major technical problems encountered were the orientation of the skull to the same position as that of the comparison photograph, and magnification of the photograph to life size, using objective magnification factors.

Modern cranio-facial identification began with the advent of photography. From the forensic point of view, the most instructive examples of the principles of superimposition are provided by the head of a criminal executed by electrocution in Egypt (Pearson and Morant, 1934) and the two skulls from the "Ruxton case" in Scotland (Glaister and Brash, 1937).

In the first case photographs of the Egyptian head were taken. The skull was preserved, then photographs of it were taken in the same position of the Egyptian head in order to show that the skull fitted the face convincingly when the two views were superimposed.

Superimposed facial tracing from the photographs and his skull was done to illustrate the match. (Appendix 7, Figure 43)

Since then, despite the techniques having changed, the principles underlying its application which encompass soft tissue thickness, the relationship between of the facial features and the underlying skull,

positioning of the skull, correct magnification of the photographs and size adjustment, the facial outline remain extremely important considerations for specialist in this field in order to achieve a successful identification.
The relationship of the size of the head in the photograph with the skull has been an important consideration to investigators such as Sekharan (1971). He has argued that 1:1 enlargements of the two negatives must be accomplished to achieve scientific objectivity. Without knowing the magnification and angulation of the life photograph, it is possible for two faces with similar skeletal features of different sizes to result in misidentification.

De Vore (1977) stated with regard to superimposition problems such as magnification and angulation of the original photograph "while the method will show the general facial shape and size, it is conceivable that two faces of completely different sizes may have similar skeletal configurations and thereby result in an erroneous identification".

To obtain the correct magnification factor has been another matter of investigation in the superimposition technique. Initially, the specialist used visible objects which could be measured, that were present in photographs, so as to produce the correct enlargement of the image.

Others investigators, to achieve correct enlargement, made measurements of the interpupillary distance. This measurement, however is not standard, and varied greatly according to race, and sex.
Sekharan (1971) suggested the use of a standard interpupillary distance of 6 cm as the measurements from which life-sized enlargements of life photographs could be made.

McKenna (1984) tested this measurement in a Chinese population and found that the interpupillary distance varied widely from 57 to 71 mm in the group sampled.

Other scale correlation methodology has involved the size of the dentition, and the marking of anatomical classical landmarks. McKenna (1984) was one of the first researchers who used landmarks and measurements of the dentition as stated earlier in this summary. The technique according to him, "depends of the recovery of teeth, particularly maxillary anterior teeth, with the skull and the availability of an antemortem photograph showing those teeth."

The use of landmarks by several authors allowed an objective method of evaluation of the superimposition technique, and consequently improved the identification accuracy.

Without a doubt, the field of superimposition has made great strides with the use of video. This new technology has given investigators in this area a powerful tool that has technically simplified the whole process.

The most important features which should be considered and examined are:

1. The contours on the photographs used for comparison must agree with the hypothetical thickness of soft tissue on the skull in question.
2. The corner of the eyes must have the correct position in relation to the orbital margin.
3. The oral fissure on the photograph must have the correct height in relation to the teeth of the skull.
4. The auditory meatus must be projected onto the proper place on the skull.

According to the experience of the authors if an examination shows congruity between the aforementioned features, the identity of a skull is proved. If essential features show no congruity, then this means as a rule that the identity can not be proved.

Lan (1990) regarding the video superimposition technique stated "This procedure has simplified photographic adjustment, and proportion of superimposed images. The gray scale of the skull and photograph can be freely adjusted and thus has great value for improving the absent gray scale of a photograph of poor quality and, particularly, the contrast variations and thus the observation accuracy".

However, investigators are not unanimous in their opinion regarding the reliability of the technique for positive identification. In many countries the superimposition technique has been accepted by the Justice system as proof of legal identification, (China, New Zealand, Australia) but in others it has been used only as corroborative evidence of identity.

The latest work by Lan and colleagues (1993) are important advances, in developing a system that is able to determine accurately the angle of superimposition through digitised measurements and calculations based on anthropological data and optical theory. There is still the need however to solve problems of differences in relation to race, age and sex. Only once, these problems are solved can the technique of skull-photo superimposition be regarded as significantly more accurate as a sole method for identification.

FACIAL RECONSTRUCTION TECHNIQUE

Reconstructing the living features of skulls has long intrigued many specialists who deal with forensic identification.

This technique is based essentially on the data taken from measurements of soft tissue thicknesses, primarily on the cadaver head and face and the relationships between facial features of the face and underlying bone.

The most popular method used in this field is the three dimensional creation of facial features onto a skull.

Facial Reconstruction historically began with His in 1895, who is recognised as one of the first anatomists, together with Welcker, interested in the study of measurements of soft tissue thickness and of the relationships between the external features of the face and the underlying bone.

His applied a method that consisted of modelling a bust on a plaster cast of the skull taking into account soft tissue thickness data obtained from cadaver specimens. Applying this technique he successfully identified the skull of Johann Sebastian Bach (Appendix 7, Figures 46 and 47). In this case, His, before identification was achieved, had carried out an anthropological assesment of the complete skeleton presumed to be that of Bach. (Appendix 7, Figure 48) He also compared the skull with portraits of the composer painted during his lifetime to demonstrate its authenticity. Thus, the reconstructed face of Bach by His' method is considered as the first attempt in facial reconstruction by sculpting. The sculptor Seffner applied His' method.(Appendix 7, Figure 49). In relation to these early studies with regard to Facial reconstruction technique it may be of interest to mention the history of Bach's monument set up in Leipzig in 1908. Fourteen years after the exhumation of Bach (1894), the German sculptor

Seffner while working on the Bach's monument utilised not only portraits but also the contour of Bach's skull. From a plaster cast he modelled the soft tissues of the head using the same technique Kollmann recommended. The reconstructed head was then checked with the portraits. As might have been expected this reasonable method resulted in an extremely precise likeness for the Johann Sebastian Bach monument. (Appendix 7, Figure 54)

His' soft tissue thickness average data was obtained in a sample of 24 male and 4 female cadavers.(Appendix 8, Table N° 6)

He measured nine points in the midline and six points in the lateral view of the face, using a sharp needle, fitted with a piece of rubber. (Appendix 7, Figure 50)

This instrument was pushed through the facial soft tissue in the sites already selected, and the distance from the point to the piece of rubber was recorded in millimetres. The measurement was recorded after the whole instrument was removed from the face at the point measured.

In 1898 Kollman and Büchly extended the research of His. They provided the measurements of facial soft tissue thickness of twenty-one males and four females, from 17 to 72 years; classifying their data according to body build. The data was divided into four classifications; thin, very thin, well nourished and very well nourished. Their data classified as well nourished was averaged with that produced by His, thus producing an increment of the sample size for Caucasian soft tissue thickness to forty-five males and eight females. They took the same sites selected by His, adding three new ones.(Appendix 7, Figures 51 and 52 and Appendix 8, Table N° 7)

Many were the attempts to reconstruct the appearance of the most ancient Man. In this context it is important to mention the research of Kollmann, the anatomist and Büchly (1898), the sculptor, recently cited who reconstructed the physiognomy of a woman from the Stone-age, exhumed in Auvenier, France. (Appendix 7, Figure 53).

In opinion of Gerasimov (1971) "This production was the first really scientific reconstruction in the sense that Kollmann and Büchly proceeded from researches that had been methodically conducted. Kollmann for instance, measured the thickness of the soft parts of a hundred women from the Auvergne region of France and proposed a definite technical procedure for reconstructing heads and faces from skulls.

In this way he produced a scheme for the head and this was "corrected" and "enlivened" by Büchly-who furnished the nose, mouth, ears, and hair. Despite the interference of the sculptor, Kollmann's work can rank as one of the most remarkable achievements in the history of scientifically based reconstructions of heads and faces from the skulls" (Gerasimov, 1971)

The 19th century studies of soft tissue thickness data did not mention the time of death. These factors were unknown and it may have influenced the results obtained. In addition the population sampled was limited and did not include enough data for sex or race.

This early attempt in the acquisition of facial soft tissue thickness data is important, because despite all adverse factors those investigators and their research marked the begining of all facial reconstruction studies.

There are two methods or a combination of both that can be used to achieve the reconstruction of facial features from a skull:

The first is to use soft tissue thickness tables available to reconstruct the contour of the face at selected classical points.
The depths of soft tissue are represented by markers placed directly on the skull which are then connected using bands of clay or plasticine or similar materials. The facial features are then formed using the same material.Appendix 7 : (Figures 55 A and B) (Figure 56)

The second method involves reconstruction of the anatomical features of the face, usually in clay using the bony attachments as parameters of size and morphology. Applying the observation and comparison of sites of muscle attachments and other features the facial muscles are modelled onto the skull using their bony attachments as indicators of size and thickness, then applying more clay to the depths specified in the tissue thickness tables overlying that form the muscles, glands, major arteries, and other structures the anatomy of the face; the sculptor rebuilds the face anatomically as it would be found in life or through the dissection. (Appendix 7, Figure 56 A)

A combination of both can be used, i.e., soft tissue thickness markers in conjunction with the construction of anatomical structures as used in Great Britain by R. Neave, artist in Medicine from University of Manchester. He has gained respect in the forensic field using his reconstruction method based on the skull. To date Neave has reconstructed about 14 forensic cases with an approximate 60% recognition rate.(Appendix 7, Figures 57 A-B-C-D-E-F-G-H) The set of photographs illustrate the stages of Facial reconstruction method applied by Neave.

These two methods represent the two principal schools involved in the development of facial reconstruction; the former being known as the American method and the latter known as the Russian method.

The Russian method has envolved principally from the work of Gerasimov (1971) who has played a valuable role in the progress and application of facial reconstruction in Russia and Eastern Europe.

His text, The Face Finder (1971) describes his methodology. He studied both historical and forensic anthropological cases.

As part of his research he reconstructed the face of well-known Russian personages such as Ivan the Terrible, Tsar Ivan IV (1530-1584), and his son Tsar Feodor Ivanovich (1557-1598). Gerasimov commented upon these reconstructions in his book as follows:

The first case "The portrait reconstructed from the skull agrees entirely with the descriptions his contemporaries gave of the appearance of Tsar Ivan IV". Second case: "When I finished my work I consulted several descriptions of Feodor Ivanovich left by his contemporaries. They described him as quite different from Ivan the Terrible. Giles Fletcher, the envoy of Queen Elizabeth I of England at Feodor's court, gives an account of the Tsar as Small and plump and inclined to dropsy, sluggish...and always smiling...he seems feeble-minded...but kindly...and exceedingly superstitious" "The appearance of Feodor's reconstructed face fully confirms Fletcher's character-sketch. When I compared the reconstruction with the seventeenth century portrait I noticed so many points of resemblance that one could almost believe that the picture was wrongly dated and was painted from life-or at least that the portrait was a copy of an earlier one made in the lifetime of Feodor Ivanovich" (Gerasimov, 1971, p: 188-190)

During a period of thirty years, he also reconstructed about 200 faces of skulls of our prehistoric ancestors, e.g., The Mousterian Child of

Staroselie, The Negroid of Markina Gora, Rhodesian man, Heidelberg man, Peking man, The men of Combe-Capelle and Cro Magnon.

In these latter cases anthropological information was not available to evaluate the accuracy of these three dimensional facial reconstructions.

The "Face Finder" also mentioned several anthropological cases and only two forensic anthropological cases are illustrated where with the author's method successfully identified the human remains belonging to two missing women. The first case was a young woman, aged twenty-two years who disappeared in April 1940 when she was eight months pregnant. In August of the same year were found the skeletal remains of a pregnant woman.

At that time the identification could not be achieved and the remains were buried. Six moths later Magistrate Kirkina re-opened the case and the remains exhumed. The skull was sent to Gerasimov, to make a three dimensional facial reconstruction, in order that the reconstruction could be compared with a photograph of the deceased taken six years before her death. Unfortunately the lower jaw was missing, but it was replaced by Gerasimov with that had similar characteristics.

Gerasimov concluded: "In fact, the likeness between the reconstruction and the portrait was so great that one could be practically certain that the skull really was of the missing woman called Valentina Kosova". **(Appendix 7, Figures 56 A and B)**

Appendix 7, Figure 56-A illustrates Gerasimov's technique or The "Russian school". This identification was supported by the existence of a gold tooth on a second incisor and the corresponding tooth of the skull also had a gold crown. This proof was accepted as evidence of identity, thus the husband was tried, found guilty and confessed to the murder.

The second case involved the human remains of a woman, aged thirty-two, a dentist, who was reported missing by her sister after she had not returned to her town from a visit to her husband from above she was separated. The magistrate Petrov who investigated the case did an exhaustive study regarding the fate of the dentist. During the investigation he learned that the body of a drowned woman had been brought to the local mortuary in the town where the husband had lived about two years before. The important clue found on that body was a gold tooth which during the post-mortem was accidentally dropped out of the window and lost, its loss was not reported by the pathologist. The body was buried shortly thereafter without being identified. Petrov ordered the exhumation of the body and brought the skull to Gerasimov for facial reconstruction. During the reconstruction Gerasimov noticed atrophic changes in the right side of the skull apparently caused by right facial paralysis and he thought it must have been especially noticeable in the upper right eyelid. If the form of the left eyelid was normal then the right eyelid must have drooped considerably and would have covered part of the side of the eye. In this case Gerasimov concluded "The resemblance was obvious. The shape of the face, the mouth and the nose was very well reconstructed. The eyes were almost identical in photograph and reconstruction, the left normal and the right with drooping lid. Perfectly right also was the asymmetry of the eyes." (Appendix 7, Figure 56 c)

The husband was charged with the murder of his wife and his daughter. (Gerasimov, 1971, p: 47-51)

Both identifications were accepted as proof of personal identification; The second case was also tested using photographic superimposition.

Gerasimov's technique continues to be used by Lebedinskaya from The Institute of Ethnography of Moscow; she has carried on Gerasimov's research since his death in 1970. Lebedinskaya and colleagues have since 1979 been collecting facial soft tissue thickness data using ultrasound.

This new method has been used in various ethnic groups from the former USSR to expand her data bank of soft tissue thicknesses.

The 20th century has produced many other studies from different investigators interested in this field; these include the work of Suzuky (1948). This author's studies have been used in anthropological cases and produced successful personal identifications using three dimensional facial reconstructions. His data was obtained from a sample of Japanese, forty-eight males and seven females. (Appendix 7, Figure 58)

Sutton (1969) was another researcher interested in the acquisition of soft tissue thickness data. His study has been considered of great significance due to its methodology.

He measured the thickness of the soft tissues over the zygions in 104 Caucasian cadavers preserved for anatomical dissection. Data such as the date and cause of death and the age of each subject was not available.

He classified his sample based on body build in three groups, thin, medium and fat. In his opinion the presence of preservatives that may have altered the thickness of these soft tissues was not taken into account because all the specimens were preserved by the same method, and those experienced with that process considered that any changes which may have occurred would have been very small.

The methodology was described as follows:

The zygions were palpated, and the bizygomatic diameter measured with a modified compass apparatus (similar to those used by His (1895) and by Kolmann and Büchly (1898), its arms being compressed against the tissues "until resistance of the bone was felt"...... Then the needle was withdrawn and the distance from its point to the base of the plunger was measured by sighting against sliding callipers. Two measurements were made of the bizygomatic breadth of each specimen. (Sutton, 1969: 304).

He concluded in his discussion: There was no significant difference between the mean thicknesses of the tissues on the two sides of the specimens...... The wide range of tissue thickness over a zygion-from 1.4 mm to 21.4 mm-disclosed by even this relatively small (208) number of specimen, demonstrates that it should not be assumed that the thickness of these tissues is relatively uniform in different subjects....... There was a marked positive relation between body-build and the thickness of the tissues which are under consideration. Although the mean thicknesses in the three body-build categories were considerably different some overlapping occurred, specimens having thicknesses of between 10 mm and 19 mm being found in each category.(Appendix 8, Table N°8 A).

In most (92%) of the specimens the thickness exceeded the figure of 6 mm used by Woods (1950) and by Lundström and Lysell (1953).(Appendix 8, Table N° 8 B) All the subjects with a soft tissue thickness of 6 mm or less were of thin body-build. In each of three classes these tissues were thicker in the females, significantly so in the thin and medium specimens.

(Sutton, 1969: 307-308)

Accounts of other notable studies in this field can be found in Krogman(1962) and Krogman and Iscan (1986). All those studies used cadaver populations to measure soft tissue thickness.

The latest studies published in soft tissue thickness data were carried out by Rhine and Campbell (1980) using an American black population.

The authors also compared their data with European and Japanese studies.

In 1982 Rhine and Moore published soft tissue thickness data in an American white population which were later updated in 1984.

This data has been found useful in current forensic cases by professionals involved in three dimensional facial reconstruction, specially by the Americans.

Before Rhine and Campbell, studies on soft tissue thickness, were based on a small sample of soft tissue thickness data obtained for early investigators, principally Kollman and Büchly (1898) for Caucasian populations and Suzuki for the Mongoloid race (1948).
Rhine and Campbell (1980) presented data from a hitherto unsurveyed section of a population of American blacks. Their data was obtained from a cadaver population, that had not been embalmed, were dead for less than 12 hours and had been kept in refrigeration no longer than overnight.
These factors were taken into account in order to eliminate the effects of post-mortem change. The sample number analysed was fifty-nine out of 250 individuals (44 males and 15 females). The instrument designed for this study was a needle with a small rubber stopper that can be considered a modified version of His' technique. Their study described the subjects involved as "adequately nourished", and they did not consider the body build of individuals.
Rhine and Campbell increased the number of landmarks previously studied from 18 to 32 points, (10 midline and 22 bilateral measurements).
Four paired landmarks were included in their studies (inferior malar, occlusal line, supra M^2 (second superior molar), Sub M_2 (second inferior molar), located in the mid-facial region and one paired in the forehead (frontal eminence). (Appendix 7, Figure 59 and Appendix 8, Table N° 9)
The results showed that almost all soft tissue measurements over specific landmarks in the American black sample were larger than in others studies

in other races except for the measurement over the supra orbital landmark which was larger in a Caucasian population. (Appendix 8, Table N° 9-A) The authors stated that the use of this data should allow more accurate facial reconstruction on the skulls of American blacks.

The use of this new data was reported on by Rathbun (1981). The forensic case involved human remains found in a wooded place in 1979. The pathologist carried out the anthropological assesment and Rathbun later corroborated the findings as an adult black female, height 167 to 174 cm,(5'-5 3/4" /5' 8 1/2") medium muscular built, and with a mean age of 29 years, with a range of 25-36 years. The manner of the death was undetermined because of the advanced state of decomposition.

A year later, the local coroner requested a facial reconstruction of this skull. The author performed it using new soft tissue thickness standards data for American black females supplied by Rhine and Campbell (1980). These were applied at 32 points and with the guidelines provided by the Gatliff and Snow technique (1979) together with a videotape provided by Gatliff (1979). Photographs of the reconstructed face were published in a newspaper and recognised by a local grocer shortly thereafter as being that of a customer's daughter who had been missing for about a year. (Appendix 7, Figure 60)

The official photograph of the missing person was provided, comparison between fingerprints from police records and her amputated post-mortem fingers preserved in formalin and retained by the Sheriff's office confirmed the identification.

Police reports indicated that the deceased was a black female, 24 years old, 5' 6"- 5' 8" tall, weighing 110-130 pounds.

Rathbun suggested in this case that the new facial tissue thickness standards worked well in this instance, but refinement of the methods and additional data around the nose, lips, and eyes needed to be documented.

Although all soft tissue thickness tables in current use have been produced using a cadaver population and facial reconstruction performed using this data has been successful in a great number of cases, according to the literature, there are still some concerns about the way this data was obtained. The importance of some parameters that were not taken into account undoubtedly play an important part in the accuracy of three dimensional facial reconstruction. These include the influence of post-mortem changes and dehydration, body build, and influence of age changes. All these parameters may have had an influence in soft tissue thickness.

Another factor which should be taken into account is that soft tissue thickness may vary greatly from person to person.

To date the acquisition technique has varied with the development of new technology and the introduction of ultrasonic instruments that permit the collection of data in a faster way without sacrificing accuracy.
In this way studies can be perform in a large living population without endangering health and thus providing a large amount of information. The expansion of the data bank using this method will be enormous and fast, thus enabling improvements to be made ultimately, to facial reconstruction.

Russian researchers have been collecting soft tissue thickness data using an ultrasonic echo location since 1971. Their data covers a population of ethnic groups and their results have recently been published. Up until now data has been collected from 1,695 individuals, aged between 20 to 50 years. Further studies using ultrasonic devices are necessary in the future in order to expand the soft tissue thickness data bank in an accurate way. Furthermore studies should be extended to all racial groups, ages, and body build.

The method of three dimensional facial reconstruction has attracted many investigators for more than 100 years and at the present time many reconstructions have lead to a successful personal identification. The advantages and disadvantages of the method have been largely discussed. Some researchers have tried to test the accuracy of this technique in order that it may be considered as a powerful tool for personal identification.

One of the first investigators who tested the three dimensional facial reconstruction technique was Professor Von Eggeling of Jena University. For a number of years he conducted very interesting observations on the variations in thickness of the soft tissue of heads and faces. He worked out a technique of measurements and collected abundant material. In 1913 he designed an experiment to test his technique. Gerasimov described Von Eggeling's methodology as follows: "He took a plaster cast of the head of a recently deceased man and measured, in accordance with a definite plan, the thickness of the soft parts at various points so that with these craniometrical data the soft parts of the subjects could be modelled. Then the skull was freed of its soft parts and two plaster casts of it prepared. The casts and the data regarding the soft parts were given to two sculptors, who working independently, were to model from the casts the portrait of a man unknown to them. Eggeling, of course, expected that the sculptors working in similar conditions would each produce a similar portrait of one and the same person. But the results were completely unexpected. The reconstructions showed no likeness either to each other or to the original"

This experiment led Von Eggeling and also most anatomists to conclude that no individualised portrait could be constructed from a skull.

Gerasimov (1971) expressed the following view about the results of this experiment "Today it can be maintained with certainty that the failure of this noteworthy test was due to the carelessness or the lack of conscientiousness of the two artists. They did not observe the all- important preliminary conditions for the success of the experiment, namely paying great attention to the correlation between shape of the skull and thickness of the soft parts."

The second investigator who tested the facial reconstruction technique was Krogman in 1946. He used the head of a forty year old Negro male cadaver. He described the method used as follows:

From the dissecting rooms in the Department of Anatomy at the University of Chicago I selected the head of an American Negro male, of about 40 years of age, and in a fair state of nutrition at the time of death. His teeth were, however, badly diseased, possibly indicative of a nutritional imbalance.

It must be remembered, however, that the features showed the characteristic slackness, or loss of tonicity, of death; the eyes were closed, the mouth loosely open and all features flabby, without resilience. In addition my medical students had accidentally removed the skin and tissue over the occiput and the back of the neck. As a result I did not attempt to measure head length and breadth.

With these reservations in mind, I offer the following measurements made as carefully as I could on the cadaver head; with special reference to the face (measurements in mm):

Results: There are two really serious restorative errors: biorbital breadth and bigonial, as shown in the table below. The biorbital measurement in the skull is from one outer orbital margin to the other; the biorbital measurement in the head is really bipalpebral from one outer eye corner to the other. The first error was due to our lack of knowledge that biorbital breadth in the skull is considerably less than bipalpebral breadth in the living. Our second error was due to not allowing enough bulk for the masseter muscle.

Conclusion: The restoration was readily recognisable. The entire technique is useful in the identification, via restoration, of an individual represented by a skull, alone.

(Appendix 7, Figure 62, Left and Right)

Comparison of measurements between the head and bust (mm)

FACE HEIGHTS	HEAD	BUST	DIFFERENCE
Total	131.5	131.0	-0.5
Upper	80.0	80.0	0.0
FACE BREADTHS			
Forehead	98.0	102.0	+ 4.0
Interorbital	34.0	30.5	- 3.5
Biorbital	**111.0**	**98.0**	**-13.0**
Bizygomatic	126.0	125.0	- 0.5
Bigonial	**100.0**	**110.5**	**+10.5**

Comparison of measurements between the head and bust (mm)

FACE HEIGHTS	HEAD	BUST	DIFFERENCE
NOSE			
Length	60.0	55.5	- 4.5
Breadth	47.0	43.0	- 4.0
Height	19.0	20.0	+1.0
MOUTH			

Total lip height	32.0	31.0	- 1.0
Upper lip height	15.0	16.0	+1.0
Lower lip height	15.0	15.0	0.0
Mouth breadth	61.0	58.0	- 3.0
EARS			
Height	61.0	70.0	+9.0
Breadth	39.0	39.0	0.0

Suk in 1935 criticised three dimensional facial reconstruction and said that a series of special investigations had proved that the reconstruction of the face from the skull, especially the modelling of the nose and mouth, was impossible. He declared that the soft tissue certainly did not correspond to shape and form of the underlying cartilage and still less to that of the bone... "Consequently the findings of osteology and anatomy allow us to conclude that Man can be examined and explored only when the soft parts are present. All the fossil remains of Man which have come down to us are in the form of skeletal bones and can be investigated only as skeletons which can offer us no clues at all for any reconstruction that is true to life."

Montagu in 1947 criticised the experiment performed by Krogman and stated "I am convinced that recognisable reconstructions would be impossible in the vast majority of Whites. Certainly one could not expect that a close likeness to a person's appearance during life could be established from the skull alone".

Stewart in 1954 stated "because of the time and artistic talents required in restoring the features, the results do not often justify the effort".

Brues in 1958 referred to this technique "probably best left to the ample literature of detective fiction".

Despite all these criticisms about the usefulness of three dimensional facial reconstruction, the value of the sculpting technique was not objectively tested until 1970 by Snow and Gatliff who designed an experiment in order to evaluate the usefulness in forensic anthropology of the reconstruction of facial features from the skull.

They performed facial reconstructions on two skulls; one of the skulls belonged to a female known to them and the other was that of a man who had been positively identified by others means. Photographs were then taken of the reconstruction in both, frontal and lateral views; these photographs were then compared to seven photographs of persons of approximately the same sex, race and general age, one of which was the subject. (Appendix 7, Figure 63)

The comparison was carried out by the Federal Aviation Administration (FAA) employees and local policemen, who were asked to select the subject's in vivo photograph. The tests were conducted informally. The posters were set up in a central location along with a supply of blank forms. On the latter were printed instructions for selecting the photograph that the identifier thought most resembled the reconstruction.

Identifiers were also asked to give their sex, age, and if police officers, their number of years of experience. A sealed box was placed beside the poster for deposition of the completed forms.

The results for the female reconstructed were 26% correct of the 104 respondents and 67% from 200 respondents were correct for the male reconstruction. In both tests policemen and civilian females performed better than civilian males.

(Appendix 8, Table N° 10)

There were three reasons postulated as to why the female reconstruction was less well received than the male.

1. Age. The female was 67 at the time of her death; the photograph used for comparison was taken in her early 40's, thus remodelling and atrophic changes in the facial skeleton associated with age may have had some significance. The male was 36 when he died and his photo had been taken six months before his death.

2. Sampling errors in skin thickness tables. The male skin thickness measurements are based on average of forty-five males. The female only had an average of eight females. The reconstruction's were based on Kollman and Büchly soft tissue thickness data. (1898).

3. Photographic technique. The female photograph was done as a studio portrait where uncomplimentary physical features are eliminated or minimised as best as possible. The male photograph was taken by the police with no such efforts being made.

Snow and Gatliff stated "on the basis of the present findings, it is apparent that positive identification could certainly not be allowed to rest on a facial restoration alone. In certain cases, the technique might be used to eliminate certain suspected individuals. In others, a restoration may be useful in helping support an identification based on other skeletal evidence. It is possible that the accuracy of female reconstructions could be improved by enlarging the sample upon which presently used soft tissue thicknesses are based." (Appendix 7, **Figure 64**)

As the time passes the value of the sculpting technique has been clarified and its application has growth; more researchers have been interested in improving of the accuracy of this technique.

The facial reconstruction work of Gatliff and Snow is well known. They started work in this field in 1967; most of the cases performed at that early time were homicide victims. In 70% of these cases (n=33), positive identifications were made; in some cases the reconstruction provided the vital link in identifying the victim and in others it was an important part of corroborative evidence of identity which was reached by other means.
Gatliff (1984) used in her first fifty cases of facial reconstructions the Kollman and Büchly (1898) soft tissue thickness data which she still continues to use in historical cases. She performed the three dimensional facial reconstructions of King Tut, Francisco Pizarro, and the massacre victim from the Wolstenholme Colony in Virginia. Since 1980, she has applied in forensic cases the new soft tissue thickness data published by Rhine and Campbell for the American black population and the revised tables from Rhine and Moore for American whites (1982).

Gatliff in collaboration with Snow has gained respect in forensic circles using her reconstruction method based on the skull. Appendix 7 : (Figures 65, 66, 67 and 68) To date Gatliff has reconstructed over 135 victims faces with an approximate 72% identification rate.

Caldwell (1981) designed a questionnaire survey for forensic anthropologists in order to investigate the usefulness of three dimensional techniques to achieve personal identification; it revealed that when the face is unknown three dimensional facial reconstruction is the preferred technique. Two or three dimensional facial reconstruction techniques have a proven success rate of approximately 50 per cent chance of developing tentative personal identification. This survey demonstrated the usefulness, reliability and validity of this method.

Other researchers interested in the facial reconstruction technique include Lawrence Angel (Washington, DC) (1977) specialist in two dimensional sketches, Iscan M (1986) and Stanley Rhine (New Mexico) (1984).

Margaret C. Caldwell (1981) achieved recognition for her study of relationships between facial features and underlying bone performed in a series of death masks and skulls of known individuals from the Terry Collection, Smithsonian Institution in 1981. She stated in that study that even though facial reconstruction techniques have proven successful in achieving personal identification in several forensic cases, there are problems with the method as a whole. Remarkable among these is the relationship between the details of facial features like the nose, eyebrows, eyelids, ears, lip size and shape, and the underlying skull for which soft tissue thickness tables do not provide information. These facial features play a significant role in the recognition of a human face, according to Zavala (1972), because accurate restoration of the facial features is decisive for the recognition of the final reconstructed face when it is viewed by relatives or friends of the deceased person for identification.

George (1987) designed an experiment to reconstruct approximate profiles of unknown skulls with the lateral craniographic method of facial reconstruction. Fifty-four lateral cephalographs of American Caucasian (17 males, ages 14 to 36, 37 females ages 14 to 34) that showed clearly the soft tissue thickness profiles were used for this study. The cephalographs were traced and measured to establish the ranges and means of midline soft tissue depths and facial angles.

According to the author this technique requires the following steps:

1. A cephalometric analysis is first made to determine the facial proportions and individual skull type.
2. The mean soft tissue thicknesses and angles are then plotted against the basic midline anthropometric points to establish the average dimensions of the nose, lips, and chin.
3. The points are connected and "harmonised" in accordance with the known anthropological data (sex, age, race).
4. The profile is finally "humanised" by adding tone, a stylised eye, hair patterns, age lines, and any other features that can be determined from an anatomic examination of the skull.

The importance of this method is to produce a more detailed facial reconstruction that could then be integrated into other methods in use for a more accurate reconstruction. It could also provide a scientific standardisation of artistic skills applied in the current methods, thus two sculptors with the same skull could reproduce a similar appearance of the face. (Appendix 7, Figures 69 A and B)

One of the common criticisms of facial reconstruction is that, given the same skull, two forensic artists will not produce a similar appearance of the face.

Haglund and Reay (1991) carried out an experiment to evaluate facial reconstruction techniques in the identification of Green River Serial murder victims. Twenty-four facial approximations (reconstructions) were used after traditional methods of identification failed in an attempt to identify nine out of a total of forty-one recovered. Nine different artists were used.

Information provided to the artist included the biological identity of the deceased, such as sex, race, age, height and approximate date of death and, if it is known, hair length and colour.

Depending on preference the artists were provided with either, the original skull or a plaster cast of the skull, radiographs, or photographs. Soft tissue thickness standards were used, as adopted from Rhine and Campbell for blacks, Rhine and Moore for Caucasians, and Suzuki for Japanese.

The authors concluded :

"Interpretation of the same victim varied greatly, resemblance of the facial approximation to the deceased for those victims already identified showed considerable variation, but in some cases were quite accurate" and they concluded "Our experience has been that facial approximations have not been useful in identifications made during the Green River investigation."

The authors used the term approximation instead of reconstruction, reproduction or restoration as used in the literature, to refer to three dimensional creations of faces from skulls. (Rhine, 1990)

Helmer and colleagues (1993) recently tested the reliability of facial reconstruction. The question was "Can two independent examiners produce similar reconstructions from the original skull, and how good is the resemblance between the reconstructed skull models and the living person?"

The authors formed a research team and two of the co-authors Röhricht and Petersen were assigned to perform the three dimensional facial reconstructions on 12 identical plaster casts of the original skulls. Both had comparable technical and sculpting skills, with no artistic training.

The method used was as follows:

1. The moulds for the skull and mandible were prepared from silicone and the skulls were cast from polyester resin. The casts were exact duplicates of the original skulls.
2. A specialist produced sets of glass eyes according to measurements from the original skulls.
3. A plan for the reconstruction was drawn up before the test was initiated. Sex, age, and constitutional type of the individual's skull were given as established data for a case investigation. In addition, all important topographic and morphologic details were studied on the original skull. Based on the experience of the team director (Helmer), soft tissue thickness was determined at 34 measuring points in the skull.
4. According to the plans, each member of the reconstruction team independently produced 12 model faces on the respective casts. Problems that arose were discussed individually with the team director, who had no access to antemortem photographs of the individuals in question during this stage of the investigation.
5. Results were discussed jointly only after completion of the respective reconstructions.
6. A systematic comparison of the reconstructions with each other and with the photographs was made. Finally, the hairstyle was recreated and the finishing touches were applied by a make-up artist (Möhr) corresponding to the photos of the individuals.

With reference to points 2 and 3, it should be noted that the measurements used for soft tissue thickness were established from living persons of all age groups using ultrasound. These values were then "individualised" according to sex, age, and constitutional type (Helmer, 1980, 1984; Helmer and Leopold, 1984).

The authors remarked that "Compulsory guidelines for the shaping of facial morphology were compiled based on the findings of Merkel (1885-90), Kollman (1910), Wilder (1912), Stadtmüller (1922), Gerasimov (1955, 1968 the latter results being clearly presented by Ullrich, 1959, 1966), Lebedinskaya (1957), and Krogman (1973), to the extent that they were compatible with each other, as well as with personal experience. We used eyeball prostheses as suggested by Gatliff (1984) because they resulted in a more lifelike appearance."

They concluded that according to statistical analysis of the sample, a comparison of the reconstructions with each other reported that 50% of the cases presented approximate resemblance, and 33% showed close resemblance, while in two cases (17%) only limited resemblance was achieved. The reconstructions showed according to the authors' classification "good to very good" agreement with reference to sex and age. The areas with the most discrepancies were the mouth and eye regions. The nose, in most cases, was reconstructed to an approximate or close likeness.

" In general it was observed that with proper methodological instruction and adherence to the standardised principles of reconstruction, various reconstructors working on the same skull were able to produce a facial model with approximate to close resemblance. Greater discrepancies in detail occurred when the reconstructors deviated from standardised principles."

The reconstructions then were compared with photographs of the individuals and the results from all reconstruction's (N=24) showed:

38% close resemblance to the original, 17% approximate resemblance, 42% slight resemblance, while in one case there was no resemblance.

The authors found that the most agreement was produced in relation to the facial profile.

In the opinion of the authors, the participation of a multidisciplinary team such as a medical professional or forensic anthropologist, as well as a criminologist should be considered. Without doubt such specialists together play a significant role in producing a successful facial reconstruction.

In addition to the physical characteristics of the individual, other clues are also important in helping to establish personal identification, e.g., signs of illness, hair colour and length, facial hair or any clues about the lifestyle or status of the deceased person. All these factors should be considered in reconstruction if one is to attain a successful result.

In Helmer's experiment aforementioned regarding the reliability of facial reconstruction, the importance of the following factors has been demonstrated:

a) The use of soft tissue thickness data from living persons of all age groups. Studies of soft tissue thickness must be obtained through ultrasound. They should be applied according to the body build of the deceased.

b) The standardisation of the technique should include strict adherence in the use of the guidelines of known background. This is an important factor in an assessment of reliability of facial reconstruction technique.

c) Furthermore, artistic training of the person carrying out the reconstruction is not necessary. It eliminates the chance of negative results influenced by "artistic feeling".

Two-Dimensional Facial Reconstruction

This method applies the same principles as three-dimensional facial reconstruction. In the two-dimensional method, the face is drawn onto an outline of the skull (frontal and lateral views). It is performed by a forensic artist under the direction of a forensic specialist.
The advantages of this technique are that it is faster, cheaper and easier to use. However advanced artistic skills are required.
According to Krogman and Iscan (1986) the procedure is as follows:

1. The skull must be identified as to race, sex and age, and it must be measured using standard craniometric parameters.

2. The skull must be x-rayed, positioned in the x-ray apparatus in the Frankfort horizontal plane. (Frontal and lateral views).

3. Both frontal and lateral x-ray films must be carefully traced with all osteological details precisely delineated. These two tracings serve as the foundation for the adding the physiognomic details.

4. Anthropometric Measurements must be taken: both cranial and physiognomic. Cranial measurements are: skull breadth, biorbital breadth, interorbital breadth, nasal aperture breadth, midfacial or bizygomatic breadth, lower facial or bigonial breadth, and total facial height.

Physiognomic measurements, those not determined by bony-tissue are: lip height, ear height, and ear breadth.

In the past the first documented application of this technique involved the artist J. T. Murray who drew the face of Bishop James Kennedy. The skull was provided by Waterston (1934) who carried out an anthropological study of the remains. The two-dimensional facial reconstruction was performed under Waterston's directions. Kennedy was the fifteenth century bishop of Scotland. According to Waterston, there are no likenesses with which to compare the reconstruction. (Appendix 7, Figure 70)

Stewart (1979) in his discussion about this two dimensional facial reconstruction in its lateral view wrote, "Murray got around the troublesome problem of the eyes by showing them as closed. Obviously, too, he gave the Bishop a benign countenance in keeping with his role in life. All this is admirable and confirms Murray's artistic ability. However, the way in which the portrait was related to the skull was not made explicit. I have been unable to superimpose satisfactorily a suitably reduced profile of the skull on the portrait. For example, when I placed the nasal bridge portion of the skull in position the chin of the mandible was further forward than that of the portrait and the eye was too low in the orbit. Be this as it may, from the forensic standpoint the procedure has the merit of being simple and on occasion, as I have shown, had led to an identification." (Stewart, 1979: 258)

A successful use of this identification method was described by Cherry and Angel (1977) who reported a forensic case where they applied two-dimensional facial reconstruction in order to achieve personal identification in unidentified human remains. Angel concluded that the skeleton was that of a Caucasian female, approximately 17 to 22 years, who was of less than average stature.

Cherry, the police artist, made a portrait from the skull for publication in the newspapers.

Soon after the photograph of the sketch appeared, three readers reported to the police that it closely resembled a young woman who had disappeared some six months earlier.

The police found among their records, an individual with the name given by the readers who had been photographed and fingerprinted by the Department six months after her death. This photograph does indeed closely resemble the artist's sketch. The personal identification also was supported by fingerprints and the biological evidence of an old fracture of the left clavicle and a subcartilage damage to the right hip joint.

The authors concluded "The case in point provides an excellent example of what can be accomplished when the police artist, scientist, and investigator pool their talents and experience in a cooperative effort to successfully reconstruct a face, former lifestyle, or personal history-a personality from skeletal remains" **(Appendix 7, Figures 71 A and B)**

The two dimensional and three dimensional facial reconstruction share the same criticisms that have been commented upon in relation to the three dimensional technique.

Stewart (1979) commented upon this technique as follows:

"Without knowledge of the unknown individual's clothing sizes, the degree of fleshiness is a matter of guesswork. Everything else-facial proportions, details of the features, and the amount and arrangement of the hair-must be developed subjectively by the artist with minimal help from the bones. Few artists have been trained or have learned to develop a portrait in this way...... Judging from my own experience in doing portraits of living people (I have been doing this as a hobby for some forty years), getting a recognisable likeness must be largely accidental when there is nothing to go on but the skull. Many artists have a hard enough time getting a sitter's eyes and mouth right when they are simply copying what is before them." (Stewart, 1979: 257)

Iscan and Charney (1981) applied two-dimensional and three dimensional techniques in a forensic case and reported their findings. In 1979 Iscan received an unknown skull for facial reconstruction from a Florida sheriff' department.

The method chosen was two dimensional and it was performed by an artist under Iscan's supervision. Later Charney, forensic anthropologist performed three dimensional facial reconstruction. However, although the victim was not identified by the drawing, they stated that "a reasonable resemblance was evident". Charney′s reconstruction would have been the same type size.

Finally the authors concluded "From the drawing and pictures of the sculpture, a number of measurements were compared and agreement between these two methods of facial restoration was very close." (Krogman and Iscan, 1986: 454)

CURRENT STATUS OF FACIAL RECONSTRUCTION

The facial reconstruction technique has become established in forensic medicine and anthropology as a reliable method to be used in personal identification when this goal cannot be achieved by other means.

Despite the fact that its usefulness has been re-emphasised recently by a number of researchers, and development in this area has improved the accuracy of the method, there are still concerns amongst some investigators about certain aspects of the technique. The necessity for further study of the relationships between facial features and underlying bone is essential. The variability reported in the literature with regard to facial details is enormous, but usually does not take into account race, age, sex and body build. Another necessary requirement for further studies of soft tissue thickness to be made to expand the present data bank and assess thickness variability in terms of race, age changes, body build and sex.

According to the latest reports using the data available from living persons which results in better facial reconstruction results, the key would seem to be in soft tissue thickness studies.

The use of ultrasound equipment in a living population eliminates problems produced by post mortem changes and tissue dehydration, or any other distortion inherent to cadavers.

Current facial perception research suggests that the individual identity of a face is a function of the scale, position and ratio of facial features relative to each other. These metric relationships are more important in facial identification than are the specific characteristics of individual features.

The application of facial reconstruction for forensic identification in controlled studies has demonstrated the correlation between the facial features and the skull. Nevertheless, further assessment of reliable standards can be established only on the basis of statistically valid data. Relevant and valid studies have been conducted by Dr. Lebendiskaya about the relationship between facial features and the underlying bone.

She has also published a further collection of soft tissue thickness data using ultrasound, with a total population studied to date of 1,695 individuals including different ethnic racial groups from the former USSR, in order to extend her data bank.

Lebendiskaya suggested "the continuation of these investigations will help to create a data bank from which a reliable basis for methods of facial reconstruction from the skull can be developed".

She also commented that even if the matches of all the points are not reached; it is still possible to achieve from a reconstruction a resemblance to the original.

"It seems that ideal precision may not be so important after all. In all likelihood, the human eye does not perceive deviations of a feature within certain limits and permits some leeway. What are those limits?".

FACIAL RECONSTRUCTION BY COMPUTING

The development and progress of computer technology in the last 10 years has also benefited facial reconstruction techniques. An electronic imaging device initially developed to illustrate ageing in missing persons has also been used in facial recontruction from human remains.

A two dimensional computer graphics system has been used with some success in the analysis of frontal and lateral profiles obtained through this method. The progress in this area has been in drawing reconstituted heads and in gathering tissue thickness data. Some equipment is mechanical for example when measuring the profile of the skull with a device that converts angles and distances into digital data. (Walker, 1975)

Ubelaker and O'Donnell (1992) reported the use of a computer assisted reconstruction technique. They stated that their method offered the potential for economical and rapid facial reproductions that maximise artist-anthropologist interaction.

The procedure they used was as follows:

The system consisted of an IBM PC-AT personal computer, data tablet, colour display monitor, and video camera with lights. Proprietary software was adapted to show age progression in cases of missing children and fugitives wanted by the FBI. The software was not modified for facial reconstruction since the methodology is similar. The system offers sophisticated photo composing and retouching capabilities, which allow it to produce electronically altered images and perform such functions as the substitutions of clothing and hair styles or the removal or addition of facial features.

To use the equipment for facial reconstruction, the cranium and articulated mandible (with the appropriate tissue depth markers) are positioned in the Frankfort horizontal plane and scanned with the camera. Selected components of a face are then added to the captured cranial image and modified by the artist and anthropologist until a lifelike image is obtained. Facial components are selected from a large FBI hand-drawn data base of drawings showing variations in eyes, noses, mouths, ears, chins, facial hair, scars, complexions, cheeks, hairstyles, and so forth.

This data base is currently being electronically scanned to make it available on computer for instant access in reconstruction.

They applied this technique in a case from North Carolina in 1990. A badly decomposed body of a young Caucasian female partially clothed, was found; the head was partially skeletalized with severe decomposition of the face and anterior neck. The biological identity was female, white (Caucasoid), age between 15 and 19 years, height 5 ft, 3 in. (160 cm). Cause of death suggested homicide. The remains could not be matched successfully with local missing persons. Although dental restorations were present, no positive identification could be made. (Appendix 7, Figure 72)

Ubelaker described the process as follows: "tissue depth markers for white female standards lengths were placed on the cranium and mandible which were oriented in the Frankfort plane and scanned with the video camera; thus appropriate facial components were selected from the FBI database and merged with the digitised image of the cranium and mandible on the computer screen. The entire procedure required about 2 h"

The authors summarised the advantages of this method as follows:

" 1. It eliminates the need for photography prior to reproduction.

2. It allows components to be added directly to cranial features.

3. It increases interactions and communications between the artist and the anthropologist in adding facial components.

4. The cutaway aspect allows the underlying skeletal structure to be viewed below the soft tissue reproduction to check its accuracy.

5. The size and proportion of the reproduction can quickly be adjusted electronically.

6. Various versions can easily be stored and reproduced for comparison.

7. The soft tissue reproduction can be partially removed at various points to view it matching with the skeletal structure."

There is no information in this article if positive identification was reached using this technique.

Ubelaker later on the same year (1992), answering a question about the rating of "positive identification" carried out with this technique, wrote that, working together with the FBI, he has applied the composite technique on many cases for 15 years. Several of these have been subsequently identified and they have been delighted with the likeness between the reconstruction and the photograph of the known individual; but "it is not clear what role our reproduction played in the identification", because in some cases the identity is based on other parameters.

Finally he stated about this new technique "We do not mean to imply that it is superior in all ways to clay three dimensional reproduction.

In contrast, I believe that in the hands of a skilled and experienced sculptor, the three dimensional approach probably offers a superior opportunity to reproduce the fine contours of the face.

The advantage of the computer assisted approach is that it is more rapid, allows for easy manipulation and adjustment of the final image, and maximises the opportunity for collaboration between the artist and physical anthropologist".

Evenhouse et al. (1992) designed an experiment using computer aided forensic facial reconstruction using a different procedure. They developed two and three dimensional computer-aided routines to reconstruct facial features on a human skull.

They stated that "These routines allow generalised facial features to be manipulated to conform to the size and shape of a specific skull".

Their method based on the authors' description was as follows:

1. Based on the principles of facial reconstruction, they first selected 22 cephalometric and craniometric landmarks. Eight landmarks defined the perimeter shape of the soft tissue face (1-8) and the other landmark locations determined the scale, translation, and rotation of the individual feature such as nose, eyes, mouth and ears (9-22). (Appendix 7, Figures 73 A and B)

2. Using a 386 personal computer with a True vision Targa 16 graphics adapter and a Howtek laser scanner, they scanned a frontal photograph view of a 24 year old woman.

3. Her face served as a template map onto which homologous features from photographs of four other women in their twenties could be placed and averaged. They used a conformal image-warping algorithm written in the C programming language.

4. They then digitally remapped facial proportions of the template face to match the idealised horizontal and vertical proportions of the normal young adult face, as determined by Farkas (1981).(Appendix 7, Figure 73 C)

5. They scaled each subjects features to a standard dimension and allowed for differences only in feature shape. Thus they created a composite output image called "average face". Since the features were remapped, the pixel locations for each set of features, made up a set of homologous points. The resulting face serves as the final template. With the "average" face determined, facial landmark control points corresponding to homologous bony landmarks on a skull were recorded. These landmark control points formed the vertices of a polygonal mesh used for warping the image (Appendix 7, Figure 73 D)

6. The skull selected for computer reconstruction was of a Caucasian female in her mid-20s and the antemortem photograph was available. The skull was fixed in a "relaxed position" (head rotated up 15 degrees from the Frankfort horizontal).

7. A frontal view of the skull was video "grabbed" using a Panasonic digital video camera. The video image was brought into the image warping program and the 37 control points resulting from the landmark locations were selected using a mouse. The homologous soft tissue control points of the "average face" were positioned to correspond to the bony landmarks chosen on the skull.

8. Alterations such as hairstyle, coloration and clothing, were accomplished using a digital paint package.

Their results were: "Subjective comparison of the reconstructed face with the photograph of the subject revealed a good overall match with the general form of the face, including asymmetries of the skull and relative size and positioning of features.

The most obvious differences are in the appearance of the eyes, the projection of the nose tip, and the hairstyle. The eyes of the reconstructed face were narrower and set more closely together than were those of the subject"

The second part of this experiment was to test whether the map of the average face could duplicate the appearance of a known face. The result was a convincing semblance between the two faces.

According to the results the authors concluded that "using this methodology we can produce a successful three dimensional facial reconstruction" The goal was to reduce the human error in reconstructions and to speed an otherwise time consuming and tedious process".

After the experiment they concluded that the two and three dimensional facial reconstructions show promise as valuable tools for forensic science.

Laser Scanner system

The department of Forensic Medicine and Science of the University of Glasgow continued with the Facial Identification Centre under the direction of Professor Peter Vanezis, a pathologist with a special interest in facial identification, who created this centre when he was head of the department of Forensic Medicine in Charing Cross Hospital and Westminster Medical School at The London University.

This centre is relatively new and uses reconstructive and comparative techniques, currently applied for identifying the face.

This centre applied a three dimensional computer graphic system for facial reconstruction called FACIA, created by University College London about 10 years ago; specifically in the Medical Physics Department, which was one of the pioneers in the creation of this three dimensional optical surface Laser. The system was developed for the study of facial changes following facial reconstructive surgery. It has been used in a wide number of medical and other applications, and has been installed in a number of leading medical units.

It is a combination of computing and laser equipment that allows one to take 20000 facial measurements of the surface scanned with a dynamic resolution of approximately 0.9 millimetres in 30 seconds.

Individuals' profiles are recorded with a resolution better than 0.5 millimetres. The system is based on the analysis of the output from a video camera that obliquely views a laser line projected vertically onto the face; in order to get information from the whole face, the subject (or skull) is sited in a chair that rotates through 360° under computer control at six degrees per second.

Using customized software, the system is able to build a face onto a skull. The computerised technique is in essence, a logical progression from sculpting methods, in accordance with the generation and development of medical imaging techniques using computer graphics.

The program briefly works as follows:

The data is acquired from an unknown skull which is then electronically "clothed" using an average face image that is selected according to the age and sex of the skull studied.

Standard soft tissue thickness data from the memory bank are placed over the skull and the face and modified on the screen according to the individual case, to produce various images of the reconstructed face.

With the development of video technology and computer assisted manipulation of images, researchers have been supplied with some very interesting tools for the development of facial identification. Facial reconstruction by computing should be considered as being in its first stage; an experimental period in which the investigators applying this technology should carry out much needed research for the development of it reliability and accuracy. The pathologist should be familiar with the availability of this method and its improving accuracy and use.

FACIAL RECONSTRUCTION USING AN OPTICAL SURFACE LASER SCANNER SYSTEM.

Historical background of Laser scanner system

The laser scanner system was developed about 10 years ago, by the Medical Physics Department of University College London, initially as a tool for the planning and simulation of facial reconstruction surgery utilizing interactive three dimensional graphic techniques and data derived from computed tomographic scans. In other words it was developed as a system to simulate the traditional procedures used in plastic surgery, but using specially developed computerised data acquisition and graphic modelling techniques. (Arridge et al., 1985). The simulation includes the surgery on the hard tissue, and modelling of the soft tissue for the prediction of the postoperative facial appearance. (Moss et al, 1988).

The computer system used produced three dimensional graphic images. (Appendix 7, Figure 74). This system allows the surgeon to manipulate a three dimensional image of the face and jaw. The advent of computed tomography (CT) and developments in computer graphics presented an opportunity to use the most advanced technology for surgical planning. Computed tomography data can be used to isolate various parts of the anatomy, enabling the surgeon to view bone structures not visualized in radiographs. The data for the internal anatomy of the hard tissue was extracted from CT scans and those for the facial surface from measurements made with a specially designed and built, low power laser surface scanner.

Computed tomography provides complete information of hard and soft tissues, but the high radiation dose does not make the technique suitable for long term investigation. Another limitation of computed tomography is that the resolution of the facial surface is limited by the distance between each scan which may be 6 mm or more. The optical surface laser scanner was developed to monitor more accurately the changes in facial morphology.

The system is based on the analysis of the output from a video camera that obliquely views a laser line projected vertically onto the face; in order to get information from the whole face, the subject (or skull) is sited in a chair or placed in a special platform that rotates in 360° under computer control at six degrees per second. (Arridge et al. (1985). Since the advent of this system, researchers involved in its development have reported their findings with regard to clinical applications such as planning and assessment of surgery, facial reconstruction, complex fracture analysis as well as other applications such as producing an average face, facial anthropometry and forensic facial reconstruction.

Moss et al. (1987) described the use of computed tomography and the laser scanner system for studying changes in the facial form, and its relationship to changes in the supporting bone structure after facial surgery. They showed that realistic images may be produced from these data sets using computer graphic techniques to give the images a solid 3-D appearance.Appendix 7 : (Figures 75A, B, C, D and 76 and 77)

They illustrated the use of the system in the treatment of patients with congenital facial deformities.

Material and methods applied were described as follows:

The computer system consist of a Norsk ND540, which is a high performance 32-bit minicomputer, 140 megabytes.

It has a Winchester hard disk. Programme and data storage is attached to a GEMS display system with 24 bit planes.

A magnetic tape deck is used for reading data acquired from CT and NMR scanners.

Storage of patient data for long term are either on magnetic tape or floppy disk.

The GEMS system includes a function box with a tracker ball for viewing and manipulatation of images.

A custom built interface to the laser scanning system allows on line acquisition of facial surface measurements. Profiles generated from the scanner may be output to a plotter.

They concluded "The graphics techniques described enable the patient to be presented with a picture of the effects of surgery on the face in three dimensions before the surgery is undertaken. It is also a valuable asset to the surgeon who is able to identify and view the morphology of the bone within the maxilla or the base of the skull to determine the areas where surgical intervention is necessary."

Moss et al (1988) described a computer system for the interactive planning and prediction of maxillofacial surgery. The computer system is the same described in their aforementioned work. They used fifteen patients with varying types of congenital and facial abnormalities. Simulated facial surgery was performed in these patients using the computer system with interactive three dimensional graphics techniques and data derived from computed tomography and laser scanner systems.

Final facial form was predicted and displayed.Appendix 7 : (Figures 78A, B,C, D, E and 79 A-1, A-2, A-3/ B-1, B-2, B-3)

The following headings were applied:

1. Data sources
2. Production of three dimensional images.
3. Procedure for simulation of surgery.
4. Modeling of soft tissues.

They concluded: "The system that has been developed produces an accurate three dimensional representation of the skull on which it is easy to perform individualised surgery to the skulls and jaws. This enables both the surgeon and patient to view the result of facial surgery before the operation is performed. It also permits accurate measurements and monitoring of post surgical changes to the face and jaws by reproducible and non invasive means."

Moss et al (1989) described the use of the laser scanner system for measurements of facial surface morphology.

Accurate facial measurements are important for planning and accurately monitoring the effects of facial reconstructive surgery, for the study of movements and expressions and for facial recognition.

For facial surgery planning a laser scanner system was developed which is able to make 20000 facial measurements of the surface scanned with a dynamic resolution of approximately 0.9 millimetres The system is automatic and the measurements are achieved and recorded in 30 seconds. Individuals' profiles are recorded with a resolution better than 0.5 millimetres.

In the performance of this system and the assessment of its application to facial measurements there are some important factors to be considered such as relative spatial accuracy (e, g., point to point or profile to shape) the resolution or smallest changes detectable and the repeatability of the system. The system must also be shown to be stable over a reasonable period so that the frequency of calibrations can be reliably planned.

For testing the **relative spatial accuracy** they placed a sphere where the patient's head would normally be and then performed a 360° scan. The diameter of the sphere was measured with a vernier height gauge and found to be 250.86 ± 0.2 mm.

The laser system produced measurements of the sphere, except over the North and South poles which were invisible to the camera. The centre of the sphere was located in the coordinate system by taking a sample surface coordinate and finding the surface point furthest from it on the other side of the sphere, thus the line joining the points should be a diameter whose middle would be at the centre of the sphere. This was repeated for 100 distributed points and the centres averaged. The radii at 14715 surface data points were then calculated. The mean value was 125.7 mm and the standard deviation 1.6 mm. Forty-two per cent (42%) of the data points were within 1 mm of the vernier gauge value and 88% within 2.5 mm. In a Cartesian coordinates system, this would imply an average standard deviation in each dimension of 0.9 mm.

Resolution in the opinion of the authors is the smallest change which can be detected on a surface over a given area or distance.

Stability and repeatability of facial scanning

Each calibration has been found to be stable over a period as long as three weeks, except in respect of the zero position, which shows a measurable change over this time scale. This is caused by drift in the camera electronics, but is not a problem in practice if the system is calibrated frecluently.

The repeatability of measurements has been expressed in terms of the percentage of the midline profile length which shows variation within a given set of tolerances. It was found that 85% of the profile length showed differences of less than 0.2 mm, 12 % differences between 0.2 and 0.5 mm, 2% differences between 0.5 and 1 mm and 1% differences greater than 1 mm. The difference includes possible variation in the disposition of soft tissue over the face from day to day. The movement of the subject during data collection has not proved to be a serious problem in spite of sensitivity of the system.

The technique was validated using a plaster cast of a subject's face. Measurements were made directly on the cast using vernier calipers and on images generated from laser data. Fourteen distances were measured between pairs of points on the face and the results from the two measurement methods can be seen in Appendix 7, Figure 80.

The opinion of the authors the operator's skill in identifying the same points on the face will have a major bearing on the variability of the results. The points which were most easily identified showed the least variation. The other part of the experiment involved a subject and his plaster cast which were scanned.

According to the authors' results, over bony areas there was good agreement between the scans of the face and the plaster cast whilst there were discrepancies of up to 10 mm where the soft tissues are unsupported by underlying bone. This was due to the weight of the plaster (1.1-1.4 kg) deforming the face.

They concluded "an accurate and efficient no contact system of recording the facial surface has been described, which is of great value in monitoring facial change in patients."

Moss et al. (1991) reported methods of three dimensional analysis of patients with asymmetry of the face. The authors applied two methods of three-dimensional analysis of facial form and their application to cases of facial asymmetry. The three dimensional data from the patients with facial asymmetry were acquired using the laser scanner system.

Methods used were:

1. **Triangle area method** using the three dimensional nature of the facial surface data.

Nineteen facial landmarks were identified and marked on a laser image of the face. Triangles were constructed by joining trails of the landmarks. (Appendix 7, Figure 81). The areas of the triangles are automatically calculated and plotted. The advantage of this method is that the appearance of these plots is sensitive to asymmetries of the face, thus describing changes in this characteristic. In cases of normal growth there is a balance between the triangles on both sides of the face, but not complete symmetry. The study of normal growth and the validity of the method was tested using a series of plaster casts of individuals between 6 to 72 years.

Analysis of the triangles demonstrates balance in normal growth of the individual through his life. On the other hand the method was applied to a patient who had a right sided hemifacial microsomia. In patients with microsomia there is a failure of development of a facial side and the normal side overgrows in order to compensate for this alteration in the development of the other side.

The analysis of the method in this case showed an imbalance of the triangles. Normally in the treatment of these patients the normal side has to be reduced in order to obtain a corrected central line, and reduce the

asymmetry of the face. Following surgery the balance is not always restored but usually improved. (Appendix 7, Figures 82 A and B). The triangles more affected in this case were related to the gonion and tragus.
In opinion of the authors "The method gave a detailed analysis of the asymmetric growth of the two sides of the face. However, it still relies on the accuracy with which landmarks can be identified".

2. Surface decomposition

This method decomposes the facial surface into a collection of fundamental surface elements. It is a method which compares quantitative as well as qualitative surface changes and allows analysis of the face in 3 ways as follows :

a) A quantitative description of the change. b) The changes in the amount of surface types over the face. c) The changes in size of surface type patches and their movement on the face.

The authors concluded "It is now possible to asses the changes in the shape of the surface resulting from surgery in a mathematically meaningful manner. These approaches may help us in the better planning of surgery."

Linney et al. (1993) described three dimensional visualisation of data on human anatomy for diagnosis and surgical planning using x-ray computed tomography (CT), magnetic resonance imaging (MRI) and ultrasonic scans(US) for the internal anatomy and laser scanner system for the external surface.

The display system also produces data to drive a numerically controlled milling machine for the production of models, prostheses and implants. Among its clinical applications are planning and assessment of surgery as mentioned above. For this purpose computed tomography and optical surface laser scanner were used. Graphics facilities have been implemented for direct surface measurements and mathematical techniques have also been developed for averaging faces.

For anthropometric measurements, anatomical landmarks are marked on the surface by the cursor using either keyboard or mouse options. The distance between any number of landmarks can be measured either as a linear measurement or across the surface. One of the advantages of this program is that once the points have been placed on the surface, they stay fixed to it even if the surface is rotated, thus allowing the operator to make corrections or to place the landmarks in the correct position according to anatomical classical definition.

The program also allows one to extract surface sections, thus the profile can be seen along the line and is shown to the right of the display screen.

The current status of this system also allows for planning facial reconstruction in trauma cases. The data can be displayed as three dimensional anatomical surfaces on the workstation thus allowing the surgeon to plan and simulate in detail the surgical strategy. Furthermore, a mathematical analysis of the treatment can be achieved.

The three dimensional visualisation of the foetus also is a matter of interest for researchers of this field. The detection of abnormalities in the foetus and specially the foetal face are the subject of investigation. For these purposes the authors (1993) described a three dimensional ultrasonographic acquisition system based on grabbing video output frames from standard scanners. Scanning by the probe is freehand and its position and orientation are sensed magnetically to build up a spatially registered three dimensional dataset. The authors have succeeded in producing images of foetuses in utero using endovaginal probes and they concluded "The technique has shown some promising results although further developments of acquisition, segmentation and display techniques are in progress.".

Other aplications of laser scanner system are :

The average face: This application involved the registration and scaling of a set of faces and the resampling of the facial surfaces onto a coordinate grid where the coordinates of corresponding landmarks may be averaged. Recently the authors have been averaging abnormal faces for comparison with the normal faces and to measure the average effect of surgical treatments. The aim for this application was to determine whether normal standards for the three dimensional face can be found. For this design a method was developed for producing an average face from the authors' data base of normal subjects.

The production of anthropometric population statistics is a further future area of study. It is possible at the present time to assess the changes in the shape of the surface in a mathematical way using three dimensional methods of visualisation of the face. (Coombes, 1990).

The new heading to quantify changes resulting from surgery or to analyse any image of the face altered to measure the sensitivity of observers to these images in psychological experiments on facial recognition.

One of the latest applications of the laser scanner system is in forensic science for forensic facial reconstruction. It is not uncommon in routine practice to find unknown skulls that require to be identified.

To perform a reconstruction of the face, the skull is first scanned optically. If the database of the system does not have an average face of similar general characteristics to the skull in question, a face of an individual of similar anthropological type to that of the skull, must be scanned. The facial surface is then adapted to the skull using accepted tables of soft tissue thicknesses, according to the race, sex, age and body build determined from the skull.

The final reconstructed image can be photographed and published in the press for facial recognition from relatives or persons involved with the deceased person in an attempt to achieve personal identity of the skull in question.

The authors (Linney et al 1993) reported the use of this method in an archaeological case:

"The techniques developed for the reconstruction of faces over skulls for forensic purposes have also been used for archeological purposes in the reconstruction of the face of a Viking for a museum in York."

Vanezis et al (1989) reported the first case using an optical surface laser scanner for forensic facial reconstruction and its comparison with sculpting techniques.

The methods were described as follows:

Two methods of reconstructing the face over the skull are compared using a skull from a known person. Photographic material of the deceased during life was concealed from the artist and computer operators. Both methods used data on measured soft tissue thickness over selected points on the skull. The first is the traditional method of an artist building up the soft tissues in clay over a plaster model of the skull. The second method used digitisation of the skull and numerical methods to reconstruct a face which corresponds to it. Three dimensional computer graphics techniques were developed as one of the application programmes for the Wolfson transputer based workstation project at University College London then used to display the reconstructed face.

Facial reconstruction by sculpting. The sculptor used a combination of the methods mentioned earlier to perform facial reconstruction. He used Rhine and Moore (1982) soft tissue thickness data for American Caucasoids.

The forensic sculptor commented that details of the mouth and lips were impossible to establish with complete accuracy but there are certain principles which are used to indicate mouth width, such as the lateral border of the first pre-molar, or, in edentulous subjects, the interpupillary distance. There is a little or no information to assist with the reconstruction of ears. The position of course is easily established but the relative size and shape of the pinna as a whole can only be done on an intuitive basis.

The criticisms of the three dimensional facial reconstruction technique from the authors were that the final reconstructed face can never produce a 100% accurate portrait, for there are so many variables in the details of the face. There are many obvious difficulties when reconstructing features such as the mouth, nose, eyes and ears. The type and colour of hair, the form of the eyebrows and the possibility of facial hair in the male will also have a profound effect upon the appearance of any individual. Surface marking such as scars and skin blemishes, deep furrows, folds, wrinkles, ethnic scarring, tattoos, and the wearing of rings, spectacles are further details of a face that cannot be ascertained from a dry skull.

The authors stated "The three dimensional reconstruction technique will, in the vast majority of cases, produce a head and face very similar to the original, but seldom exactly the same."

Computer based method of reconstruction

Measurement on the skull. To perform a reconstruction based on numerical and computing techniques, a large number of surface coordinates of the skull must be measured.

Data acquisition using the second method described by the authors developed at University College London (UCL) on the human face, is fully automated. The system used was described as follows:

"A computer controlled rotating platform, a projected laser line and a video camera interfaced to the computer, able to record 20000 surface coordinates with a resolution of 0.5 mm in 30 s. Simple triangulation is used to derive the required numerical representation of the surface from the digitally recorded video signals. This technique has a minimal amount of manual intervention and is therefore, less prone to inaccuracy due to human error. A plot of the data points in a straight line frame work can also be made immediately to check for any data acquisition errors."

The numerical reconstruction technique was described as follows:

The computer technique for reconstructing a face over a skull was developed as an application programme for the Wolfson Transputer-based Medical Graphics Workstation at UCL.

Both manually digitised and the laser scanned data sets from the skull may be used. First the data set on the skull is displayed as a fully shaded 3-D surface. The operator then chooses a number of sites and the same facial thickness measurements equivalent to those used by a sculptor when placing tissue thickness pegs. The tissue thickness distributions are then "grown" on to the skull surface.

The resulting surface is smoothed to produce a featureless mask of the face lacking eyes, ears, nose and mouth. Although this facial mask does not look very human, it does convey the fundamental facial shape. The method used in this reconstruction is a facial surface data set from a library of living subjects' faces and remoulding it to match the simple mask.

To place the digitised facial surface over the simple mask, techniques have been developed which adjust both the scale and the spatial position of facial features. In this way the facial data set is registered and scaled to match the dimensions of the skull on which the reconstruction is to be made. The facial surface profile is effectively "transplanted" on to the skull surface and adjusted by the computer programmes to fit at selected corresponding sites.

The facial form generated by the techniques described is not likely to be sufficiently detailed on its own to permit positive identification. Adjustment of primary features such as the nose, mouth, lips and eyes as well as eyebrows and possibly hair colour are necessary to produce a recognisable face.

The authors concluded "The manual technique, despite the many limitations which are inevitably imposed when working from quite limited information, can be very effective provided the reconstruction is used in the right way. It is also very adaptable, as no highly specialised equipment is required, and work can be carried out on damaged or incomplete material. The disadvantages are that the process can take from 2 days to 2 weeks to complete.

Also once complete, it is not a simple matter to quickly modify a head to become fat or thin or make major changes to provide variations. The computer reconstruction technique is feasible for generating faces from skulls. The advantage of this technique is that not only can more anatomical data be incorporated, but within a matter of minutes, it is possible to generate several faces compatible with the underlying skull but with small variations in facial features.

This will allow reconstructors to generate a range of possible faces, rather than a single reconstruction, in order to increase the chances of identification. Subjective characteristics associated with a unique manual reconstruction will also be avoided."

The authors in the final analysis stated:

"However, no matter how accurate a reconstruction may be, it is the circumstances pertaining to the subjects in life than can determine the success or failure of such an undertaking"

FACIAL RECONSTRUCTION TECHNIQUE USING AN OPTICAL SURFACE LASER SCANNER

The technique employed in the Facial Identification Centre at Glasgow University involves reconstructing a face onto a skull using an optical surface laser scanner; a computer image is rendered using computer graphics techniques. (Arridge et al. 1985, Vanezis et al, 1989)

The background of this system has been discussed. The computerised technique is based on the same principles of facial reconstruction previously discussed. With the advent and development of computer graphics techniques and their application to medical engineering imaging, computerised facial reconstruction was a natural progression from sculpting techniques.

Briefly to perform a reconstruction of the face, the skull is scanned optically using an optical surface laser scanner and video camera interfaced to a computer. A face from a data bank which has been previously scanned, is then placed over the skull in the form of a mask. The face should be selected, taking into account all the information acquired from the general anthropological data of the skull such as sex, race, age and body build. The facial surface is then adapted to the skull using accepted tables of mean soft tissue thicknesses.

To achieve this computerised facial reconstruction special software has been developed which can distort an optical surface scan of a face so that it matches the dimensions of an optical surface scan of a skull.

The software uses forty-four facial tissue measurements according to the method of Rhine et al. (1980, 1982) (Appendix 9, Figure 83).

The selection of soft tissue thickness is according to the characteristics of the general identification available.

The software allows one to modify facial soft tissue thickness values; thus the operator can select and use the best data available including the latest soft tissue thickness data published using living persons (Helmer, 1984 b).

The resulting reconstructed face can be considered to be approaching to the expected facial shape of the owner of the skull. This approach should be reasonably good where the features of the face depend directly upon the shape of the skull, but in regions where the facial appearance does not directly depend upon the shape of the skull, such as eyes, lips, ears, nose, the reconstruction will resemble the original face selected.

Procedures for facial reconstruction :

1. Acquisition of data from skull or face.

2. Numerical Reconstruction Technique

1. Acquisition of data from skull or face:

The scanning system was set up as previously described (Arridge et al., 1985), Moss et al., (1987, 1988, 1989), Coombes et al., (1990), Linney et al., 1993), Vanezis et al., (1989). (Appendix 9, Figures 84 and 85)

<u>Laser Scanner specification:</u>

The FACIA Laser Scanner is controlled by an IBM-compatible PC, which hosts a transputer, device controller card, video capture card and two video output cards. Since it is the various expansion cards which do most of the work a basic 386SX25 processor is adequate, with 1 Mb of main memory.

It is the transputer card that performs most of the computational work involved during the image capture, display and data processing.

The transputer card consists of four INMOS processors, each with 1 Mb of private memory. The result of a scan is displayed on a high resolution monitor, while the user interface to the scanner software is displayed on a separate lower-resolution monitor.

The mechanical sub-system includes a platform rotated by a simple stepping motor, which is controlled by the host computer via the device controller card. The angular position of the platform is relayed back to the controller card.

The optical sub-system consists of a Class 3B Laser (5mW, 670 nm), a columnar prism, four optical mirrors and a CCD camera. The narrow beam from the laser passes through the columnar prism, resulting in a vertical red line which illuminates a single profile of the object being scanned on the platform. The four mirrors are arranged in such a way that two images of the illuminated profile are seen by the camera as mirror images of each other. This double image is then captured by the video capture card in the computer. As the platform turns, further profiles are obtained. The transputer analyses approximately 200 points in each profile. The distance of a point from the centre of rotation of the platform is a function of the distance between the two mirror images. From this and the angular position of the platform for a given profile a set of three dimensional points on the surface of the object is built up.

An accurate acquisition of the data requires a large number of surface co-ordinates of the facial or skull surface to be accurately measured. The data acquisition is fully automated.

Description of the system: A line of laser light is projected onto either the patient's face or a skull in order to illuminate the profile.

The patient or the skull profile is viewed from either side by two large mirrors which in turn are viewed by a charge coupled device (CCD) camera via a pair of small mirrors. The arrangements of the mirrors allow the line to be viewed by the camera from two opposing directions. Opposing views are necessary to avoid the loss of data caused by the occlusion of parts of the facial surface by the prominence of the nose.

The output of the camera may be seen on the small black and white monitor; thus the lines shown on this monitor allow the operator to analyse the shape of the patient's or skull profile and then to adjust the height of the patient or skull in the screen. In other words the B/W monitor allows one the proper patient's head or skull position to be checked for a successful scan to be made. The camera is connected to a computer via a customised interface board. Video signals from the camera are pre-processed by an interface board.

The system is based on the principle of triangulation. The triangulation is used to derive the required numerical representation of the surface from the digitally recorded video signals. A calibration programme converts these numbers into spatial coordinates of points lying along the laser line illuminating the surface. A plot of the data points in a straight line frame work can also be made immediately to check for any data acquisition errors.

To scan the facial or skull surface, the patient sits in a chair or the skull is placed in a special platform; which is rotated by a stepper motor under microprocessor control. This allows 360 degree exposure of the information by the rotation of the subject or skull. For the face, the platform is usually rotated through 200° in 15 seconds, but both the speed and extent of rotation may be varied to suit the subject.

The angle at which the profiles are collected is measured using a shaft encoder attached to the base of the scanning chair.

Resolution may be adjusted to correspond to surface detail and curvature. Up to 256 profiles may be read into the computer at one scan. The computer uses these profiles to generate a picture of the patient or skull that is similar to a plaster cast and which can be measured three dimensionally.

The system is able to collect and record in a single scan 20000 three dimensional coordinates of points lying on the anatomical surface with a resolution better than 0.5 mm in 30 seconds. The data is stored in the computer memory and approximately 20000 coordinates on the facial surface are derived. A patchwork of triangles (facets) is constructed from these to represent the facial or skull surface with a precision of 0.5 mm.

A specific advantage of the system is the ability to store and retrieve the full database in its original and modified form, and provide a long term follow up study.

The optical scanner data is usually displayed on the graphics monitor as a rendered surface which may be displayed and seen from any chosen viewpoint. The transputer enables this image to be produced in a few seconds. The red line that is projected onto the patient's or skull surface comes from the small laser that is situated at the back of the camera.(Appendix 9, Figure 87) The beam of light coming from the laser is fanned out into a line (0.7 mm wide) by the glass, cylindrical rod in front of the laser. The laser has a low energy (1 milliwatt) and the attachment of this glass to the system reduces the intensity at the patient's eyes. According to the supplier of this equipment and the literature suggested by them this line (0.7 mm) of the laser light is safe to be shine directly into the patient's eyes for up to 10 seconds.

According to measurements it would be safe to stare at it for up to 100 seconds.

On the basis of an international safety standard IEC825 that applies to laser light, due to its low power there is no hazard for the subjects under the condition mentioned above.

With respect to the safety of the system some concern was expressed to the University Laser Safety Officer as to the laser radiation levels emitted by this device and whether a possible hazard existed from the cumulative effect of constant exposure to the operators of this equipment. He issued the following report:

"The technical manual states that the laser is a low power (1mw class II) He/Ne device, operating at 633 nm. The beam of laser radiation emitting from the aperture is fanned out into a vertical beam by a cylindrical rod, thus by the time the laser radiation reaches the patient (1 m away) the intensity has been greatly reduced. The manual claims that it is safe for the patient to peer into the beam for up to 100 seconds, although in practice the eyes are scanned for a much shorter time. To confirm the above, measurements were taken using a Macam digital radiometer, type R102, serial number 1604, calibrated at 633 nm with an absolute accuracy of 5%.

Results:

1. Background radiation from light = 136 μ Wcm^{-2}
2. Background pointing at wall = 10 μ Wcm^{-2}
3. At 30 cm from laser source = 136 μ Wcm^{-2}
4. At patient's eyes = 62 μ Wcm^{-2}

From the above results it can be seen that there is no significant hazard to the eyes of the patient or the operator from laser radiation emitted from this device. However, it is not recommended that this beam be observed directly any closer than 30 cm from the laser source"

2. The numerical Reconstruction Technique

The computer technique for reconstructing a face over a skull was developed as an application programme for the Wolfson Transputer-based Medical Graphics Workstation at University College London (UCL).

First the data set on the skull is displayed as a fully shaded three dimensional surface. The next step is to select an average face from our stored data bank corresponding to the anthropological information that we have concerning the skull in question.

The average face data cited above were obtained using a previous study (Vanezis et al. (1992-1993).

Briefly, the study involved anthropometric measurements of the face and its constituents including ear, orbit, nose and mouth in the frontal plane in a sample of 50 Caucasian adult males and 50 adult females with different body types. All were healthy volunteers from Charing Cross Hospital and included staff, medical students and occasional visitors. Their ages ranged from 18 to 79 years for males and from 18 to 53 years in females. None of the cases had obvious facial deformity or previous facial surgical operations or disfigurements, they were normal on visual examination. None of the volunteers wore glasses at the time of the scan or were excluded if they had significant facial hair, such as moustache or beard that would have hampered scanning. The patient's head was placed in the "natural position" according to classical anthropological criteria (Ghafary, J, 1987) (Moorees CFA, 1985) and prior to commencement of the scan. The neutral, relaxed posture with eyes closed was chosen for the study. Their faces were scanned, recorded and stored.

Using other applications of the laser scanner system, called the average face program, we obtained the average face for a specific range of age in both sexes. The average face involved the registration and scaling of a set of faces and the resampling of the facial surfaces onto a coordinate grid, where the coordinates of corresponding landmarks may be averaged.

Landmarks selected for an average face were :

Frontal view : metopion, glabella, nasion, nasal midline (midnasal point), subnasale, labiale superious, stomion, labiale inferious, pogonion, gnathion, superciliare (r, l), frontosupraorbitale (r, l), exocanthion (r, l), orbitale (r, l), zygomatic maxillar junction (r, l), alare (r, l), cheilion (r, l)

Lateral view left- right : zygion, porion, gonion

As we may often do not know the body build of the subject we use "normal" soft tissue thickness data according to the race and sex of the skull, based on accepted soft tissue thickness tables. (Rhine et al., 1980, 1982). The program also provided sets of soft tissue thickness tables.

The term "normal" means to use the mean average body build of soft tissue thickness for that sex and race. Once the appropriate soft tissue thickness data has been selected the operator chooses and places a number of sites equivalent to landmarks onto the skull and face to be matched.

The program works with 44 landmarks that are the same soft tissue thickness measurements to those used by a sculptor when placing tissue thickness pegs. These landmarks locate soft tissue thickness measurements at those sites that must be placed in their anatomically correct positions on the skull so that the reconstructed facial proportions correspond to underlying skeletal proportions. Thus, the facial surface profile is effectively "transplanted" on to the skull surface.

Once the landmarks have been placed correctly it is then possible to align the two scans into matching orientation. The marker points can be further adjusted if necessary. The program also allows one the set of landmarks to be saved for future use.

The process of adjusting the surface is a single automatic menu option, but it will only succeed if all the previous steps have been carried out correctly.

The operator's skill in placing the landmarks in the proper position, according to the classical anatomical criteria is essential for a successful facial reconstruction to be carried out.

After a complete alignment of the two scanned surfaces selected from the menu, it is necessary to re-check all the landmarks to be sure of their correct positions in the two scans, then the operator can apply the face shift option. This function performs the facial surface adjustments, and must be preceded by a complete alignment. All the adjustments of the positions of the pegs, tissue thickness, etc., should be finalised before applying this option, which takes between 15-20 minutes.

If the procedure has been performed with the appropriate guidelines the final reconstructed face should be successful, the reconstructed facial form may now be displayed from any viewpoint.

The system is able to store this modified facial surface for later use, the saving process taking between 15 to 20 minutes.

The entire proceedia can be completed in 2 or 3 hours depending upon the ability of the operator and his/her basic knowledge of the program and of facial identification as a whole.

The facial form generated by the techniques described is not likely to be sufficiently detailed on its own to enable a positive identification to be made. The identifier should be familiar with facial shapes and computer images. Adjustments of primary features such as eyes, lips, mouth, nose and the "good" identifier elements for facial recognition cited by Zabala et al. (1972) (Appendix 8, Table N° 11) must be taken into account when attempting to produce a recognisable face. It is necessary to add features to the "mask" in order to "humanise" and make it more life-like.

A number of techniques for adding the facial features are being investigated. Features could be scaled according to their anatomical relationship with the skull in question and transferred to their corresponding position on the face using interactive computer graphics techniques. A similar approach may also possibly be used effectively on many commercially available 2-D "identi-kit" systems.

The use of computerised facial expressions and possible animation should be investigated as an additional aid to recognition. These latter factors were suggested earlier by one of the most relevant researchers of the Biometrics school. (Pearson, 1926)

Catterick (1992) reported a study of facial measurements as an aid to recognition in order to determine the value of using measurements from photographs for facial comparisons.

In his summary he described that an image processing system was used as an aid to locate four facial features on two sets of passport-sized photographs.

He concluded that the discriminating power based on these facial measurements was assessed to provide some idea of their value for facial comparisons. The discriminating power using these four measurements amongst subjects was ~66% (i.e., 2 in 3 pairs of subjects were distinguishable).

Iscan (1993) described the techniques used for photographic comparison. He commented that the comparison of two or more photographs remains

one of the most difficult types of identification. No standard procedures have been developed for the analysis of photographs or video images.
The techniques involved in photographic comparison can be divided into three categories:

1. Morphological analysis of facial structures.
2. Photo-anthropometry of the face.
3. Photo-to-photo video superimposition.

The technique selected according to its principles and thus more closely to the purposes of the present work was Photo-anthropometry of the face. This technique is defined as the analysis of anthropometric landmarks, dimensions and angles to quantify facial characteristics and proportions from a photograph.
This technique involves measuring similar dimensions of a known person's photographs with those of the individual in question. The problem with this technique is that sometimes the landmarks are not easily identifiable or visible on the photographs, depending of the quality of the photograph in question. However if the investigator works with a good quality photograph in which the features are clearly demonstrated, then the landmarks can be defined and measurements obtained.

In order to make the value truly comparable, proportion indices must be calculated from these measurements. As we know in a photograph we cannot always find objects of known size to enlarge the image to its natural size. More often it is impossible to determine the actual dimensions of the face and its features.

Proportion Indices must function to eliminate the effects of absolute size differences between individuals or objects. The general formulae for obtaining any proportion index is as follows:

$$\text{Index (I)} = \frac{\text{Numerator (smaller measurement)} \times 100}{\text{Denominator (Larger measurement)}}$$

In the formulation of an index, the smaller measurement is multiplied by 100 (numerator) and divided by the larger measurement (denominator). Thus the smaller measurement is expressed as a percentage of the larger. (Farkas, 1987). The result quantifies the proportion of the small dimension to the large dimension and thus the problem of scale is eliminated. As many proportion indices as needed can be generated.

These calculations can be carried out easily on any computer spreadsheet program. In this study a statistical package called Minitab was used. This technique attempts to metrically compare the proportional relationships of one photo to another rather than determine absolute visual similarities. The method, as it is quantitative, reduces the subjectivity of photographic comparison, but it is not always possible to reach a definitive conclusion regarding the matching of two images.

Iscan (1993) described the problems involved with this technique as follows:

1. The photographs may have been taken under different conditions (e.g., lighting).
2. The angle of the lens and the distance between the camera and the subject alter the apparent proportions of the face.
3. Some photographs may have been retouched to improve the appearance of the subject; in this case the facial features may not match those of the unretouched photographs even if it is the same individual.

4. Weight and age differences may bring about changes in the location and appearance of landmarks.

5. Differences in facial expression may result in different values. This is especially true when a photograph with a laughing or smiling face is compared with a serious or frowning one. Laugher, for example, may widen the mouth, shorten the nose-to mouth distance, and lengthen the face.

PRESENT STUDY

Introduction

From the preceding chapters, the reader will have an appreciation for the role and current status of the facial reconstruction techniques in personal identification for forensic anthropological purposes. According to the literature the techniques by themselves are still a long way from being accepted as definitive methods for identification on their own. The latest investigations show much research remains to be carried out to improve the techniques. There are many important factors, which affect the final results obtained, which must be understood before these techniques can be considered as satisfactory for positive identification. Researchers in this field have indicated the lines of investigation in each area which should be followed up to achieve a reliable standard of methodology sufficient to validate these techniques, for positive forensic identification.

Mindful of computer technology and its applications in forensic science, the study presented here is a preliminary effort to asses the reliability of computerised facial reconstruction using a special system, as a method for forensic identification.

Objectives:

The aim of the present study is to evaluate the results of computer aided facial reconstruction using an optical surface laser scanner. The results will be evaluated as they stand alone and also in support of recognition of facial features carried out by other means.

These others means are :

a) Visual perception of the resemblance between the reconstructed faces and photographs of the presumed missing persons included in the investigation.
b) Anthropometry of the 3-dimensional reconstructed faces.
c) Photogrammetry of 2-dimensional photographs presumed to be of the missing individuals.
d) Statistical comparison of b) and c) using proportional indices.

The three dimensional graphics system described also has the capability of measuring acquired facial or skull surface data. The system is able to make accurate measurements, either linear or projective as the projected two dimensional co-planar image and in three dimensions, taking into account surface contours. Thus various sets of measurements of facial features and landmark distances can be measured accurately. (Moss et al., 1989)

Iscan and Charney (1981) compared two and three dimensional facial reconstructions using measurements from their photographs. They found that the two forms of facial reconstruction produced dimensional similarities but very different morphological features. This early study pointed out the problems associated with the process and introduced measurements that might allow valid comparisons.

Materials and methods

The samples used in this study were part of a number of human remains exhumed from a mass grave in a South American country in 1991.

Brief summary of Human Remains:

The human remains were buried in 1973 in one of the largest cemeteries of the capital city. In 1973, according to the existing records, a post-mortem examination was carried out in those bodies, but no identifications were made. The main reason given by the forensic specialist and documented in their post-mortem records of that year for not being able to determine identity was that most of the cadavers were in advanced decomposition. They were killed by Military Forces between September and December of 1973. The cause of death was mainly by shooting in several anatomical regions, mainly in the head.

The bodies were kept buried for about 18 years until a judicial investigation was opened and ordered the exhumation. One hundred and twenty six cases were exhumed. Most of the cases were found buried individually in coffins, but in a few cases two or three cadavers were found in one coffin.

An anthropological assessment was carried out in all the human remains in the country of origin by forensic specialists who carried out the general identification.

At the end of 1994, twenty-one plaster casts out of 126 cases which were still unidentified were brought to Glasgow University in order to carry out personal identification by applying the latest techniques development in facial identification at the Facial Identification Centre, unfortunately the original skulls were not available for the study.

The reason given was that there had been a court ruling preventing the skulls from leaving their country of origin.

Twenty-two presumed life photographs of the missing individuals were provided, together with twenty-seven pre-mortem records and twenty anthropological records. A special form was designed in order to collect all the antemortem and pre-mortem records.

The presumed photographs of the missing persons provided were in relation with the same names of the pre-mortem records.

Most of the pre-mortem records available were not complete. They were completed according to the relatives′ memories with regard to features and particular characteristics of the missing persons remembered after a long time of their disappearance. These records were not reliable at all, because they were not based on confiable medical or dental records.

Pre-mortem records included the name of missing person, sex, age, race, date of birth, date of disappearance, complexion (clothes size), body type, stature, weight, blood type, hair, beard, moustache, bone trauma, profession, eyes, teeth, nose, form of head and face, size of feet, presence or not of any trauma or pathologies specially in bones.

Anthropological records included the state of preservation, time since death, cause and manner of death, sex, race, age, stature, pathologies/anomalies, handedness and or others indications of habitual behaviour and odontological records.

The general identification of the human remains provided, according to the records, was male, aged between 19-70 years, Caucasoid, height between 151-187 cm. (Appendix 9, Table 12)

The records for the missing persons showed the following general characteristics; They were all male, Caucasoid, aged between 20-49 years, with heights between 155-180 cm. (Appendix 9,Table 13)

In this way one could eliminate the effects of absolute size differences between the three dimensional images of the reconstructed faces and two dimensional photographs of the missing persons.

Methods

The samples used in this study were not selected at random. After a comparative analysis of samples using the pre and post-mortem information, there were two samples (plaster casts) which were not found to be compatible with the missing persons' information provided. Thus the numbers of samples left for study were nineteen plaster casts. However twenty-one facial reconstructions were performed.

After an analysis and a complete comparison were made of the antemortem and post-mortem records provided with all its limitations and under reasonable doubts related to the information contained in those records, a presumed identity was assumed for some samples ; the next step was the application of superimposition techniques together with facial reconstruction through computing. After all these steps, an approximation of identity in fourteen of the nineteen samples was seen.

Thererefore for a facial anthropometric comparison between computerised three dimensional measurements of reconstructed faces and direct two-dimensional measurements of photographs, fourteen photographs and fourteen three dimensional facial reconstruction were used.

The study involved:

1. Anthropometric measurements of the face in the frontal plane in 100 Caucasian, adults, volunteers using an optical surface laser scanner system.(1993 study ; Vanezis et al)

2. Computerised facial reconstruction of fourteen plaster casts of skulls, using an optical surface laser scanner.

3. Computerised facial anthropometry in the frontal plane of the fourteen reconstructed faces using the same system used for facial reconstruction.

4. Photogrammetry of the face or indirect facial anthropometry from fourteen missing persons' photographs.

5. Comparison of proportion indices selected between three-dimensional reconstructed faces with two-dimensional missing persons' photographs.

Procedures:

1. Anthropometric measurements of the face in the frontal plane in 100 Caucasian adult volunteers (50 males and 50 females) using an optical surface laser scanner system.

Introduction

For many years various authors have been interested in anthropometric measurements of the face and their applications to a number of medical and related fields such as Genetics, Orthodontics, Plastic Surgery, Physical Anthropology and Forensic Medicine.

In an attempt to test the accuracy of our optical scanning technique (Linnney et al., 1993) in the study of facial anthropometry, we have designed a protocol paralleling the methods of classic anthropometry (Farkas, 1981, Farkas and Munro 1987). In addition, we set out to demonstrate its use in practice.

Methods and Materials

The present study involves anthropometric measurements of the face and its constituents including orbit, nose, mouth and ears in the frontal plane in a sample of 50 Caucasian adults males, and 50 Caucasian adults females with different body types. All were healthy volunteers from Charing Cross Hospital and included staff, medical students and occasional visitors. Their ages ranged from 18 to 79 years for males and from 18 to 53 years in females.

These volunteers were chosen from the first 100 consecutive laser scans (excluding non Caucasian from the total number). None of the cases had obvious facial deformity or previous facial surgical operations or disfigurements, e. g, were normal on visual examination. None of the volunteers wore glasses at the time of the scan or were excluded if they had significant facial hair such as beard or moustache that would have hampered scanning.

The scanning system was set up as previously described (Linney et al (1993), Moss et al (1989). Briefly, it consists of a laser beam, a rotating chair in which the subject sits during the examination, a transputer, a video display unit (VDU) and another VDU for image projection. Up to 240 profiles over 360° may be imputed into the computer at one scan. (Linney et al 1993, Moss et al (1989).

The computer uses these profiles to generate a picture of the subject that is similar to a plaster cast and which can be measured three- dimensionally. To collect more than one profile, the subject is rotated on the chair and the angle at which the profiles are collected, is measured using a shaft encoder attached to the base of the scanning chair. Between 30.000 and 60.000 three-dimensional coordinates of points lying on the anatomical surface are usually collected in a single scan. Initially the patient's head was placed in the natural position according to classical anthropological criteria (Ghafary, 1987, Moorees 1985) and prior to commencement of the scan. A total of 5 scans were taken per each individual. Five different expressions including eyes closed, eyes open, looking up, mouth open and smiling were considered. The neutral, relaxed posture with eyes closed was chosen for this initial study.

Image measurements were obtained as it has been described by Linney et al (1993). Images were retrieved from the hard disk and the following procedures were adhered to :

1. Using the three dimensional computer system each facial image was rotated at different angles until face symmetry was obtained.
2. The Frankfurt Horizontal plane (Farkas, 1981) was set on the screen in the lateral view before the corresponding frontal view was obtained. All faces were measured at a constant angle.
3. Classical anatomical cephalometric landmarks (Farkas, 1981, 1987) were selected and located. Landmark location was obtained by the same operator. The following were the landmarks used to carry out the measurements of each facial component.

I. Face

Five midline

Trichion (tri)
Nasion (n)
Subnasale (sn)
Stomion (sto)
Gnathion (gn)

Three paired

Zygion (zy)
Gonion (go)

Tragion (t)

II. Orbit

Four midline

Glabella (g)

Nasion (n)

Facial midline (m)

Stomion (sto)

Twelve paired

Fronto supraorbitale (fs)

Endocanthion (en)

Exocanthion (ex)

Orbitale (or)

Superciliare (sci)

Orbitale superius (os)

Otobasion superius (obs)

Tragion (t)

Gonion (go)

Zygion (zy)

Cheilion (ch)

Frontotemporale (ft)

III. Nose

Four midline

Nasion (n)

Midline (m)

Pronasale (prn)

Subnasale (sn)

Four paired

Endocanthion (en)

Maxillofrontale (mf)

Alare (al)

Subalare (sbal)

IV. Mouth

Five midline

Subnasale (sn)

Labiale superius (ls)

Stomion (sto)

Labiale inferius (li)

Chin lip fold (sl)

Four paired

Subalare (sbal)

Crista philtri (cph)

Labiale superius (ls)

Cheilion (ch)

V. Ear

Three midline

Nasion (n)

Subnasale (sn)

Gnathion (gn)

Seven paired

Otobasion superius (obs)

Otobasion inferius (obi)

Preaurale (para)

Postaurale (pa)

Superaurale (sa)

Subaurale (sba)

Exocanthion (ex)

4. The computer maintained the landmarks on the surface as the image was rotated.
5. Once the appropriated landmarks were selected, the measurements of their respective linear distances were obtained and represented in mm. All measurements were taken by the same operator and validated subsequently by repeated measurements at a later date.
6. A special form to chart results according to the classification given by Farkas (1981, 1987) was designed.
7. Measurements chosen for the study (Farkas, 1987)

Face

I. Single

A. Horizontal

1. Width of the face (zy-zy)
2. Width of the lower face (go-go)

B. Vertical

3. Physiognomical height of the face (tri-gn)
4. Morphological height of the face (n-gn)

5. Physiognomical height of the upper face (n-sto)
6. Height of the lower face (sn-gn)
7. Height oh the lower third of the face or height of the mandible (sto-gn)

II. Paired

A. Horizontal

8. Depth of the upper third of the face (n-t)
9. Depth of the middle third of the face (sn-t)
10. Depth of the lower third of the face (gn-t)
11. Depth of the lower jaw (gn-go)

Orbit

I. Single

A. Horizontal

1. Supraorbital diameter (fs-fs)
2. Intercanthal width (en-en)
3. Biocular width (ex-ex)

II. Paired

A. Horizontal

4. Supraorbital half diameter (fs-g)
5. Orbito aural distance (ex-obs)
6. Orbito tragion distance (ex-t)
7. Orbito gonial distance (ex-go)
8. Orbito glabellar distance (ex-g)
9. Endocanthion facial midline distance (en-m)

10. Eye fissure width (en-ex)

B. Vertical

11. Orbit height (os-or)

12. Eyebrow height (sci-or)

Nose

I. Single

A. Horizontal

1. Width of the nasal root (mf-mf)

2. Width of the nose (al-al)

3. Intercanthal width (en-en)

B. Vertical

4. Nose height (n-sn)

5. Nasal bridge length (n-prn)

II Paired

A. Horizontal

6. Nostril floor width right (sbal-sn)

7. Nostril floor width left (sbal-sn)

8. Nasal root length rigth (en-m)

9. Nasal root length left (en-m)

Mouth

I. Single

A. Horizontal

1. Width of the mouth (ch-ch)

2. Philtrum width (cph-cph)

B. Vertical

3. Medial height of the cutaneous upper lip (sn-ls)

4. Medial vertical upper lip length (sn-sto)

5. Medial vermilion height of the upper lip (ls-sto)

6. Medial vermilion height of the lower lip (sto-li)

7. Medial height of the cutaneous lower lip (li-sl)

8. Medial vertical lower lip length (sto-sl)

II. Paired

A. Horizontal

9. Width of the half mouth right (ch-sto)

10. Width of the half mouth left (ch-sto)

B. Vertical

11. Lateral vertical upper lip height right(sbal-ls′)

12. Lateral vertical upper lip height left (sbal-ls′)

Ears

I. Paired

A. Horizontal

1. Upper naso-aural distance (n-obs)
2. Lower naso aural distance (n-obi)
3. Upper subnasale aural distance (sn-obs)
4. Lower subnasale aural distance (sn-obi)
5. Upper gnathion aural distance (gn-obs)
6. Lower gnathion aural distance (gn-obi)
7. Width of the auricle (pra-pa)

B. Vertical

8. Length of the auricle (sa-sba)
9. Morphological width of the ear (ear insertion height (obs-obi)

8. Proportions Indices were selected and calculated using the measurements obtained by computer. (see Appendix 10)
9. Results were tabulated. Mean and standard deviation (SD) of each measurements were calculated and analysed. The normal range was conventionally established between +2 SD and -2 SD (see Appendix 10)
10. Results of measurements were tabulated and compared analytically between the male and the female group. Absolute differences are expressed as a percentage of the larger value.

RESULTS :

I. Face

1. All mean values were particularly larger in the male group than the in the female one in the sample studied.
2. Paired horizontal measurements had all mean values larger on the right side in males, while females did not have such consistency, the exemption was depth of the lower jaw. This quantitative facial

dissymmetry was more notable in the male sample rather than in the female one.

II. Orbit

1. Mean values were invariably larger in the male sample than in the female one for all single horizontal and paired vertical measurements.
2. Paired horizontal measurements presented less consistency and in the measurements N° 6 and 10 the female sample was the exemption. Paired vertical measurements showed larger mean values on the left side of both males and females.

III. **Nose**

1. Single horizontal and vertical measurements showed systematically mean values larger in the male group than in the female group.
2. Paired horizontal measurements, width of the nostril floor was the exemption.

IV. **Mouth**

1. The male sample had mean values constantly larger than the female one.
2. Paired horizontal measurements exhibited mean values larger on the right side of both sexes.

   Paired vertical measurements showed larger mean values on the left side of both males and females.

V. **Ear**

1. The male group showed mean values regularly larger than the female one.

2. Paired vertical measurements showed larger mean values on the left side of both sexes while mean values in paired horizontal measurements had a very variable distribution, in respect to both sides and sexes.

DISCUSSION

It is essential to have experience in the use of the scanning apparatus in order to obtain an accurate location of the anatomical landmark on the surface of the computerised image. Anatomical landmarks were located in the frontal plane by computer and according to their classical anatomical definition (Farkas, 1981). To achieve more accurate measurements some midline landmarks (n, sn, gn) were fixed in the lateral plane before the respective frontal plane was obtained.

In order to achieve a reliable computational framework the operator must obtain symmetry of the facial image. It is a prerequisite for setting the Frankfurt Horizontal plane, which is used to standardise measurements. This plane was used as a standard of reference for craniometry and it was set on the screen upon recognition of the appropriate anatomical landmarks. This plane showed a horizontal line between the orbitale and the porion and this is at variance with the findings of the others authors that have used non computerised anthropometric techniques (Stengel et al, 1984). Symmetry and therefore consistent orientations in all facial images were obtained. It was also observed that the Frankfurt Horizontal Plane was an useful tool to correct the changes in the "natural head position" Movements of the subject's head can occur due to the rotation of the chair and there is not a reference point on the horizon during darkness. Setting the plane correctly will obviate these variables. There are advantages and disadvantages of the present method when compared with classical in vivo morphometric and photometric techniques (Mc Kenna, 1983)

Advantages :

- Rapidity of execution
- Friendly user once basic training has been given
- Objectivity of measurements
- It does not require subject manipulation
- Measurements can be made with accuracy. This could be further improved by restricting the gathering of data to 180° rotation, thus doubling the number of coordinates of the face with improved resolution.

Disadvantages :

Some anatomical landmarks including endocanthion (en), exocanthion (ex), alare (al), Subalare (sbal), cheilion (ch), labiale inferious (li), labiale superious (ls), midline and lateral (m-ls′) were relatively difficult to locate on the computer image compared with those points closely related to the underlying bone. Other landmarks can not be located because anatomical reference points are not visualised in the scanned image, e.g., opisthocranion, eurion and vertex.

Moss et al (1991) addressed the problem of asymmetry of the face by using the same apparatus utilised in the present study. The present results provide quantitative information about the distribution of facial measurements that enables to analyse normal physical variations of the face between both sexes and sides. In general, it is observed that mean values were larger in males than in females. However, a few exemptions were observed in the female group including orbito-tragion distance, eye fissure width, and width of the nostril floor. The male and female samples presented a very variable distribution of the larger mean values in respect to both right and left sides. For instance, paired horizontal measurements of the ear exhibited a variable distribution in the larger mean values in relation to both sexes and sides, while mean values of paired vertical measurements were larger on the left side of both males and females.

In mouth it was observed that for both males and females, the width of the half of the mouth had greater mean values on the right side, while lateral vertical upper lip height showed larger mean values on the left side. Another inconsistency was appreciated in nose measurements. The width of the nostril floor in the female sample showed mean value larger than the male group. It is necessary to point out that in the two samples studied, the possible variation in soft tissue thickness that are known to occur with age and body type (Rhine et al 1980), was not taken into account. It has to be observed that the two population groups were not selected for tissue thickness and that there was no pre-ordained matching, hence the average of age in the male group was different from the female. Although the greatest variations of tissue thickness in both skin and bone area more likely to occur before puberty (Farkas, 1987), the existent difference for age group in the population studied may contribute to the variability of the results to a certain extent.

The development of an accurate method to measure the morphological aspects of the face, could provide an objective way to study and support direct anthropometry investigations. Thus, using an optical laser scanning system to carry out classical anthropometric measurements of the face seems to have the potential to achieve the required accuracy. This method is based on a 3-D computer graphics system (Linney et al , 1993). This laser scanning system is a non-invasive technique, it does not provide any hazard for the patient and it can be completed in a short time (10 seconds). It has proved efficacy in others areas such as Plastic Surgery, Orthodontics, Forensic Medicine, and many others disciplines.

2. Computerised facial reconstruction using an optical surface laser scanner.

The scanning system was set up as described (Arridge et al., 1985), (Moss et al, 1987, 1988, 1989), Linney et al., 1993).(Appendix 9, Figures 86 A, B, C)) All sixteen plaster casts were scanned and recorded as previously described (Linney et al., 1993). (Appendix 9, Figure 87). For details of skulls see (Appendix 9 :Tables 12-13-14)

Scans were stored in a special directory with a specific file name.

Data Acquisition from the skull

The material used to mark the craniometric points was blue-tack®.

The facial reconstruction software uses a total of forty-four landmarks some of which are controlled automatically.

The landmarks selected for the program were the same as those used by Rhine et al. (1980, 1982) (Appendix 9, Table N° 15).

The landmarks used in the software were numbered from 1 to 58. The midline landmarks are from 1 to 10; anatomical right side from 11 to 24; anatomical left side from 31 to 44; others landmarks existing in the program are 53-54-55-56-57- and 58. Numbers 45 to 52 do not exist.

In this way from a total of 44 landmarks 41 were on the skull and the other 3 correspond to the neck. (Appendix 9, Figure 88).

Craniofacial landmarks.

The craniometric and cephalometric landmarks selected for the software are: Ten midline: supraglabella, glabella, nasion, end of nasal or nasale, mid-pilthrum, supradentale or phrostion, infradentale, point B or supramentale, pogonion, gnathion.

Fourteen paired landmarks (frontal eminence, supraorbital, orbitale, inferior malar, lateral orbits, zygion, supraglenoid, gonion, supra-M^2, oclusal line, infra-M^2, ectoconchion, alare, cheilion. (These aforementioned landmarks are cranio skeletal).

Craniometric and cephalometric points used (see Appendix 5)

The numerical facial reconstruction. (see Appendix 6)

3. Computerised Facial anthropometry of the fourteen reconstructed faces using the same system used for facial reconstruction in the frontal plane.

This study involves measurement of the face in the frontal plane in a sample of fourteen computerised three dimensional facial reconstructions from an initial sample of nineteen plaster casts. As explained earlier the three dimensional image generated from the profiles imput into the computer during the acquisition data, is similar to a mask or plaster cast which can be measured three dimensionally. Image measurements were obtained as described earlier.

Images were retrieved from the hard disk and the following procedure was applied:

1. Using the three dimensional computer system each image was rotated at different angles until facial asymmetry was obtained.

2. The Frankfort horizontal plane (Farkas, 1981, 1994) was set up on the screen in the lateral view before the corresponding frontal facial view was obtained so that all reconstructed faces were measured at a constant angle.

3. Classical anatomical landmarks (Farkas, 1981, 1994) were selected and positions located. In this study 8 midline landmarks were used: glabella (g), nasion (n), subnasale (sn), labiale superius (ls), stomion (sto), labiale inferius (li), infralabiale (sl), gnathion (gn) and 6 paired landmarks: exocanthion (ex), endocanthion (en), alare (al), cheilion (ch), zygion (zy), gonion (go). The system uses letter for to individualise the respective landmarks; thus the same landmarks selected were named respectively as follows [A, B, C, D, E, F, G, H, I (left), J (right); K (r), L (l); M (r), N (l); O (r), P (l); Q (r), R (l); S (r), T (l).] (Appendix 9, Figure 109)

4. The computer maintained the landmarks on the surface as the image was rotated.

5.The appropriate landmarks were selected and projective linear measurements values in mm were obtained.

6. Nineteen measurements were selected. Measurements chosen for the present study (Farkas, 1981, 1994) are shown in Appendix 9,Figure 110.

7. Thirty-three proportion indices were selected (Farkas and Munro, 1987) and calculated using the measurements obtained by the computer.

For the calculation a statistical software programe Minitab® was used.. The proportion indices selected are shown in Appendix 9, Figure 111.

8. Mean and standard deviation were calculated using Minitab®. The normal range was conventionally established between + and - SD.

9. Results were tabulated

The proportion indices were analysed following the classification mentioned above at item N° 7.

10. A comparative analysis of proportion indices produced by the nineteen measurements taken on the three dimensional reconstructed faces and photographs, is shown.

For this purpose t- confidence interval for the difference of two means and one-sample-T- test on unpaired data were applied. (Appendix 9, Table N° 27)

11. The level of confidence interval chosen was 95%. To perform one sample t test, the null hypothesis test value selected was P> 0.05.

12. The null hypothesis was that the proportion indices selected are not different when a comparison of them is performed among facial reconstructions by computing and the photographs.

13. Statistical method was achieved using Minitab software.

14. Interpretation of the results is also discussed.

Measurements selected in both two and three dimensional images (19): (Appendix 9, Figure 109)

Area Face (7)

I. SINGLE

A. HORIZONTAL

1. Width of the face (zy-zy) (M-1)

2. Width of the lower face (go-go) (M-2)

B. VERTICAL

3. Morphological height of the face (n-gn) (M-3)
4. Physiognomical height of the upper face (n-sto) (M-4)
5. Height of the lower face (sn-gn) (M-5)
6. Height of the lower third of the face or height of the mandible (sto-gn) (M-6)
7. Chin height (sl-gn) (M-13)

AREA ORBITS (3)

I. SINGLE

A. HORIZONTAL

8. Intercanthal width (en-en) (M-14)
9. Biocular width (ex-ex) (M-15)

II. PAIRED

A. HORIZONTAL

10. Eye fissure width (en-ex) (M-16). It was just measured left side due that the proportion index respective use only this measurement.

AREA LIPS AND MOUTH (7)

I. SINGLE

A. VERTICAL

11. Upper lip height (sn-sto) (M-8)

12. Lower lip height (sto-sl) (M-19)

13. Cutaneus upper lip height (sn-ls) (M-9)

14. Cutaneus lower lip height (li-sl) (M-12)

15. Upper vermilion height (ls-sto) (M-10)

16. Lower vermilion height (sto-li) (M-11)

B. HORIZONTAL

17. Mouth width (ch-ch) (M-17)

AREA NOSE (2)

I. SINGLE

A. VERTICAL

18) 1. Nose height (n-sn) (M-7)

B. HORIZONTAL

19) 1. Nose width (al-al) (M-18)

PROPORTION INDICES SELECTED in both two and three dimensional facial images. (33) (Appendix 9, Figure 111)

AREA FACE (11)

1. F-1 Facial Index

F-1:

$$\frac{\text{Face height (Nasion-Gnathion)} \times 100}{\text{Face width (Zigion-Zygion)}} \qquad \frac{\text{n-gn} \times 100}{\text{zy-zy}}$$

2. F-2 Mandible-Face width Index

F-2:

$$\frac{\text{Mandible width (Gonion-Gonion) x 100}}{\text{Face width (Zygion- Zygion)}} \qquad \frac{\text{go-go x 100}}{\text{zy-zy}}$$

3. F-3 Upper face Index

F-3:

$$\frac{\text{Upper face height (Nasion- Stomion) x 100}}{\text{Face width (Zygion- Zygion)}} \qquad \frac{\text{n-sto x 100}}{\text{zy-zy}}$$

4. F-4 Mandible width- Face Height Index

F-4:

$$\frac{\text{Mandible width (Gonion-Gonion) x 100}}{\text{Face height (Nasion- Gnathion)}} \qquad \frac{\text{go-go x 100}}{\text{n-gn}}$$

5. F-5 Mandibular Index

F-5:

$$\frac{\text{Mandible height (Stomion- Gnathion) x 100}}{\text{Mandible width (Gonion- Gonion)}} \qquad \frac{\text{sto-gn x 100}}{\text{go-go}}$$

6. F-9 Upper Face-Face Height Index

F-9:

$$\frac{\text{Upper face height (Nasion- Stomion) x 100}}{\text{Face height (Nasion- Gnathion)}} \qquad \frac{\text{n-sto x 100}}{\text{n-gn}}$$

7. F-10 Lower Face-Face Height Index

F-10:

$$\frac{\text{Lower face height (Subnasale-Gnathion) x 100}}{\text{Face height (Nasion- Gnathion)}} \qquad \frac{\text{sn-gn x 100}}{\text{n-gn}}$$

8. F-11 Mandible-Face Height Index

F-11:

Mandible height (Stomion-Gnathion) x100 / Face height (Nasion-Gnathion)	sto-gn x 100 / n-gn

9. F-12 Mandible-Upper Face Index

F-12:

Mandible height (Stomion- Gnathion) x100 / Upper face height (Nasion Stomion)	sto-gn x 100 / n-sto

10. F-13 Mandible-Lower Face Index

F-13:

Mandible height (Stomion-Gnathion) x 100 / Lower face height (Subnasale-Gnathion)	sto-gn x 100 / sn-gn

11. F-32 Upper Face Height--Biocular width Index

F-32:

Upper face height (Nasion- stomion) x 100 / Biocular width (Exocanthion-Exocanthion)	n-sto x 100 / ex-ex

AREA ORBITS (6)

12. O-1 Intercanthal Index

O-1:

$$\frac{\text{Intercanthal width (Endocanthion-Endocanthion)} \times 100}{\text{Biocular width (Exocanthion- exocanthion)}} \qquad \frac{\text{en-en} \times 100}{\text{ex-ex}}$$

13. O-3 Orbital width index

O-3:

$$\frac{\text{Eye fissure width (Exocanthion- endocanthion)left} \times 100}{\text{Intercanthal width (Endocanthion-Endocanthion)}} \qquad \frac{\text{ex-en l} \times 100}{\text{en-en}}$$

14. O-8 Biocular-Face width Index

O-8:

$$\frac{\text{Biocular width (Exocanthion- Exocanthion)} \times 100}{\text{Face width (Zygion-Zygion)}} \qquad \frac{\text{ex-ex} \times 100}{\text{zy-zy}}$$

15. O-9 Intercanthal Width- Upper Face Height I ndex

O-9:

$$\frac{\text{Intercanthal width (Endocanthion-Endocanthion)} \times 100}{\text{Upper Face Height (Nasion- Stomion)}} \qquad \frac{\text{en-en} \times 100}{\text{n-sto}}$$

16. O-10 Intercanthal-Nasal Width index

O-10:

$$\frac{\text{Intercanthal width (Endocanthion-Endocanthion)} \times 100}{\text{Nose width (Alare-Alare)}} \qquad \frac{\text{en-en} \times 100}{\text{al-al}}$$

17. O-12 Intercanthal-Mouth Width Index

O-12:

$$\frac{\text{Iintercanthal width (Endocanthion-Endocanthion)} \times 100}{\text{Mouth width (Cheilion-Cheilion)}} \qquad \frac{\text{en-en} \times 100}{\text{ch-ch}}$$

AREA LIPS AND MOUTH (10)

(Indices 18 to 26 and 33)

18. L-1 Upper Lip Height- Mouth Width Index

L-1:

Upper lip height (Subnasale-Stomion) x 100	sn-sto x 100
Mouth width (Cheilion- Cheilion)	ch-ch

19. L-5 Cutaneous-Total Lip Height Index

L-5:

Cutaneous upper lip height (Subnasale- Labiale Superior) x 100	sn-ls x 100
Upper lip height (Subnanale- Stomion)	sn-sto

20. L-6 Vermillion-Total Upper Lip Height Index

L-6:

Upper vermillion height (Labiale Superior-Stomion) x 100	ls-sto x 100
Upper lip height (Subnasale- Stomion)	sn-sto

21. L-7 Vermillion-Upper Lip Height Index

L-7:

Upper vermillion height (Labiale Superior- Stomion) x 100	ls-sto x 100
Cutaneous upper lip height (Subnasale- Labiale Superior)	sn-ls

22. L-9 Vermillion Height Index

L-9:

Upper vermillion height (Labiale Superior- Stomion) x 100	ls-sto x 100
Lower vermillion height (Stomion-Labiale Inferior)	sto-li

23. L-10 Mouth- Face Width Index

L-10:

Mouth width (Cheilion-Cheilion) x 100	ch-ch x 100
Face width (Zygion- Zygion)	zy-zy

24. L-11 Upper Lip- Upper Face Height index

L-11:

Upper lip height (Subnasale- stomion) x 100	sn-sto x 100
Upper faec height (Nasion- stomion)	n-sto

25. L-12. Upper Lip- Mandible Height Index

L-12:

Upper lip height (Subnasale -Stomion) x 100	sn-sto x 100
Mandible Height (Stomion- Gnathion)	sto-gn

26. L-14 Upper Lip- Nose Height Index

L-14:

Upper lip height (Subnasale- Stomion) x100	sn-sto x 100
Nose Height (Nasion- Subnasale)	n-sn

AREA NOSE (7)

27. N-1 Nasal Index

N-1:

Nose width (Alare-Alare) x 100	al-al x 100
Nose height (Nasion-Subnasale)	n-sn

28. N-24 Nose- Face Width Index

N-24:

Nose width (Alare-Alare) x 100	al-al x 100
Face width (Zygion-Zygion)	zy-zy

29. N-25 Nose Height- Face Width Index

N-25:

Nose height (Nasion- Subnasale) x 100	n-sn x 100
Face width (Zygion-Zygion)	zy-zy

30. N-26 Nose-Face Height Index

N-26:

Nose height (Nasion-Subnasale) x 100	n-sn x 100
Face height (Nasion- Gnathion)	n-gn

31. N-27 Nose- Upper Face Height Index

N-27:

Nose height (Nasion-Subnasale) x100	n-sn x 100
Upper face height (Nasion-Stomion)	n-sto

32. N-28 Nose- Face Height Index

N-28:

Nose height (Nasion- Subnasale) x100	n-sn x 100
Lower face height (Subnasale-Gnathion)	sn-gn

Area: Lips and mouth:

33. AL-3 Lower-Upper lip height Index
AL-3:

Lower lip height (Stomion-sublabiale) x 100	sto-sl x 100
Upper lip height (Subnasale-Stomion)	sn-sto

4. Photogrammetry of the face or indirect facial anthropometry from fourteen missing persons' photographs.

This study involved indirect measurements of the face in the frontal plane from a sample of fourteen missing persons' photographs. The size of prints was 24 x 18 cm. Measurements were obtained using a slider calliper similar to that described by Farkas (1994).

The procedure applied was the same as three dimensional facial reconstruction, applicable to two dimensional images. The photographic prints were not altered. All the landmarks selected were marked over a transparency, using a technical pen "Staedtler Marsmatic 700"®, number 0.2.

Due to the quality of the photographs some rules regarding inclusion or exclusion of measurements were applied:

a) Horizontal measurements were not taken if the face showed some deflexion (from the midline frontal view).

b) If the anatomical area was not clear for any reason, such as rotation of the face, distortion of the facial proportion or fuzzy images, landmarks which could not be adequately visualised were not selected for measurement in the photograph.

c) If there were any doubts regarding the landmark selection due to bad quality of photographic material, the measurement was not taken. Thus the number of measurements sampled in some photographs where the quality was bad is lower than in the better photographs and indeed lower than in the reconstruction.

Cephalometric landmarks were marked according to classical anatomical definition and taking into account the latest research in this field carried out by Farkas (1994).

The landmarks were not placed directly on the photograph's surface. A transparency over the photograph was used where outlines of the face were traced together with the main features used to determine deflection and pitch angles of the image. In other words the procedure applied was similar to that which is applied in superimposition techniques in order to match the corresponding homologous bony landmarks.

Once the above procedure was applied, the landmarks were marked in the transparency and the respective measurements taken.(Appendix 1).

Most of the landmarks selected for this study were clearly defined in both two and three dimensional images.

Two factors were taking into account in the selection of the points, such as the position of the subjects in the photographs; most of them showed a frontal view, and the quality of the photographs.

The criteria for selection of linear or projective measurements took into account the latest studies in photogrammetry of the face performed by Farkas (1987) (1994) and Iscan (1993). Frontal view prints, according to Farkas, supply the most precise measurements of orbits, lips and mouth.

Assessment of the reliability of the indirect measurements obtained by photogrammetry has been limited because of differing methods of evaluation and analysis of the sample. The latest studies in photogrammetry performed by Farkas (1994) using his method, involved a large number of direct facial measurements. Thus he was prompted to determine how many of these measurements could also be reliably obtained from photographs.

The study involved 36 young North American Caucasian (18 males and 18 females). His study was described as follows:

Standard landmarks were placed over the face using small ink dot. Before photographing, 100 measurements were taken from the head, face, and ears of the subjects. Then he took standard frontal and lateral black and white photographs. Life size photographs were printed, and a second set of 60 measurements was taken from them. The two sets of measurements were later compared to test the validity of the second set of indirect measurements.

Then each measurement obtained from the prints was compared to the corresponding direct measurements, and the difference was registered. The differences in all 18 subjects of each sex were averaged.

A measurement was regarded as reliable only if the average difference between the indirect and direct measurement was not greater than 1 mm; otherwise it was considered inaccurate.

Inaccurate measurements were consistently longer or consistently shorter than the corresponding direct measurements, or a combination of two depending of the subjects. With respect to the accuracy of indirect measurements from the prints, he found that 20 out 60 measurements were reliable, and seven of these were from the area of the lips and mouth. (Appendix 9, Table N° 16B) Forty measurements were unreliable; three of them were consistently longer and 22 consistently shorter, the remaining measurements were mixed. The measurements that were consistently longer were: the width of the face (zy-zy), the width of the nose (al-al), and width of the lower face (go-go).

Eleven shorter and fifteen mixed measurements from the prints can be seen in Tables N° 16C and D. His comparative results analysis of direct and indirect measurements can be seen in Appendix 9, Table N° 16 A

5. Comparison of proportion indices selected between three-dimensional reconstructed faces with two-dimensional missing persons' photographs.

Index values obtained from a representative number selected of similar subjects such as age, sex, ethnic origin, provide the data for calculating the mean index value.

Statistical Analysis:

The mean index value represents the average proportion between the related measurements. An Individual's proportion indices may differ even in the most homogenous sample, which is the clue to individuality.

Standard deviation (SD) quantifies the normal differences between the index values of the members of the samples within the level of the factor being investigated. It determines the width of the normal range of the index, from 2SD below to 2SD above the mean.

All indices in the normal range are regarded as variations of normal proportions. For example a small SD in combination with a large mean indicates high homogeneity, whereas a large SD suggests large differences within the range. The face is considered as proportionate if the indices are in the normal range (mean ± 2SD).

The standard error is a measure of the uncertainty in a sample statistic. The sample statistic is imprecise, and the standard error (SE) is a measure of this imprecision.

Confidence intervals. The main purpose of confidence intervals is to indicate the (im) precision of the sample study estimated as a population value. Confidence intervals present a range of values on the basis of the sample data, in which the population value for such a difference may lie. Confidence intervals for means are constructed using the t distribution if the data has an approximately normal distribution. A confidence interval indicates the precision of the sample means or the difference between two samples means as an estimate of the overall population value.

It is desirable to calculate the confidence interval around such estimate. In the present study 95% confidence interval was chosen.

This is the range of values that it includes the true value. Therefore there is a close relation between the results of a test of a hypothesis and the associated confidence interval: if the difference between proportion indices is significant at the 5% level then the associated 95% confidence interval excludes the zero difference as will be showed in results of this study.

The confidence interval conveys more information because it indicates a range of values for the true effect which is compatible with the sample observations. It reveals the precision of an estimate.

Hypothesis test. A hypothesis test assesses, by means of the probability P, the plausibility of the observed data when some "null hypothesis" is true. The P value is the probability that the observed data, or more extreme outcome, would have occurred by chance, that is just due to sampling variation when the null hypothesis is true. If P is small the researcher must have doubts about the null hypothesis. If P is large the data is consistent with the null hypothesis, which thus cannot be rejected. The 0.05 level is a convenient cut off point as it was selected for this study when one sample t test was performed. A non-significant result, conventionally $P > 0.05$ does not mean that there is no effect but only that the data is compatible with there being no effect.

RESULTS

Results are shown in tables 18I to 34 (see Appendix 9)

Table 18: Nineteen computerised facial measurements in a sample of fourteen three dimensional facial reconstructions by computing.

Table 19: Nineteen Indirect facial measurements in a sample of fourteen photographs.

Table 20: Mean and standard deviation (SD) of nineteen facial measurements in a sample of fourteen facial reconstructions.

Table 21: Mean and standard deviation (SD) of nineteen facial measurements in a sample of fourteen photographs.

Table 22 : Mean and standard deviation (SD) of thirty-three proportion indices in a sample of fourteen facial reconstructions by computing.

Table 23 : Mean and standard deviation (SD) of thirty-three proportion indices in a sample of fourteen photographs.

Table 24 : Mean, standard deviation, standard error mean and 95% confidence interval of thirty-three proportion indices in a sample of fourteen facial reconstructions.

Table 25 : Mean, standard deviation, standard error mean and 95% confidence interval of thirty-three proportion indices in a sample of fourteen photographs.

Table 26 : Comparison of mean and standard deviation of thirty-three proportion indices of facial reconstruction with photographs, using P value and T test.

According to these results fifteen out of thirty-three proportion indices were significant at the 5% level, because the 95% confidence interval excluded the zero difference. These indices were: F-10, F-13, O-1, O-8, L-6, L-9,

L-11, L-12, L-14, N-1, N-25, N-26, N-27, N-28 and AL-3.

The explanations for such results are consistent with the accuracy of the measurements involved in their calculations.

The differences between facial reconstruction and photographs lay mainly in the two dimensional nature of prints, where landmarks cannot easily be placed or definitely cannot be marked, due to the sources of error mentioned above.

Table 27 : Mean and the 95% Confidence intervals for the difference of mean of thirty-three proportion indices.

Table 28 : Comparison of mean and standard deviation of thirty-three proportion indices of facial reconstruction with photographs according to P value.

The results of the present study were compatible and consistent with those measurements which cannot be taken from photographs, and would account for the reason why fifteen of the thirty-three proportion indices showed significant statistical differences when a comparison was carried out between proportion indices of facial reconstruction and photographs, and applying the one sample t test to show the difference between means. (Tables 26 and 28)

With regard to those measurements which could not be taken from photographs, the sample had, in the majority of the cases the same pattern as that found by Farkas, showing proportion indices with statistical significant differences illustrated by a P value lower than 0.05, which was the null hypothesis test value selected with the associated confidence intervals which excluded the zero difference.

In other words both statistical methods were complementary and did not show incompatibility with regard to statistical significant differences. (Tables 26, 27 and 28)

Individual proportion indices of facial reconstruction with photographs according to P value in the sample studied.

Table 29-1 to 29-4 : P value greater than 0.05

29-1: P Value > 0.05

29-2: 0.5 > P > 0.2

29-3: 0.2 > P > 0.1

29-4: 0.1 > P > 0.05

Table 30-5 to 30-10 : P value lower than 0.05

Table 31 : Comparison of mean of thirty-three proportion indices selected from other studies with the present study. The mean of proportion indices from facial reconstructions and photographs were within normal range, as

can see in Appendix 9, Table 31, except for those where measurements involved may provide some source of error when the indices were calculated, i.e., F-2, F-4, F-5, F-11, F-13, F-32, O-1, O-3, O-8, O-12, L-1, L-5, L-6, L-7, L-9, L-11, L-12, L-14, N-1, N-26, N-27, N-28, AL-3.

The proportion indices which are indicators of the proportionality of the major features of the craniofacial complex, including the face, are (F-1, F-3, F-5, O-1, O-3, N-1, L-1, L-10 and AL-3. Results from the present study showed that 3 out 5 mean proportion indices were found within the normal range of proportionality and the others were out of this range because of the measurements involved in their calculation. These indices corresponded to the measurements which could not be taken from the prints or could not be obtained with accuracy with the system, for the reasons previously discussed.

Using other applications of the laser scanner system, called the average face program, it was obtained the average face for a specific range of age in both sexes. The average face involved the registration and scaling of a set of faces and the resampling of the facial surfaces onto a coordinate grid, where the coordinates of corresponding landmarks may be averaged.

Landmarks selected for an average face were :

Frontal view : metopion, glabella, nasion, nasal midline (midnasal point), subnasale, labiale superious, stomion, labiale inferious, pogonion, gnathion, superciliare (r, l), frontosupraorbitale (r, l), exocanthion (r, l), orbitale (r, l), zygomatic maxillar junction (r, l), alare (r, l), cheilion (r, l)

Lateral view left- right : zygion, porion, gonion

For the present study, in order to show the reliability of measurements using an optical surface laser scanner system, an average face from our data bank was selected and measured. The average face was of the same age range, race and sex to the data used in the present investigation.The proportion indices obtained from the measurements taken from an average face is shown . The pattern shown by the results of the average face has the same results as those of the present study, the 1993 study and Farkas′s studies.

Table 32 : Comparison of mean of measurements involved in the calculation of thirty-three proportion indices from other studies with the present study.

The pattern shown by the results of the present study together with the 1993 study have almost the same as that of Farkas's studies (1994).

The comparison performed between facial reconstruction by computing and photographs, using computerized facial anthropometry for facial reconstruction and photogrammetry, has not been unsuccessful. Despite all the negative factors which could affect the accuracy of the study, its results were compatible and consistent with the data used, showing a pattern similar to other studies in this field.

The present study and the 1993 study through its results, showed the reliability of assessing facial anthropometry using the optical surface scanner system. Results were comparable with those obtained in studies using direct facial anthropometry.

Table 33 : Summary of the distribution of thirty-three proportion indices selected according to P value.

The null hypothesis for the present study was that "the facial proportion indices of the presumed identity are not significantly different when a comparison of these indices is made between those derived from the facial reconstructions with those derived from the photographs." For this purpose one sample t test was applied and the null hypothesis test value assigned was 0.05. According to the results, which the reader can appreciate in tables 26, 28 and 34, fifteen out of thirty-three proportion indices selected showed a p value lower than 0.05.

It means those indices that represent 45.45% of the proportion indices selected showed statistically significant differences at the 5% level. This result was strongly confirmed with the associated 95% confidence interval shown in Appendix 9, Table 27. This confirmed that there was a close relation between the results of a test of a hypothesis and the associated confidence interval. Thus, with those small P values, the null hypothesis was rejected for those indices.

On other hand the study also showed eighteen proportion indices which represent 54.54% of the total of proportion indices selected with a P value greater than 0.05. These indices supported the null hypothesis. In other words there were eighteen proportion indices which did not show statistical significant differences between computerized facial

DISCUSSION

According to Farkas study (1994) there are some sources of error in photogrammetry such as measurements from bony landmarks, i.e., zy-zy, go-go, go-gn. When these landmarks are taken in living individuals the instrument used pressed the bony surface, thus if the anatomical points were left unmarked in the skin before taking the photograph such as is the present situation the errors might be greater. An other source of error is the difficulty in identifying some landmarks located on the edges or contours of anatomical features.

Some of these landmarks cannot be placed, i.e., inner or outer commisure of the eye fissure and the mouth (en, ex, ch), the most lateral point of the alae (al). These points are not always seen clearly because the anatomical feature where the landmark is located is not sharp enough on the print as a result of different intensities of reflection in various parts of the face. On the frontal print the exocanthion cannot be seen clearly in all people. In some people, the edge of the upper lid overlaps the lateral commissure of the eye fissure. Another source of error is introduced by photographic distortion. Farkas found that the greatest distortion was observed when measuring the distance between the base of columella (subnasale) and the tip of the nose (pronasale); this distance was 46% shorter on the print than on the direct measurement because of the great level difference between the two points.

On the other hand the measurement between nasion and stomion proved to be accurate because of the similar relationship of the two points to the focusing plane.

In the present study due to the nature of two dimensional prints the most difficult points to be marked were nasion (n), gnathion (gn), sublabiale (sl), where the curvatures or contours presented sources of error.

Adding to the difficulties inherent in this kind of research were the poor quality of photographs provided. These factors played an important role in affecting the accuracy of measurements taken and proportion indices calculated from them. However, results of the present study, despite all the difficulties reported, and the 1993 study showed the same pattern and sources of errors reported by Farkas. (Appendix 9, Table 31)

The differences found may also be explained on the basis of variation of soft tissue thickness and to some extent on bone thickness in different age groups.

Computerized facial anthropometry has also disadvantages with respect to direct anthropometry, but even these results are better than two dimensional prints and can be considered closer in accuracy than photogrammetry, as it was reported in the 1993 study.

The disadvantages of computerized anthropometry are: difficulty in locating the endocanthion and exocanthion on the computer generated image, especially so, with the image eyes are closed. These points are much more difficult to mark compared to points closely related to underlying bone. Furthermore these landmarks have also been considered as unusable for accurate measurements because they cannot be taken from the prints. Other anatomical landmarks such as cheilion (ch), labiale superius (ls), labiale inferius (li), alare (al) were relatively difficult to locate on the computer image compared with those points closely related to the underlying bone as it was reported in the 1993 study. However, when results from facial reconstruction were compared with those reported from other studies (Appendix 9, Table 31) the differences were consistent with the sources of error provided by the difficulty in locating the referred landmarks, except proportion index O-10 where the landmarks involved in their calculation are controlled automatically by the facial reconstruction program. Landmarks such as endocanthion and alare were not selected for the facial reconstruction program; thus they may be considered as non modifiable measurements from the data provided for the respective skull.

Another landmark which is difficult to place in three dimensional generated images is the gnathion, which could be the reason why proportion indices which have this landmark included, showed differences when they were compared with their homologous image from other studies, although these differences were not highly significant. Due to the difficulty in locating this point and taking into account the differences found between the means when the indices included it, such a landmark should be considered as unusable when measured from three dimensional generated images. In other words this landmark showed the same pattern when taken from prints.

The accuracy of landmarks can also be affected if the operator is not experienced in the use of the scanner system. Special skills are necessary to achieve this work under accepted standards of quality, as a solid acknowledgement of facial anthropometry. A professional training is also desired for locating the landmarks in the right position over both the face or skull, according to classical definition. In my opinion, after this investigation I insist that landmarks must be placed over the surface in investigation, before the laser scan is taken for two reasons ; to obtain better results and it is crucial for obtaining more accurate measurements even on a living person or skull.

The mean and standard deviation (SD) of thirty-three proportion indices selected for facial reconstruction and photographs can be see in Appendix 9, Tables 22 and 23 respectively.

The difference and the 95% confidence interval between the sample means of thirty-three facial proportion indices in facial reconstruction by computing, and photographs is shown in Appendix 9, Table 27.

T test statistic and associated P value is shown in Appendix 9, Table 26

According to these results fifteen out of thirty-three proportion indices were significant at the 5% level, because the 95% confidence interval excluded the zero difference. These indices were: F-10, F-13, O-1, O-8, L-6, L-9,

L-11, L-12, L-14, N-1, N-25, N-26, N-27, N-28 and AL-3.

The explanations for such results are consistent with the accuracy of the measurements involved in their calculations.

The differences between facial reconstruction and photographs lay mainly in the two dimensional nature of prints, where landmarks cannot easily be placed or definitely cannot be marked, due to the sources of error mentioned above.

Furthermore, the latest research carried out by Farkas (1994), shows that there are some measurements which cannot be taken from photographs, although others are usable from them (Appendix 9 : Tables 16 A, B, C and D). The results of the present study were compatible and consistent with those measurements which cannot be taken from photographs, and would account for the reason why sixteen of the thirty-three proportion indices showed significant statistical differences when a comparison was carried out between proportion indices of facial reconstruction and photographs, and applying the one sample t test to show the difference between means. (Tables 26 and 28)

The proportion indices which are indicators of the proportionality of the major features of the craniofacial complex, including the face, are (F-1, F-3, F-5, O-1, O-3, N-1, L-1, L-10 and AL-3. Results from the present study showed that 3 out 5 mean proportion indices were found within the normal range of proportionality and the others were out of this range because of the measurements involved in their calculation. These indices corresponded to the measurements which could not be taken from the prints or could not be obtained with accuracy with the system, for the reasons previously discussed.

With regard to those measurements which could not be taken from photographs, the sample had, in the majority of the cases the same pattern as that found by Farkas, showing proportion indices with statistical significant differences illustrated by a P value lower than 0.05, which was the null hypothesis test value selected with the associated confidence intervals which excluded the zero difference.

In other words both statistical methods were complementary and did not show incompatibility with regard to statistical significant differences. Appendix 9 : (Tables 26, 27, and 28)

The null hypothesis for the present study was that "the facial proportion indices of the presumed identity are not significantly different when a comparison of these indices is made between those derived from the facial reconstructions with those derived from the photographs." For this purpose one sample t test was applied and the null hypothesis test value assigned was 0.05. According to the results, which the reader can appreciate in tables 26, 28 and 34, fifteen out of thirty-three proportion indices selected showed a p value lower than 0.05.

It means those indices that represent 45.45% of the proportion indices selected showed statistically significant differences at the 5% level. This result was strongly confirmed with the associated 95% confidence interval shown in Appendix 9, Table 27. This confirmed that there was a close relation between the results of a test of a hypothesis and the associated confidence interval. Thus, with those small P values, the null hypothesis was rejected for those indices.

The explanation for the rejection of these proportion indices was explained in the discussion of confidence intervals.

On other hand the study also showed seventeen proportion indices which represent 54.54% of the total of proportion indices selected with a P value greater than 0.05. These indices supported the null hypothesis. In other words there were seventeen proportion indices which did not show statistical significant differences between computerized facial anthropometry performed in three dimensional facial reconstruction and photogrammetry when the indices were constructed from measurements which come from a presumed identity. With regard to these results it is also important to comment on another interesting finding.

The present study also showed some indices that should have shown a P value lower than 0.05 because of the measurements involved in their calculation.

They might have been considered unsuitable for considering them as inaccurate because of those measurements which could provide sources of error in the production of those indices. However, in spite of this prediction according to the literature those indices showed a p value greater than 0.05. These indices were: L-10, N-24, F-1, F-11, F-5, F-4, F-2, O-12, O-3. Appendix 9 : (See tables 26, 28, and 33)

Although the proportion indices discussed above showed a P value greater than 0.05, it is also important to note that the P values for five of them were in the range $0.2 > P > 0.05$.

In other words they were not statistically different and they did not reject the null hypothesis; the data was compatible with the null hypothesis. However, five of these proportion indices did not show a high p value, but they were above the test hypothesis test value selected.

The interpretation for these findings could be explained on the basis of the measurements involved, which have been considered as sources of error for the reasons just discussed.

It could be the reason why five of the proportion indices classified as unusable due to the measurements involved, did paradoxically not show a high P value. However the pattern shown by the results of the present study together with the 1993 study have almost the same as that of Farkas's studies (1994).

The present study and the 1993 study through its results, showed the reliability of assessing facial anthropometry using the optical surface scanner system. (Appendix 9, Table 32). Results provided clear information about proportion and disproportion as it was discussed in the 1993 study.

There were a few proportion indices, i.e., F-2, L-10, and N-24 which showed a good correlation between measurements taken from facial reconstruction and photographs, in spite of the measurements involved in the calculation of those indices, which should have been considered unusable according to Farkas' study. However those indices cited, had theoretically contradictory results. (Tables 26, 28 and 33)

These results could be better explained by another study by Fraser and Pashayan and cited by Farkas, in which these measurements showed a good correlation, as can see in Appendix 9, table 17.

From the literature and information provided for the present study the method of photoanthropometry that has been used with slight modifications to its classical definition, to compare facial proportion indices of three dimensional facial reconstruction on casts of skulls with photographs of the presumed identity. This has been carried out to check the techniques reliability, and has shown the same pattern as described in the literature.

According to Catterick's method (1992) the result's of photoanthropometry were significantly poorer if the photographs were taken at different camera angles.

According to Iscan (1993) the main value of this technique is to narrow the range of possible matches.

According to Farkas although standard photographs help to visualize the areas of marked change in a patient's face; they cannot be considered adequate substitutes for the living face. Significant improvements must be made in the field of photogrammetry for it to be considered as being of the same standard as direct facial anthropometry. To produce the best results, obviously the subject must be photographed with the landmarks marked on the skin and in the same standardized position of the head from the front and the side utilizing the standard plane, known as the Frankfurt horizontal, for ensuring uniformity.

The value of photogrammetry can be greatly enhanced by developing new techniques for identification of all the important landmarks and by the introduction of additional special views of the face and head in order to improve the technique when it is used for identification purposes.

Farkas proposed to study those indirect measurements which consistently revealed small differences from corresponding direct measurements in large population samples in order to calculate "correction factors" for each measurement which would then convert them into acceptable values.

The current status of this technique has shown the potential to lead to a definitive decision with regard to identity or a match. However in most cases the results would be undetermined depending on the quality of material used. This technique and others used in photo comparison cannot stand by themselves as evidence to convict or exonerate a suspect, or in the facial identification process to be proof of a positive identification.

The technique applied in the present study showed almost the same pattern of that of Farkas's studies. The comparison performed between facial reconstruction by computing and photographs, using computerized facial anthropometry for facial reconstruction and photogrammetry, has not been unsuccessful. Despite all the negative factors which could affect the accuracy of the study, its results were compatible and consistent with the data used, showing a pattern similar to other studies in this field. Results from the present study also were supported by the statistical methods applied.

The other important observation from this study was the application of computerized facial anthropometry using the optical scanner system. Results provided clear information about proportion and disproportion.

This enables analysis of relationships between facial proportion as well as the ability to discriminate between measurements.

To determine the correct anatomical points on the surface of the computerized image it is essential that the operator is experienced in the use of the scanning apparatus. All the landmarks were located by computer according to their classical anatomical definition but some midline landmarks such as nasion, subnasale and gnathion which furthermore are midline indicators were located and set up in the lateral plane before rotating the image to the frontal plane. The visualization of the data from the optical scanner via computer graphics allows the operator to manipulate the scanned image at different angles, achieving symmetry amongst other manoeuvres. This is necessary in order to achieve a reliable computational framework, and this in turn is a prerequisite for setting the Frankfurt horizontal plane in order to standardize measurements. The Frankfurt horizontal plane was used as a standard reference for anthropometry and the plane was set up on the screen upon recognition of the appropriate bony anatomical landmarks. This plane showed a horizontal line between the orbitale and the porion and this is at variance with the findings of others authors that have used non computerised anthropometric techniques (Stengel-Rutkowsky, 1985). Symmetry and therefore consistent orientations in all facial images were obtained. It was also observed that the Frankfurt Horizontal plane was useful tool to correct the changes in the "natural head position". Movements of the subject's head can occur due to the rotation of the chair and there is not a reference points on the horizon during the darkness. Setting the plane correctly will obviate these variables. In this way a consistent orientation of the face in all the images visualised was obtained.

Taking into account all the observations previously discussed, computing facial anthropometry is reliable in a very accurate way, even though the capture of the skull data is taken in a different day or under different angulations due to the fact the operator can manipulate the computer image in all the angles required. The Frankfurt plane must set on the screen before any study of anthropometry can to be done, so any measurement is measured at a constant angle and its results must be reproducible and validated subsequently by repeated measurements at a later date, as it was discussed in the 1993 study.

There are advantages and disadvantages of the present method when compared with direct facial anthropometry.

The advantages are:

1. Rapidity of execution
2. Friendly user once basic training has been given
3. Objectivity of measurements
4. Does not require subject manipulation
5. Measurements can be made with accuracy

The disadvantages are:

1. Difficulty in locating some landmarks such as endocanthion or exocanthion and gnathion on the computer generated image. These points are much more difficult to locate as compared to points closely related to underlying bone.
2. Other landmarks cannot be located because anatomical reference points are not visualised in the scanned image, (i.e., vertex) because the laser scanner does not take data from the poles.

The study through its results, showed the reliability of assessing facial anthropometry using the optical surface scanner system. Results were comparable with those obtained in studies using direct facial anthropometry.

The preceding sections have demonstrated the role and current status of facial reconstruction techniques in personal identification for forensic applications. According to the literature the techniques have a long way before to go they could be accepted as definitive methods for identification by themselves.

However, in spite of this current status, facial reconstruction techniques have been successful in obtaining personal identification in forensic cases. According to Caldwell (1981), when the face is totally unknown, the three dimensional facial reconstruction is the preferred technique, but both this one and the two dimensional facial reconstruction have approximately only a 50% success rate at developing leads to personal identification.

The aim of the present study was to evaluate the computer aided facial reconstruction using an optical surface laser scanner as a method of valid identification.

The investigation once all the facial reconstructions which were included in the study were carried out did not focus only on the visual perception of the resemblance between the reconstructed faces and the missing person photographs. The study fundamentally was based on classical facial anthropometry using proportion indices as an objective method of comparison of three dimensional facial reconstruction by computing with indirect facial anthropometry from the photographs of the missing person in question.

When facial reconstruction images were compared with a photograph of the missing person in question, morphological similarities were noted and in some there was a close resemblance.(See appendix 4)

Important morphological similarities which were found in this study included the fundamental facial shape, chin shape and a closer relationship between features and underlying bone, principally where the skin was close the skull; in these areas such as the glabella, supraorbital margin, zygomatic bone, and mental protuberance the resemblance was reasonably good but in regions where the facial appearance does not directly depend upon the shape of the skull, such as the eyes, nose, ears and lips the reconstructed face resembled the face of the average male from the computer databank used during the process of reconstruction. The resulting reconstructed face in all cases showed a very closer resemblance to the expected facial shape of the owner of the skull. (See Appendices 3 and 4)

Considering that is the first time that the optical surface laser scanner system has been tested using original cases, it would appear that it has both fulfilled some expectations whilst illustrating some of its limitations. The advantage of the computer method is its speed and flexibility. Although the finished facial reconstruction does not look very human, it does convey the fundamental facial shape. It is possible to add features to this final image in order to make it more life-like, but it is important to realise that these features must conserve and respect the updated facial reconstruction guidelines and take into account the relationship between features and underlying bone of the owner of the skull. If these added features are unlike those of the original subject, they may produce a facial image that is less recognisable than the generated reconstructed face. It is therefore essential to ascertain as much information as possible with regard to the general identification of the individual, and all the premortem information such as ethnic group type, body build, age, sex in order to produce recognisable face. The facial form generated by this technique is not likely to be sufficiently detailed on its own to permit positive identification. If the viewer does not have some experience examining in computer generated images the comparison appears very difficult to carry out.

One of the major problems for the individual inexperienced with such images is the appearance of the reconstructed face itself, because each generated face is shown with its eyes closed, and has no hair. The image resembles a mask with no a real or living appearance.

Should researchers in this field wish to design a study to investigate further the reliability of this method based on results from morphological comparisons, the participants in such an experiment must be familiarised with such computer images. A clear understanding of facial morphology is necessary before any attempt to evaluate the system is attempted.

The reason for this is to ensure that a credible assessment and evaluation of the technique is made.

Another important factor in the accurate evaluation of the system is the need for good quality with no distortion of the facial anatomy with which to made morphological comparisons. The finished image should ideally be a modified skin colour not the present unnatural yellow but like normal skin colour appropriate to the facial type, to enable recognition to be made by the viewer. The change of skin colour of the computerized image can be facilitated by using another program in the same system used, as seen in all the figures illustrating the finished reconstructed face. (Appendices 3 and 4)

There are problems with the method, most notable are the relationship between the details of the facial features such as the nose (tip of the nose), eyes, lips (shape) and ears. Adjustment to all these features, including the eyebrows and possibly the hair colour, is necessary to produce a recognisable face. Methods using interactive computer graphic techniques are at present being developed and they will allow the merging in three dimensions of a library of key facial features with the basic facial form, in a realistic manner as determined by skull shape and facial type.

The study has shown that computerized facial reconstruction is feasible for generating faces from skulls, in this case from plaster casts of the original skulls.

The method allows for the generation of a range of possible faces (fat, thin, medium) according to soft tissue data to increase the chances of identification. Another advantage is that subjective characteristics associated with a unique facial reconstruction by sculpting will also be avoided. The subjectivity of choosing facial features from the library it is also less, because the software allows to generate a face according and related to bony landmarks of the subject in study.

The method has not only demonstrated its feasibility by showing that one can show a close resemblance between the finished facial reconstructions and photographs of missing persons, but it has also shown, through the application of facial anthropometry, that 54.54% of the proportion indices selected did not show a statistically significant difference between three dimensional computer generated facial reconstructions and photographs. The other indices which showed a statistically significant difference and corresponded to 45.45% of the total indices, showed the same pattern reported in the literature, with regard to the measurements that could not be taken from the prints, these were the main sources of error and inaccuracy in the final results.

The lines of action for improvement of the system suggested by the results of the present study include the following:

For the computer to produce a satisfactory image, facial soft tissue thickness data needs to be taken from a greater number of anatomical points, ethnic racial groups, sex, age and body build. According to the latest updated information the best soft tissue thickness data comes from living individuals obtained by The Russian and German researchers using ultrasound. The new data without doubt would contribute to produce better and more accurate three dimensional facial reconstruction either by sculpting or by computer.

From the preceding chapters the reader has known the crucial and relevant role of the new soft tissue thickness data obtained by ultrasound, its contribution to produce better and more accurate three-dimensional facial reconstruction when these data are applied. Succesful results using the new data have been illustrated by no great number of cases, but its application could be controversial because of its present experimental stage. The present study used tested and accepted soft tissue thickness tables because the current software uses forty-four facial tissue measurements according to the method of Rhine et al., (1980, 1982). These first results of three dimensional facial reconstruction by computing using known parameters are a preliminary effort to show with standard methods how effective or not this novel technique is.

The computer-generated three dimensional facial reconstruction in common with other facial reconstruction techniques, can never produce a 100% accurate image. The reason for this is that there are too many variables in the details of the face. Whether artistic or computerised means are used for three dimensional facial reconstruction, the accurate assessment of the nose, eyes, lips and ears other features which most often cannot be ascertained from the anatomy of the skull, are equally or even more important than other features, such as hair style and colour, eyebrows, facial expression, variation in skin colour. In this respect the artist skills would be essential to add the final "touch" necessary to "humanise" the face. For computerised images it is possible to add such features using interactive computer graphics. Thus those features which have been studied and reported as fundamental for the recognition process, could be scaled and transferred to their corresponding position on the face, but the operator must realise that if these features are unlike those of the original individual, they may produce a reconstructed image that is less recognisable than the original "untouched" reconstruction. At the present time a number of techniques for adding facial features are being investigated and developed which would enable the use of a library of facial features in a practical way, as determined by skull shape and facial type.

From a practical point of view and for a more accurate reconstruction it is essential that the landmarks be physically placed on the skull and correspond in numbers to the scheme of the software, before the laser scan is made. This will give the operator a better chance of seeing all the points on the screen. Another suggestion would be to retain the original skull for reference during the process.

The new method therefore requires the expertise of and input from, many others disciplines such as forensic engineering, forensic science, medical computing, forensic odontology, plastic surgery, forensic anthropology, and art, to achieve a feasible solution within the limitation of the system.

The new method also requires further investigation and evaluation using both known control and unknown remains for consolidating its status as a new tool for facial identification in the forensic field.

In summary this study has assessed the reliability of another method of facial reconstruction that by itself, has some limitations but has nevertheless produced good likenesses between some of the finished reconstructed faces and the photographs of missing persons. Further, the similarities were supported by comparative facial anthropometry.

Although an enormous amount of work remains to be done, the time and effort invested in this crusade without doubt is worthwhile, especially if future research will improve the success of the technique as a tool for personal identification in forensic cases. The computer generated facial reconstruction technique has proved its usefulness in achieving personal identification, but not by itself, because the facial form generated by the technique is not likely to be sufficiently detailed on its own to permit positive identification. However, combining this technique with other current techniques available for identification makes it a powerful tool for helping to achieve its goal; namely the recognition and personal identity of the deceased.

I would like to finish with the following observations:

"The reconstruction from the skull of the head is a branch of science, which has of recent years made some progress, but while the facial expression does to some extent depend on the form of the skull, and the strength of the musculature which can be partially judged from the skull markings, we are left wholly in the dark as to those facial lines which leave no permanent traces on the skull itself, and which have so much to do with our judgement of character" (Pearson, 1926: 2)

"In the final analysis, however, no matter how accurate a reconstruction may be, it is the circumstances pertaining to the subject in life than can determine the success or failure of such an undertaking"
(Vanezis et al., 1989)

"It is, therefore, possible to reconstruct the major features of the human head with some degree of accuracy. However, a reconstruction can only reveal the type of face that may have existed the position and general shape of the main features can be accurate reconstructions but subtle details such as wrinkles and folds are inevitably speculative as there is no evidence as to their form or even their existence. It appears that facial reconstruction depends as much upon the circumstances pertaining to the subject under investigation as it does upon the accuracy of the technique in order to be successful"
(Neave, 1980, 1988)

"In general, positive identification from the skeleton depends upon isolating factors that make one person unique from the rest. Evidence from dentition and antemortem radiographs are probably the most effective"
(Iscan, 1993)

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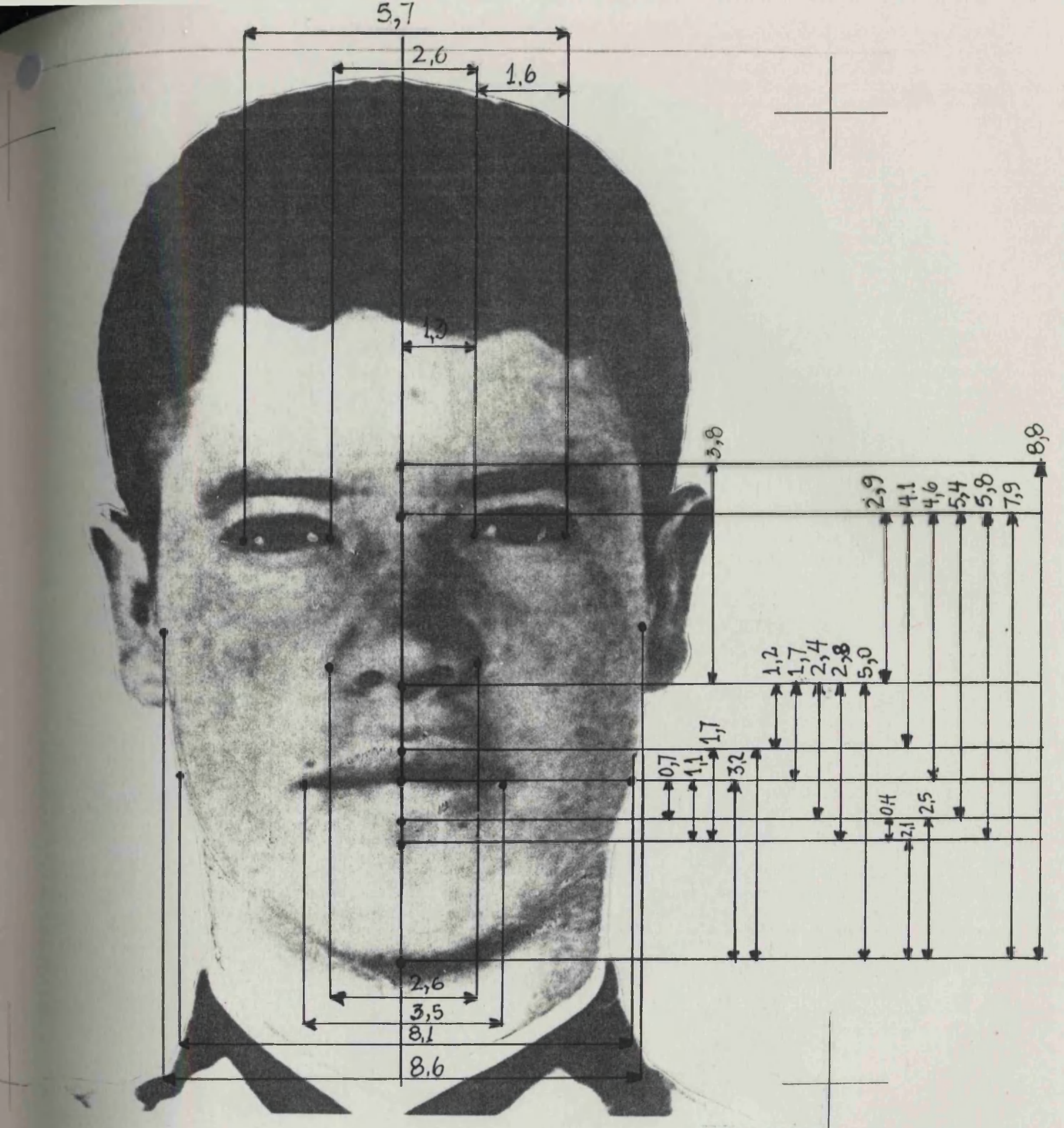
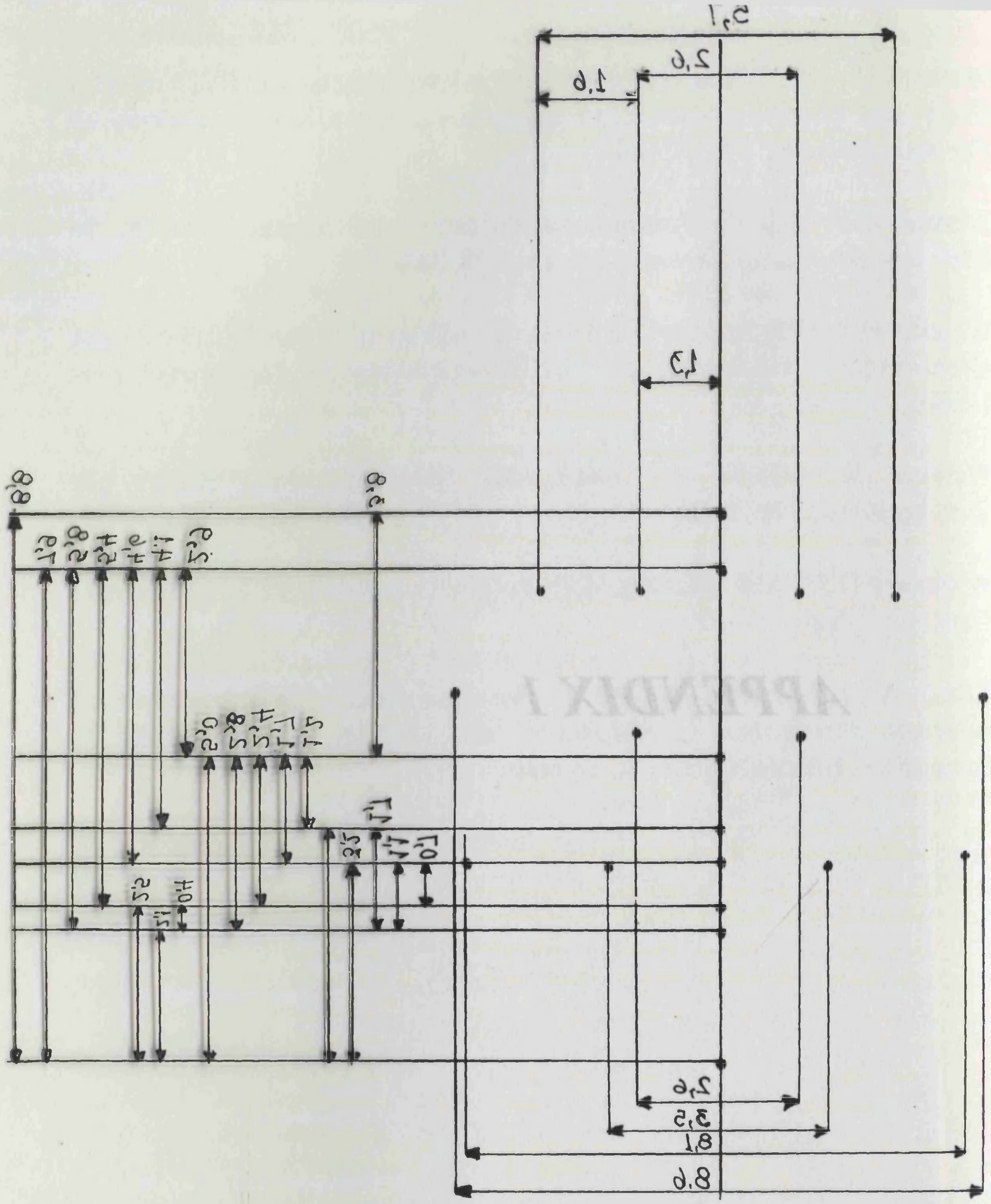
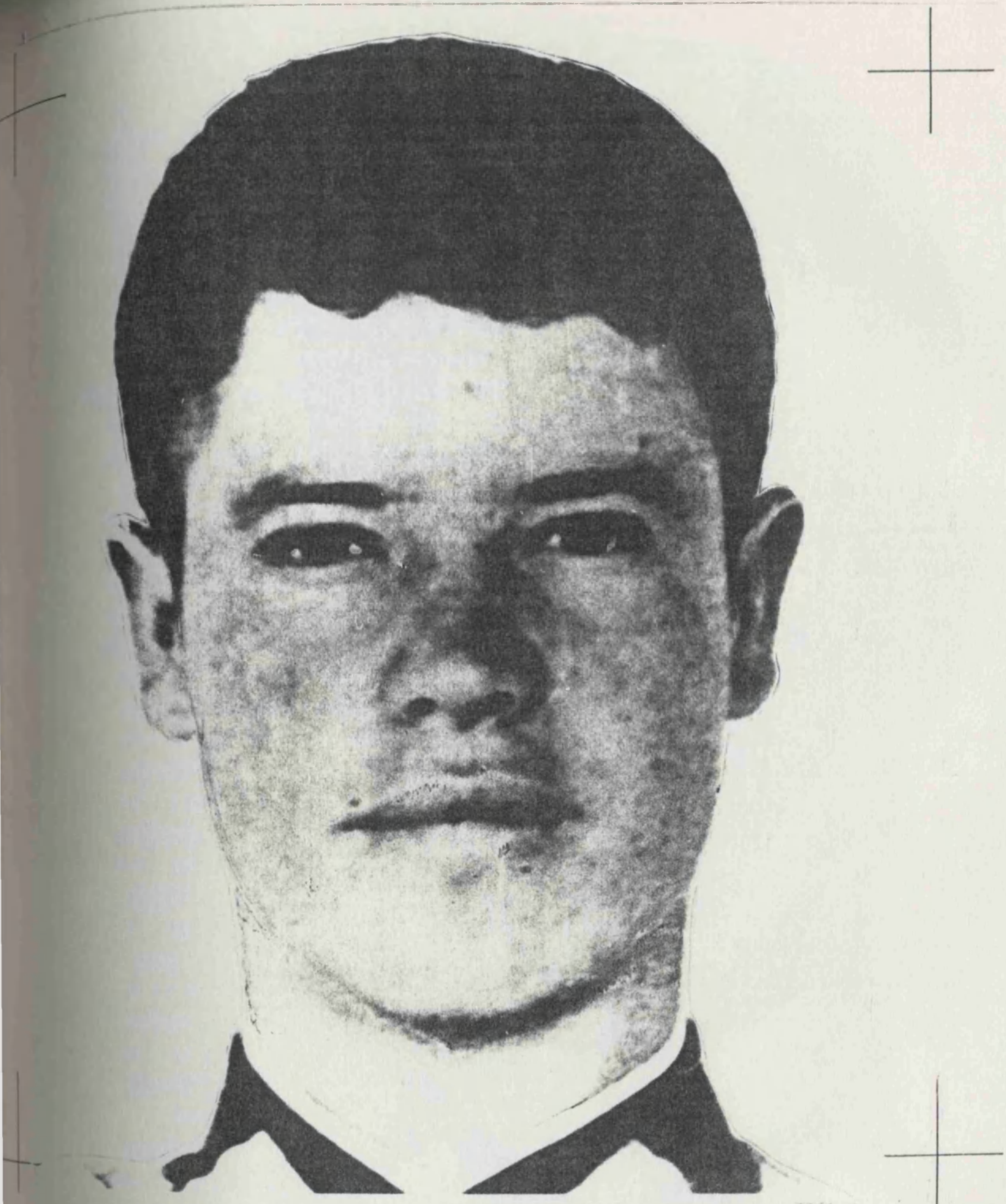
APPENDIX 1



APPENDIX 1

Transparency illustrating the outlines of missing person's photograph over it showing all cephalometric landmarks selected for Facial Anthropometry.


2,6
3,5
8,1
8,6



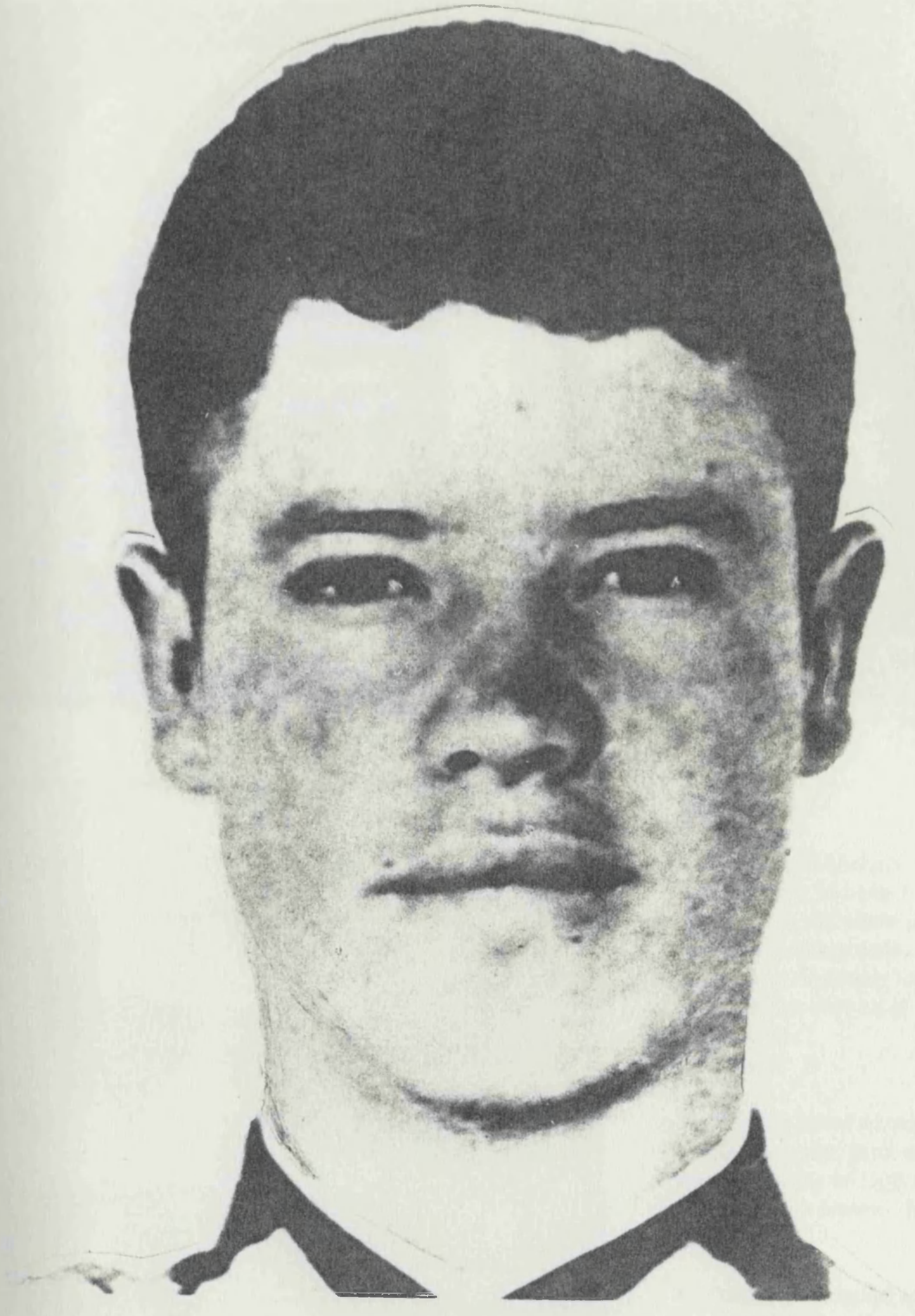
APPENDIX 1
Transparency illustrating the outlines of missing person's photograph over it showing all cephalometric landmarks selected for Facial Anthropometry.

APPENDIX 2

APPENDIX 2

Photograph of one of the missing persons and photograph in transparency of the plaster cast of skull selected for illustration of the whole process of the present study showing:

Static Superimposition between the plaster cast of skull with the missing person's photograph showing the correlation of facial landmarks with their cranial landmarks and the match between them.

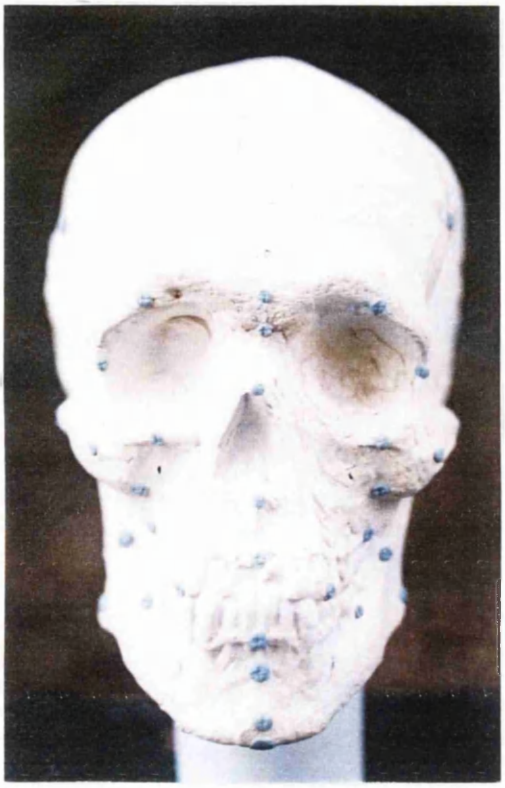


APPENDIX 2

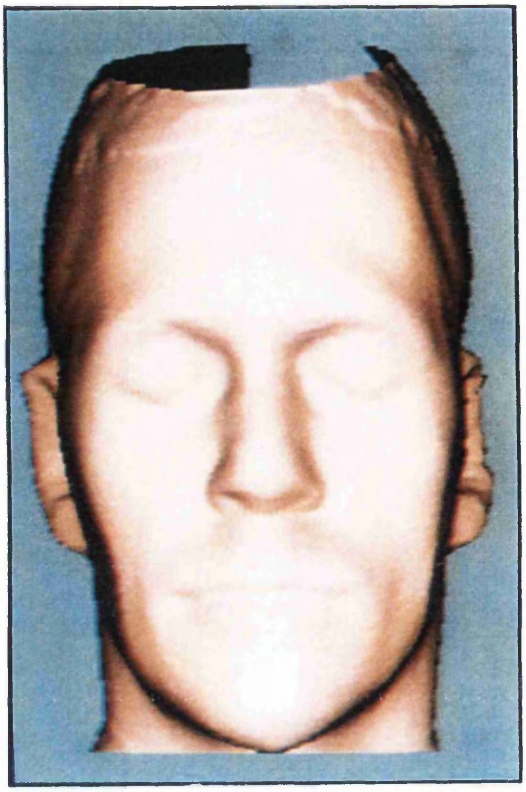
Photograph of one of the missing persons and photograph in transparency of the plaster cast of skull selected for illustration of the whole process of the present study showing:

Static Superimposition between the plaster cast of skull with the missing person's photograph showing the correlation of facial landmarks with their cranial landmarks and the match between them.

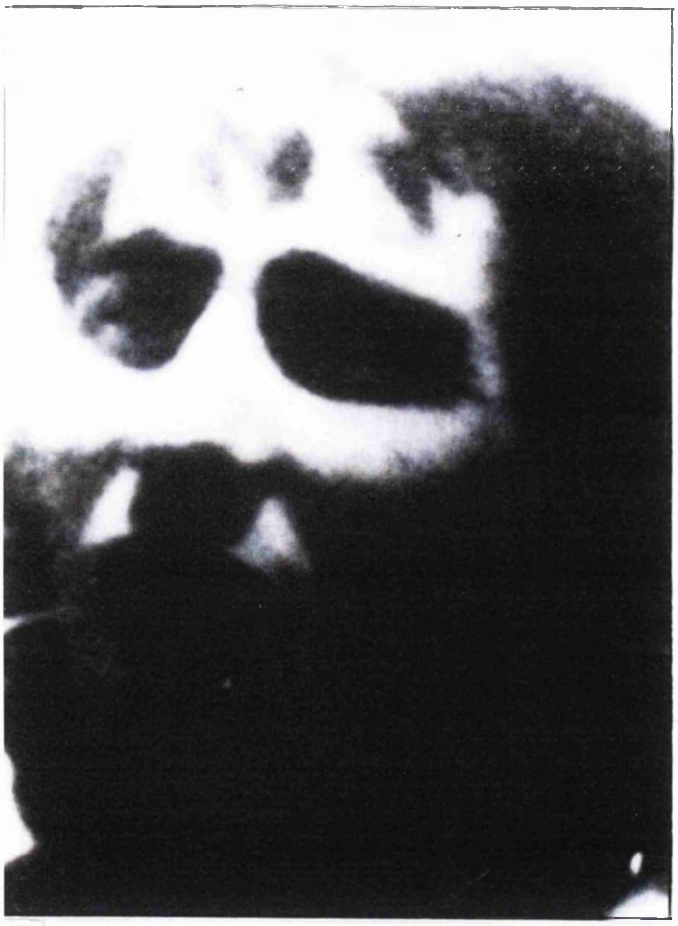
APPENDIX 3



A.



B.



C.

APPENDIX 3

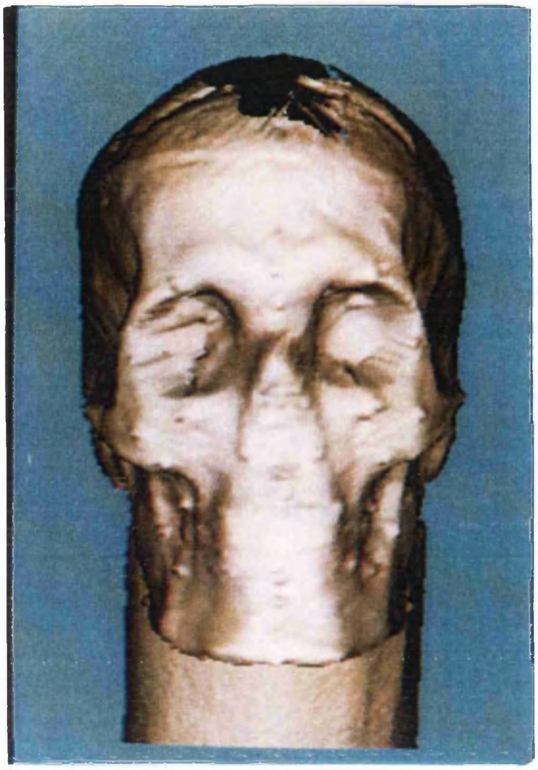
A. Plaster cast of skull N° 2832 selected from 16 cases for representing the whole process of Facial Reconstruction by computing. Positively identified as the person showed in photograph C. (Identity N° 1)

B. Finished facial reconstruction on plaster cast of skull shown in figure A, using an Optical Surface Laser scanner. Frontal view.

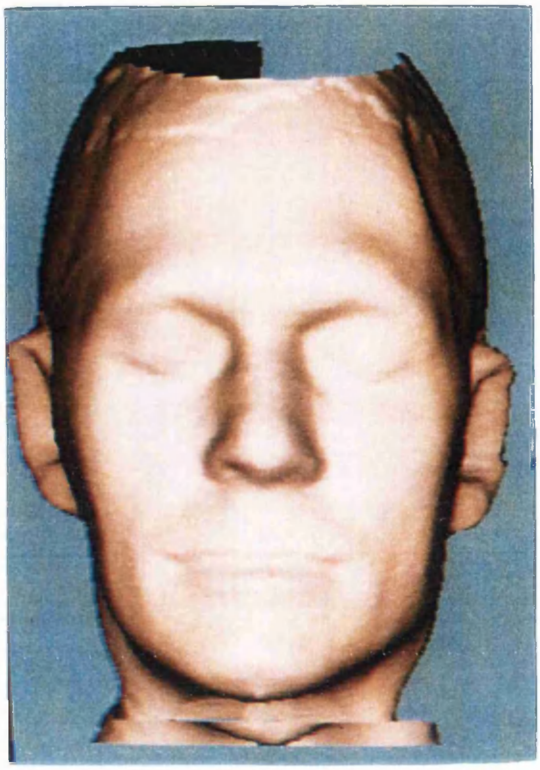
C. Frontal photograph of missing person.

APPENDIX 4

APPENDIX 4

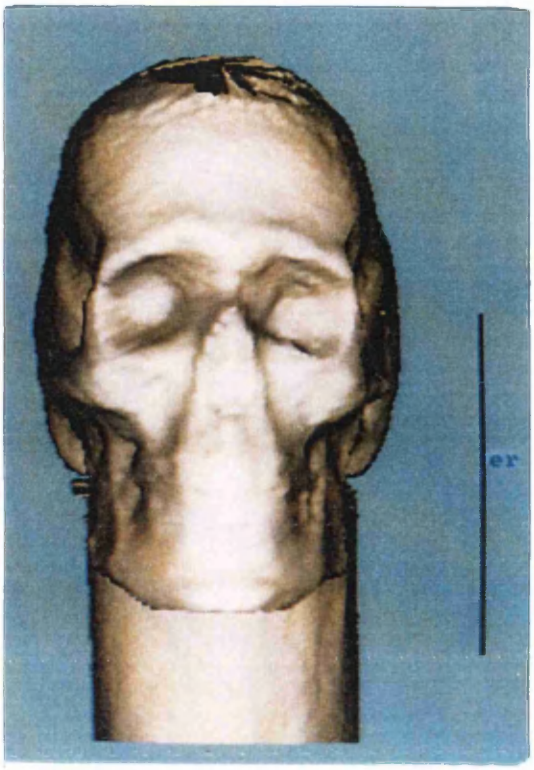


Scan of plaster cast of skull N° 2915

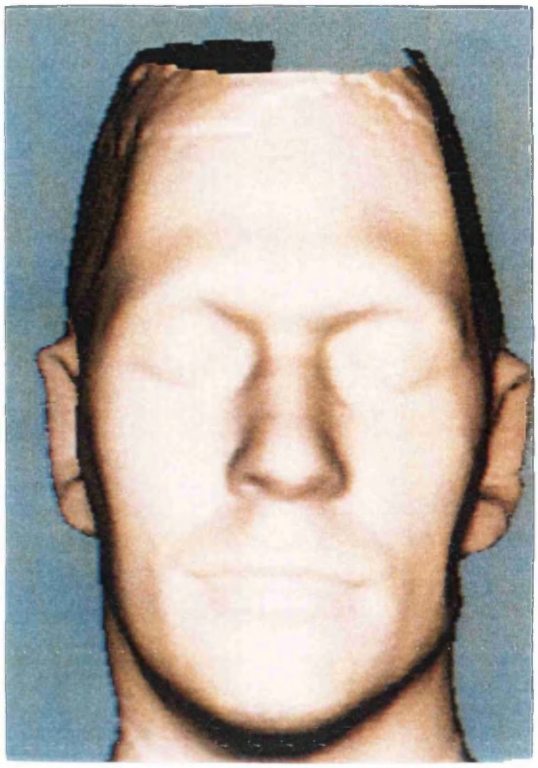


Finished facial reconstruction of plaster cast of skull N° 2915

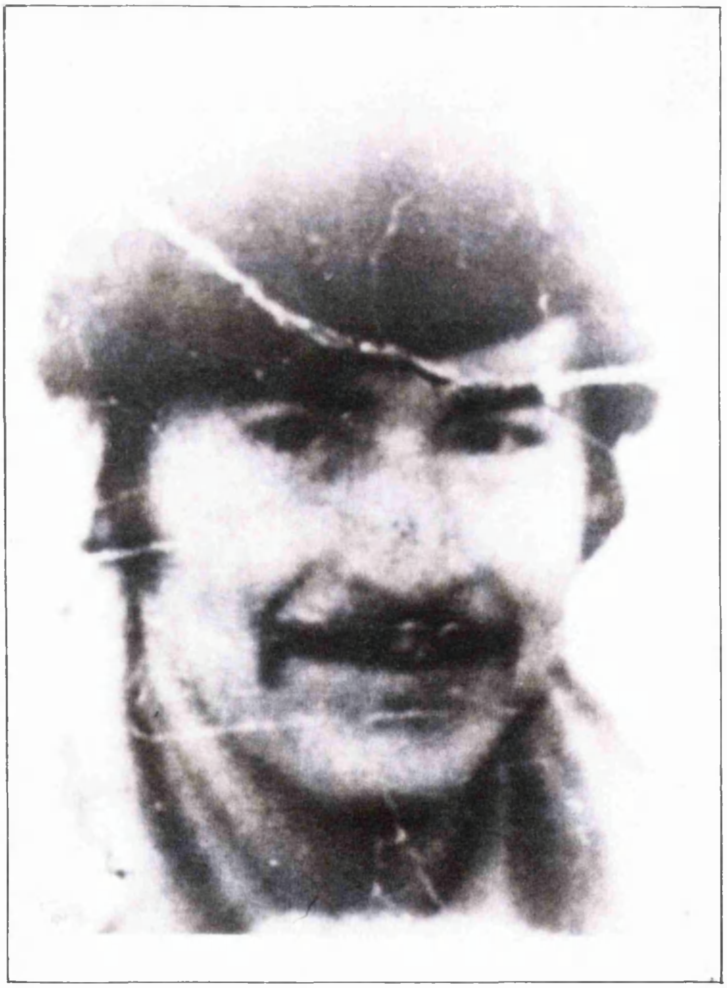
Photograph of missing person corresponding to identity N° 2



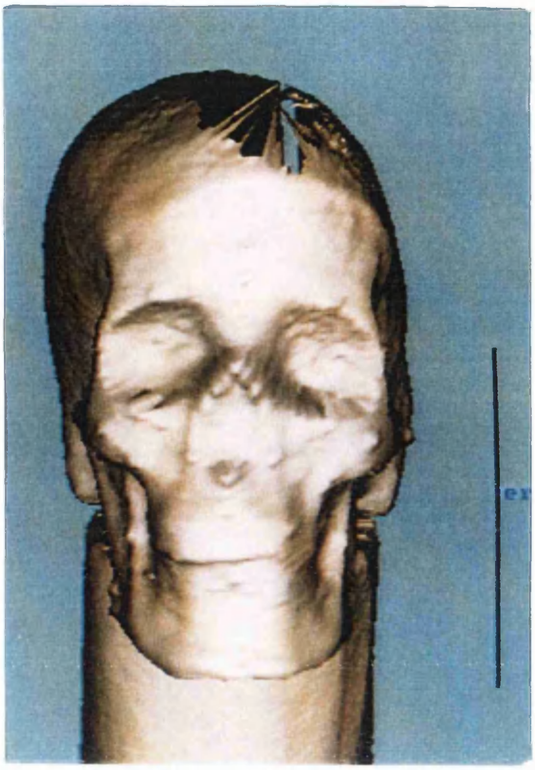
Scan of plaster cast of skull N° 2950



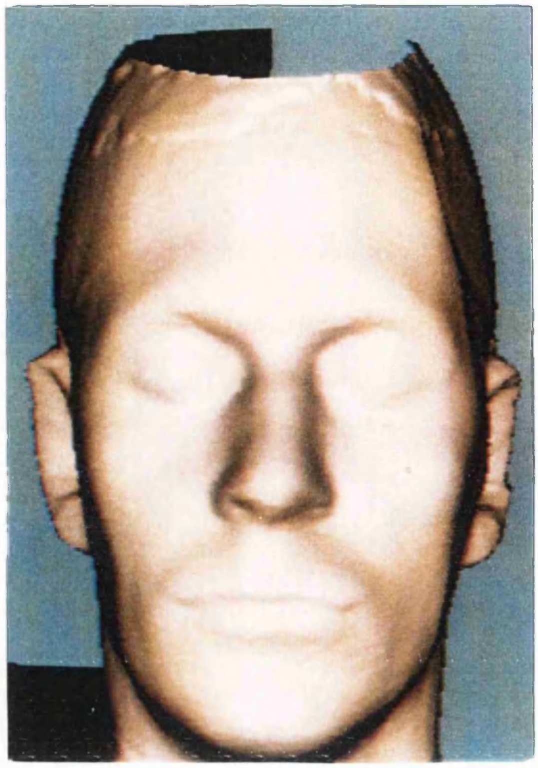
Finished facial reconstruction of plaster cast of skull N° 2950



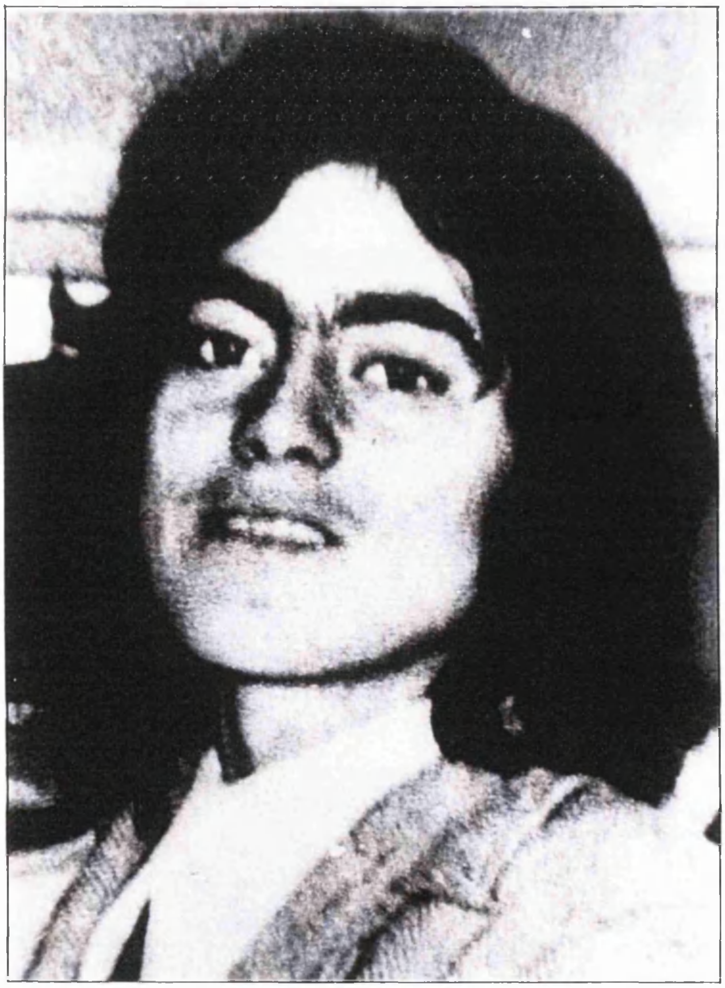
Photograph of missing person corresponding to identity N° 3



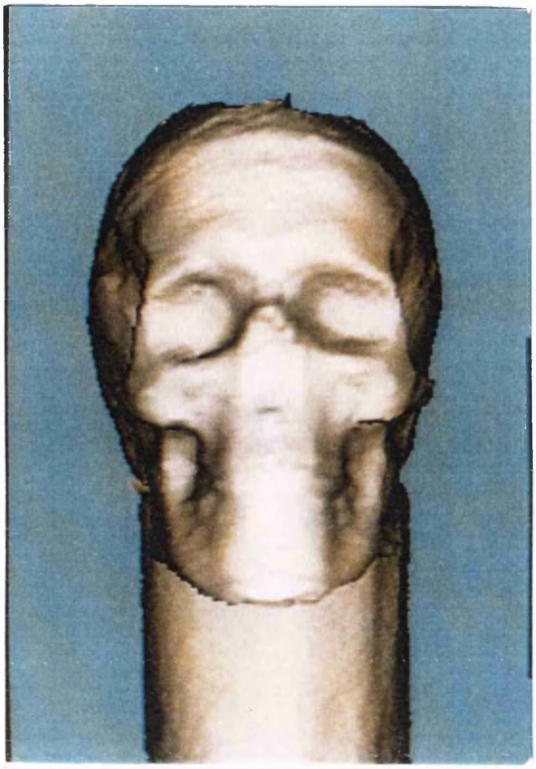
Scan of plaster cast of skull N° 2973



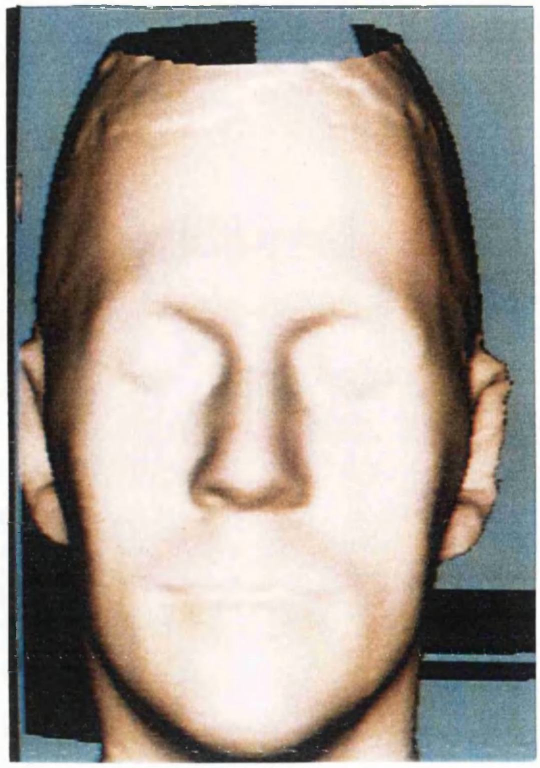
Finished facial reconstruction of plaster cast of skull N° 2973



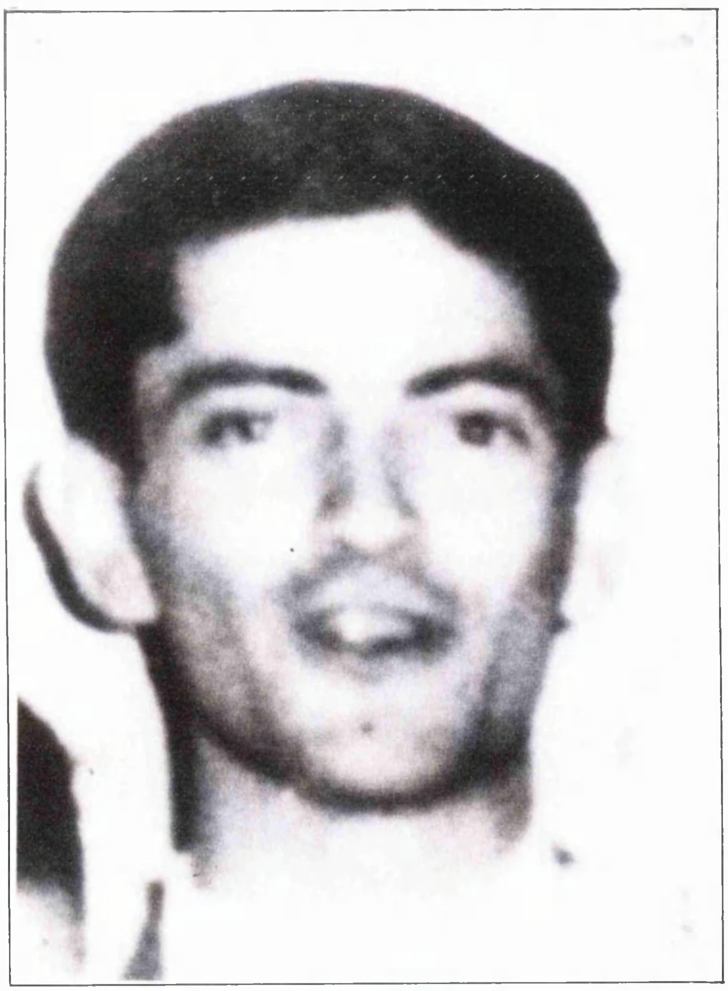
Photograph of missing person corresponding to identity N° 4



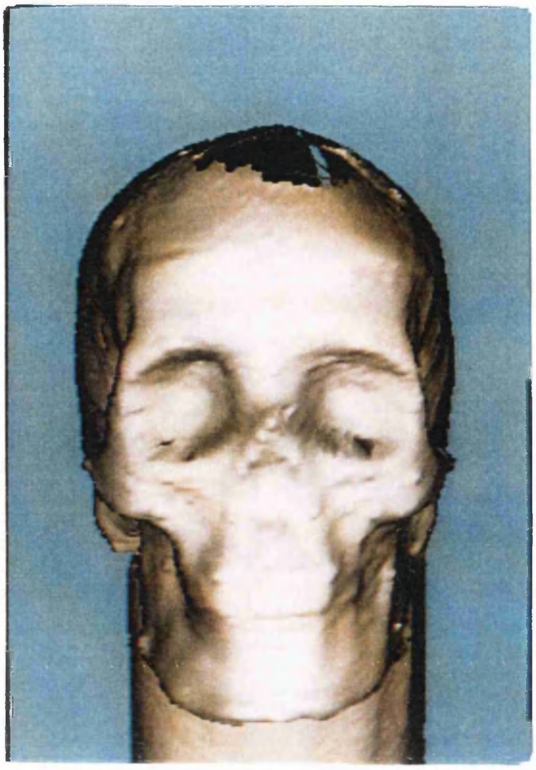
Scan of plaster cast of skull N° 3018



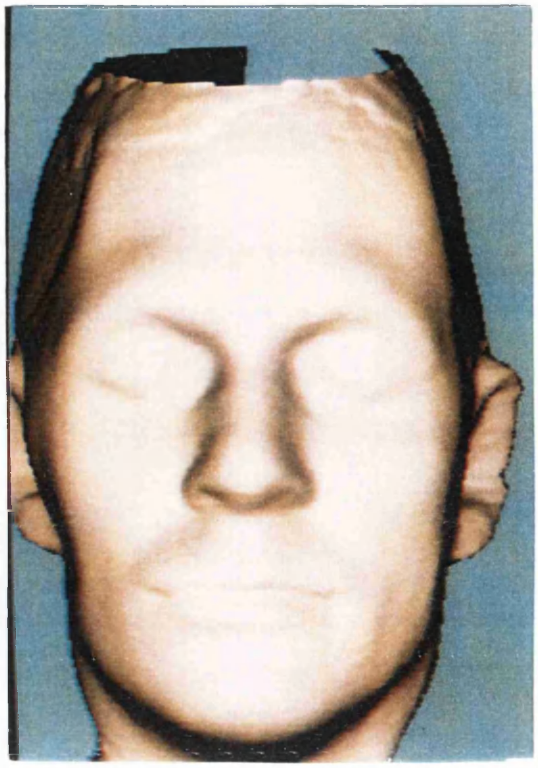
Finished facial reconstruction of plaster cast of skull N° 3018



Photograph of missing person corresponding to identity N° 5

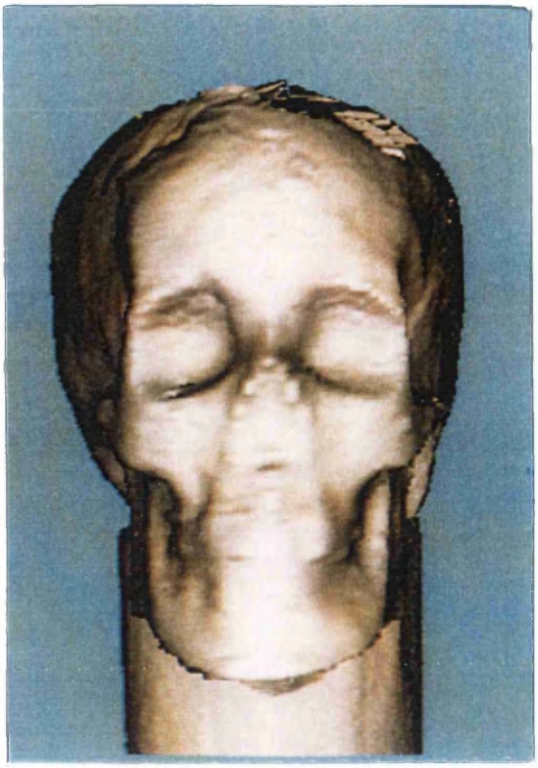


Scan of plaster cast of skull N° 3019

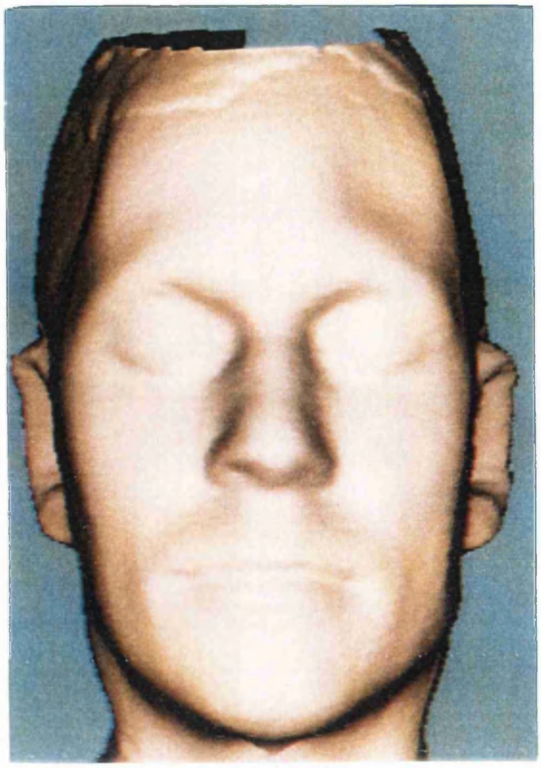


Finished facial reconstruction of plaster cast of skull N° 3019

Photograph of missing person corresponding to identity N° 6

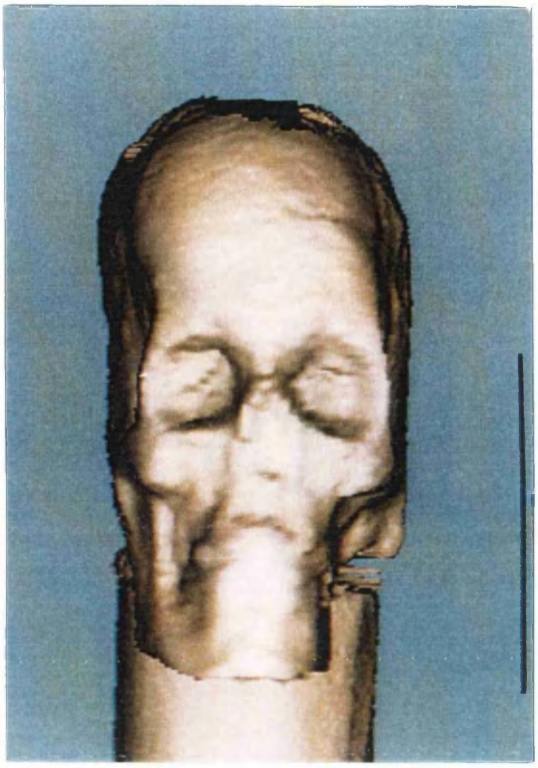


Scan of plaster cast of skull N° 3039

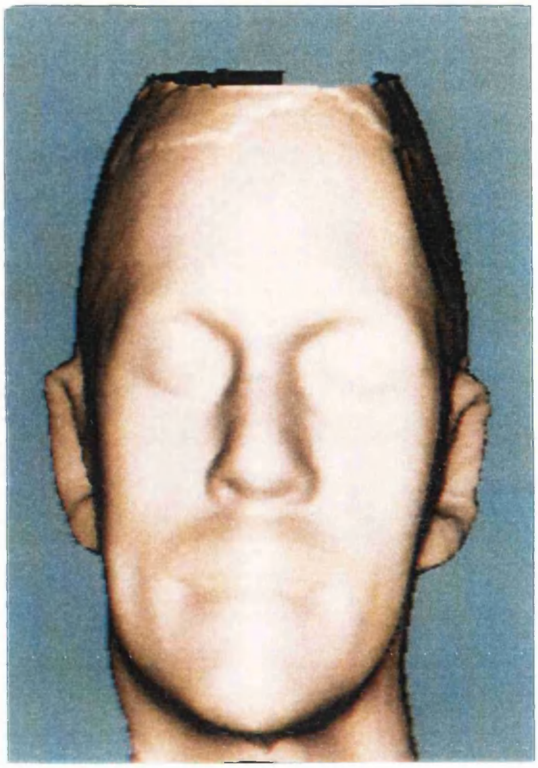


Finished facial reconstruction of plaster cast of skull N° 3039

Photograph of missing person corresponding to identity N° 7

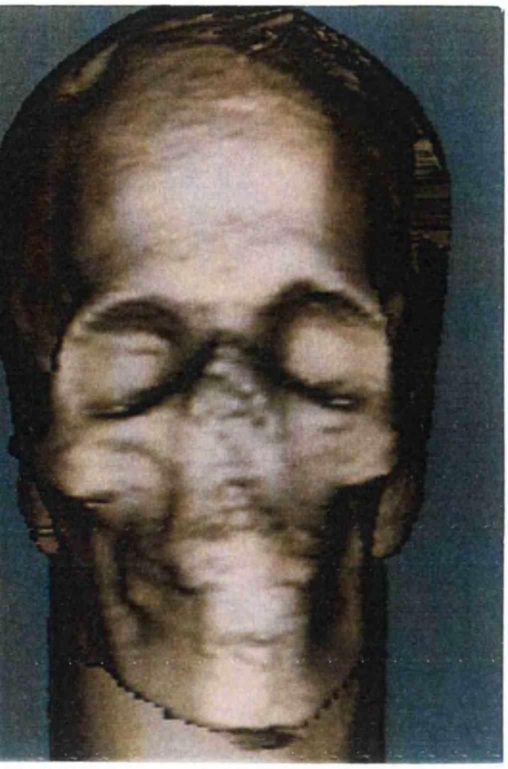


Scan of plaster cast of skull N° 3052

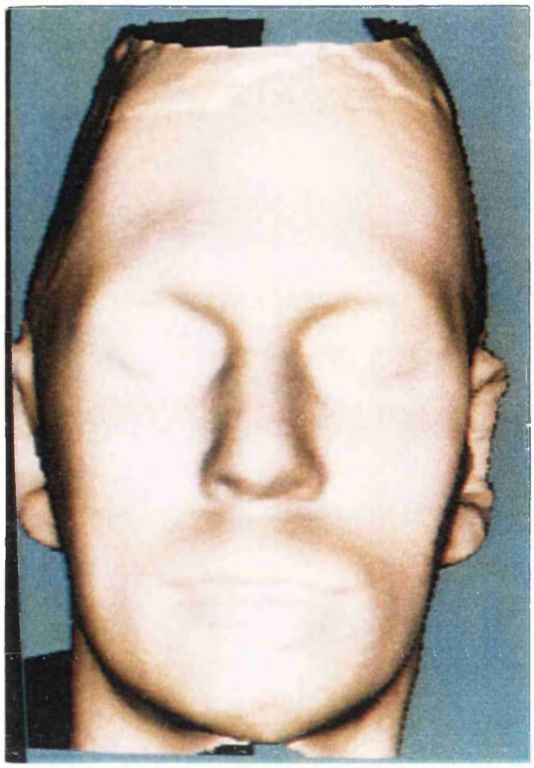


Finished facial reconstruction of plaster cast of skull N° 3052

Photograph of missing person corresponding to identity N° 8



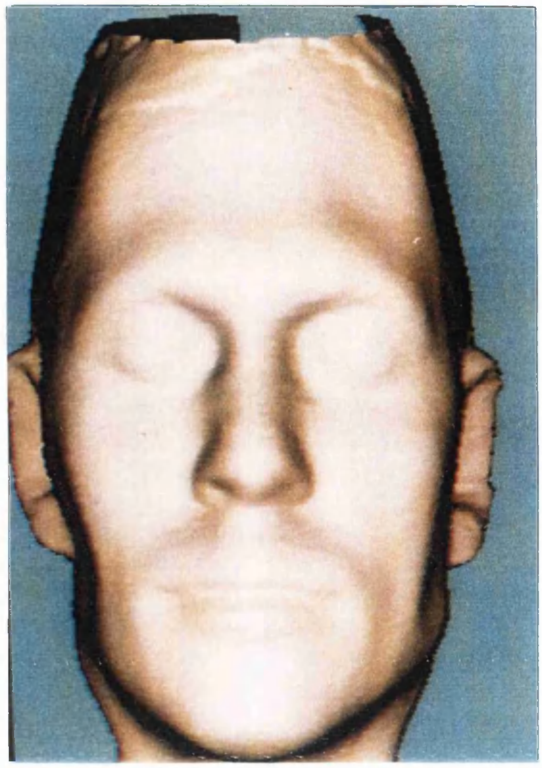
Scan of plaster cast of skull N° 3055



Finished facial reconstruction of plaster cast of skull N° 3055

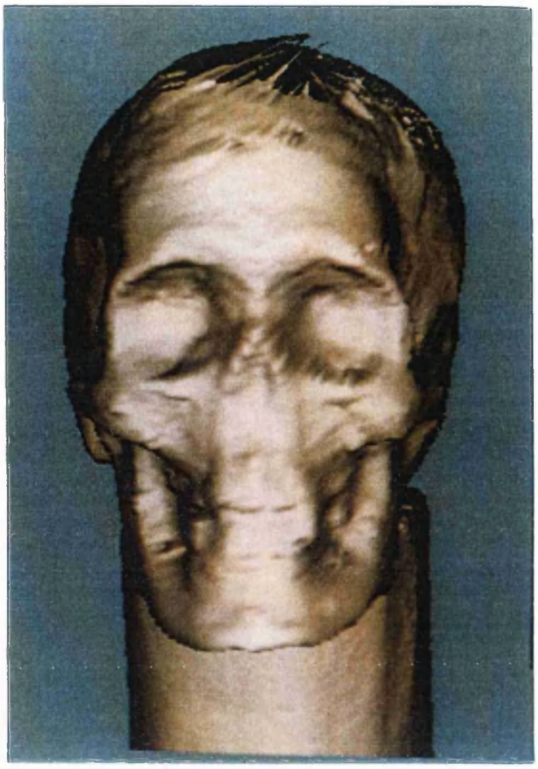
Photograph of missing person corresponding to identity N° 9

Scan of plaster cast of skull N° 2831

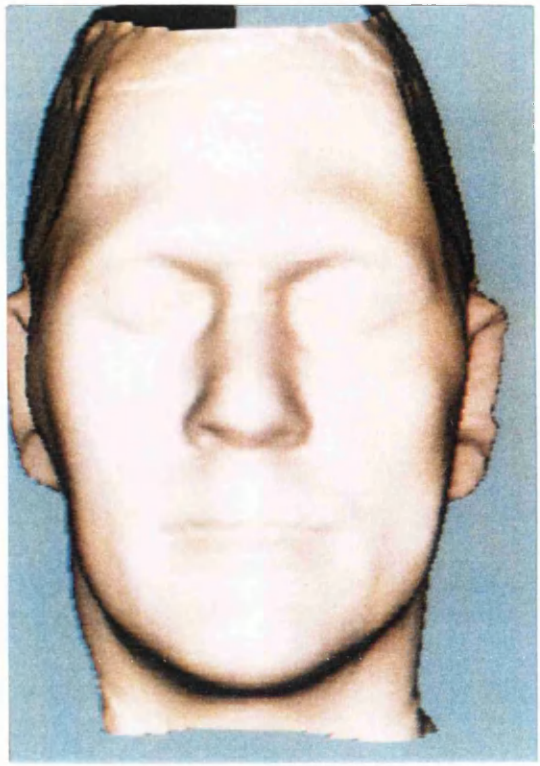


Finished facial reconstruction of plaster cast of skull N° 2831

Photograph of missing person corresponding to identity N° 10



Scan of plaster cast of skull N° 2996



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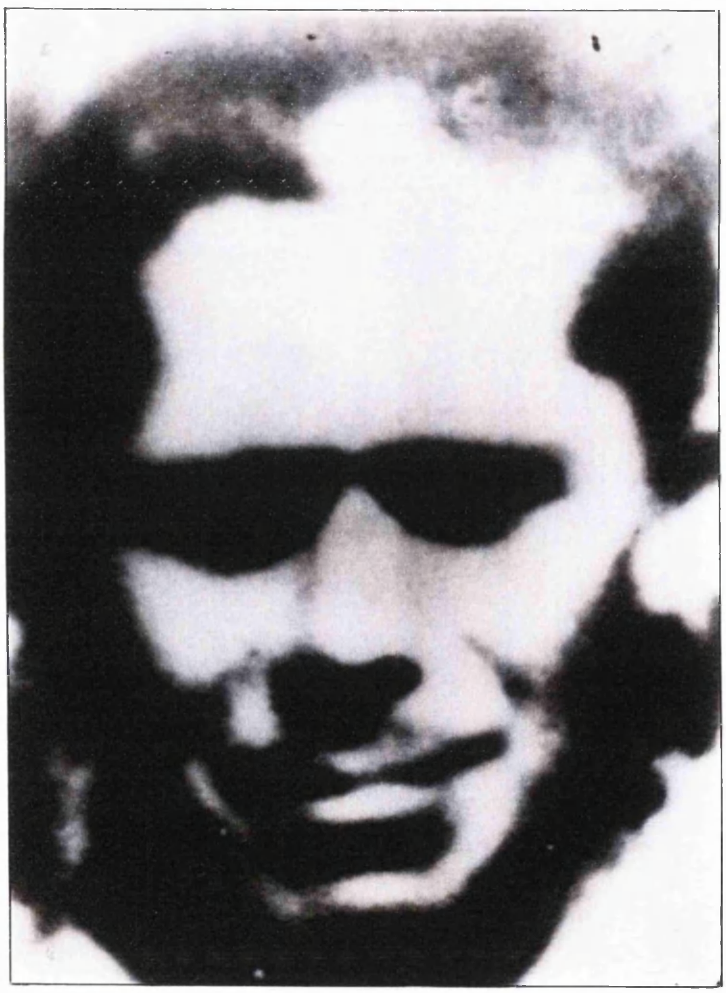

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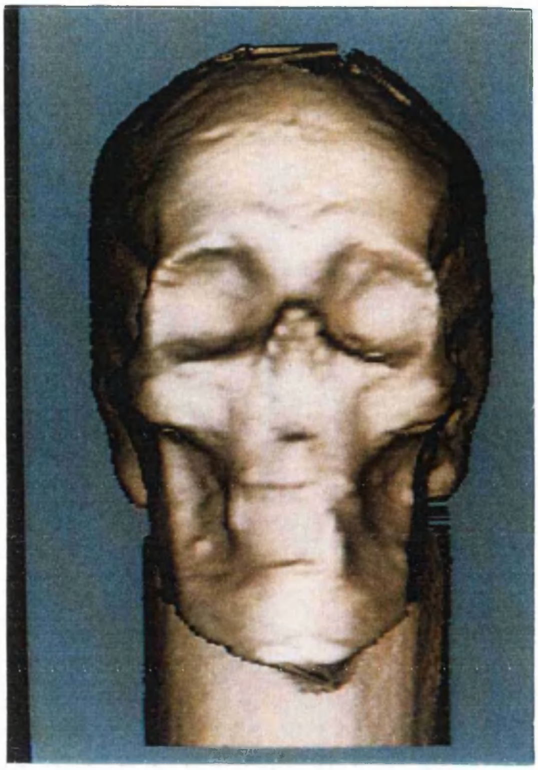
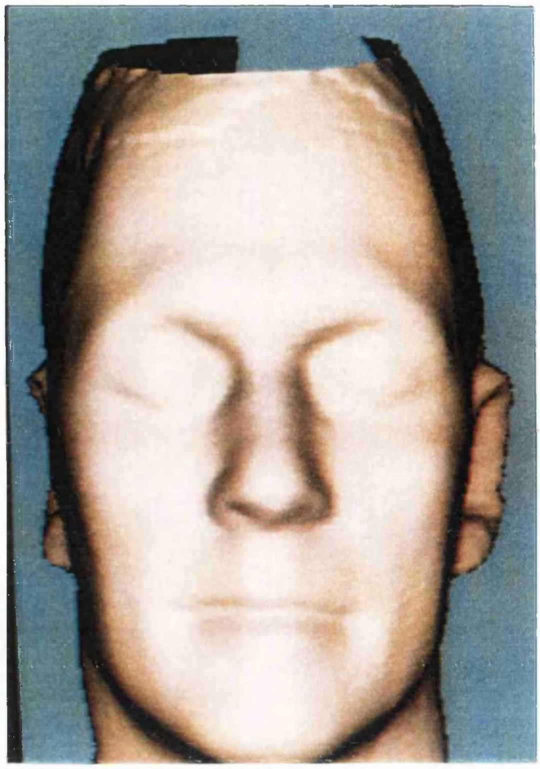


Scan of plaster cast of skull N° 2850



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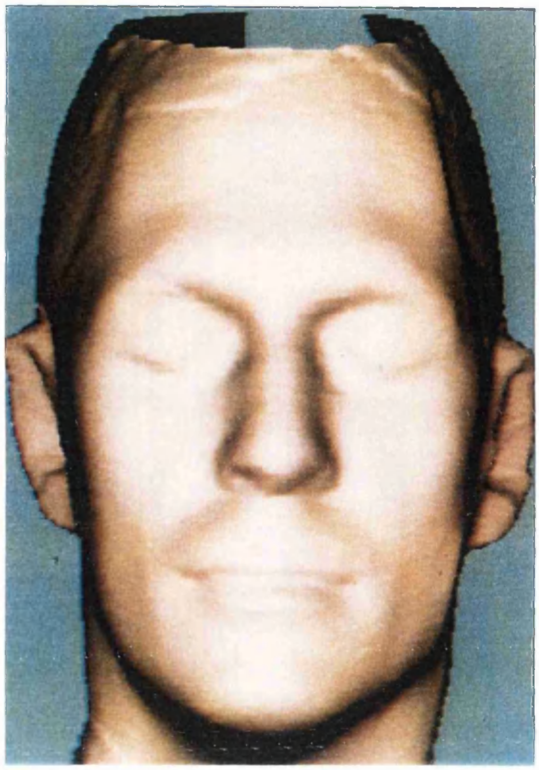
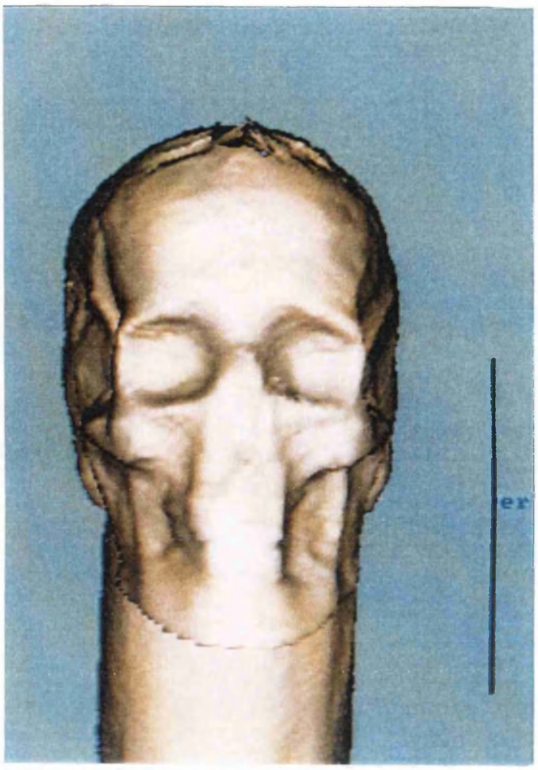


Finished facial reconstruction of plaster cast of skull N° 2938

Photograph of missing person corresponding to identity N° 13



Scan of plaster cast of skull N° 3009

Finished facial reconstruction of plaster cast of skull N° 3009

Photograph of missing person corresponding to identity N° 14

APPENDIX 5

APPENDIX 5

Craniometric points: Cranio skeletal landmarks

(Appendix 9, Figure 88)

Midline

1. Supraglabella
2. Glabella: The most prominent point between the supraorbital ridges in the midsagittal plane.
3. Nasion: The midpoint of the suture between the frontal and the two nasal bones.
4. End of nasal or nasale: The anterior tip of the nasal bones at their junction with the lateral nasal cartilages.
5. Mid-philtrum: The deepest midline point on the indentation between the anterior nasal spine and the supradentale.
6. Supradentale or Phrostion: The apex of the alveolus in the midline between the maxillary central incisors.
7. Infradentale: The apex of the alveolus in the midline between the mandibular central incisors.
8. Point B or Supramentale: The deepest midline point on the indentation between the infradentale and pogonion.
9. Pogonion: The most anterior point in the midline on the mental protuberance.
10. Gnathion: A constructed point midway between the most anterior (pogonion) and most inferrior (menton) points on the chin.

Paired landmarks (11-24 anatomical right)

11. Frontal eminence
12. Supraorbital: The highest bony point on the upper margin of the orbit.
13. Orbitale: The most inferior point on the margin of the orbit.

14. Inferior malar or maxillo-malar: It is located at the intersection of a vertical line between supraorbitale and orbitale and a horizontal line level with the nasal spine.

15. Lateral orbits or malar: A point located over the tubercle of the bony malar.

16. Zygion: The most lateral point on the zygomatic arch.

17. Supraglenoid: The most superior and posterior point on the condyle of the mandible.

18. Gonion: A constructed point at the intersection of the lines tangent to the posterior margin of the ascending ramus and the mandibular base, or the most lateral point at the mandibular angle.

19. Supra-M^2: The point located above of the maxillary second molar.

20. Occlusal line: The point on the mandible, level oclusion

21. Infra-M_2: The point below of the mandibular second molar.

22. Ectoconchion: The most lateral point of the lateral wall of the orbit.

23. Alare: The most lateral point on the nasal aperture.

24. Cheilion: The point located on the junction of the maxillary canine and first premolar on each side.

Paired landmarks (31-44 anatomical left)

31. Frontal eminence
32. Supraorbital
33. Orbitale
34. Inferior malar
35. Lateral orbits
36. Zygion
37. Supraglenoid
38. Gonion
39. Supra-M^2

40. Occlusal line

41. Infra-M_2

42. Ectoconchion

43. Alare

44. Cheilion

Others landmarks:

53. Line between bottom of mental and external auditory meatus (anatomical left).

54. Junction between superior temporal line and coronal suture. (anatomical left).

55. Above supraglabella.

56. Junction between superior temporal line and coronal suture. (anatomical right).

57.Line between bottom of mental and external auditory meatus (anatomical right).

58.Midline between points 53 and 57

Landmarks controlled automatically are (ectoconchion, alare, cheilion anatomical right and left), (22, 23, 24, 32, 33, 34 and points 53 to 58).

Cephalometric points: Soft tissue landmarks. (Appendix 9,Figure 89)

Midline

1. Supraglabella

2. Glabella: In the midline, the depression betweenn the eyebrows.

3. Nasion: In the midline, the point of maximum convexity between the nose and the forehead. Frontally, this point is located at the midpoint of a tangent between the right and the left superior palpebral folds.

4. End of nasal: The soft tissue point directly above bony nasale.

5. Subnasale: The midpoint of the columella base at the angle where the lower border of the nasal septum meets the upper lip.

6. Upper lip margin or Labiale superius: The point of maximum indentation of the upper lip.

7. Lower lip margin or Labiale inferius: The midpoint on the vermilion line of the upper lip.

8. Sublabiale: The point of maximum indentation of the lower lip, usually at its junction with the soft tissue chin.

9. Pogonion: The most anterior point of the soft tissue chin.

10. Gnathion: The point on the soft tissue chin midway between pogonion and menton.

Paired landmarks (11-24 anatomical right)

11. Frontal eminence

12. Superciliare: The highest point of the eyebrow's upper edge.

13. Orbitale: The lowest point on the lower margin of each orbit. It is identical to the bony orbitale.

14. Inferior malar:

15. Lateral orbits:

16. Zygion: The most lateral point of each zygomatic arch. It is identical to the bony zygion.

17. Supraglenoid: The most lateral point on the surface of the condile of the mandible.

18. Gonion: The most lateral point on the mandibular angle close to the bony gonion.

19. Supra-M^2

20. Occlusal line

21. Infra-M_2

22. Exocanthion: The point at the outer commissure of the eye fissure. The soft exocanthion is slightly medial to the bony exocanthion.

23. Alare: The most lateral point on each alar contour.

24. Cheilion: It is the point located at each labial commissure.

Paired landmarks (31-44 anatomical left)

31. Frontal eminence

32. Superciliare

33. Orbitale

34. Inferior malar

35. Lateral orbits

36. Zygion

37. Supraglenoid

38. Gonion

39. Supra-M^2

40. Occlusal line

41. Infra-M_2

42. Exocanthion

43. Alare

44. Cheilion

Others landmarks:

53. Line between bottom of mental and external auditory meatus (anatomical left).

54. Junction between superior temporal line and coronal suture. (anatomical left).

55. Above supraglabella.

56. Junction between superior temporal line and coronal suture. (anatomical right).

57.Line between bottom of mental and external auditory meatus (anatomical right).

58.Midline between points 53 and 57

APPENDIX 6

APPENDIX 6

Manual of the software "The face change program"

The numerical facial reconstruction: The program is called "The face change program" and the procedure followed was the same as described earlier in the description of laser scan technique. The software is self explanatory; all its practical steps will be explained in detail in this section.

The numerical facial reconstruction :

Images were retrieved from the hard disk and the following procedure was adhered to:

A. After the program is selected from the main menu the following specific menu is displayed. (Appendix 9, Figure 90)

MAIN MENU:

The main menu is divided into six basic sections. (Appendix 9, Figure 91)

[FILE MENU] Data files loading and saving.

[VIEW CONTROL MENU] This option allows an interactive viewing of three dimensional data, scaling, rotation, swapping between face and skull.

[TISSUE TYPE] Selection from a table of soft tissue thicknesses. The program has recorded soft tissue thickness data from Rhine et al., (1984) for different body build and sex for Caucasoids. The software allows the operator to modify the soft tissue values according to the race, sex and age of the skull.

[ALIGN & DISTORT] This process allows adjustment of a face scan to match the shape of a skull scan.

[PEG EDIT] This option allows the operator peg marker locations to be edited.

[EXIT SYSTEM] This option allows the operator to escape to another program or to terminate the current program.

B. The first instruction of the program is "Select skull data": To perform it the operator must select FILE MENU. From this menu the operator must select [Load skull data] and to follow the instruction of this option. (Appendix 9, Figures 92 and 93)

The data set on the skull is displayed as a fully shaded three dimensional surface. (Appendix 9, Figure 94)

The FILE MENU option is the first step for loading data into the system and also allows data to be saved from the system.

This option comprises the following 5 sections: (Appendix 9, Figure 91)

1. [Load skull data] This option allows selection of the directory and specific scan data. It displays a list of available optical surface data. The skull scan of interest should be selected using either the mouse or the keyboard.

Once the scan is selected, it will then be loaded. It is possible to change directory and disk to search the entire filing system for data, if necessary.

2. [Load face data] this displays a list of available optical surface scan data. The appropriate face scan should be picked. As with the skull scan, other files will be looked for and loaded if necessary.

3. [Save face data] The adjusted facial data set currently being displayed can be saved to a named user file. This allows a modified face to be saved. The new facial shape should not be saved to the same name file as either of the sources files as this will involve loss of the source data. The data can be placed anywhere in the entire disk filing system for future use. A specific file must be created for storing this new data. In this way it easier to find specific data sets at a later time.

This process involves re-sampling the edited surface and will take several minutes. In routine practice the saving option takes about 15-20 minutes.

4. [Save peg data] The peg location information, for either the skull scan or for the source face scan, should be saved to disk file if the peg positions are modified and these changes need to be kept. Only one peg file can be associated with each scan. An edited scan will need a new peg file if it is to be modified again.

5. [Save thickness data] The current tissue thickness table can be saved to disk for future use. The default tissue thickness settings can be modified within the [Peg adjustment] menu.

C. The second instruction from the program is "Select facial surface scan".(Appendix 9, Figure 95) To bring this image to the screen the operator should select again [File menu] and from this option the item [Load face data]. The procedure is the same as described for selecting the skull.

If the user does not have the information regarding the presumed body build of the skull in question, an average face would be the next best option. (Appendix 9, Figure 96)

The software will allow an average face to be produced from all the scans in a particular directory. All the scans must have the same number of landmarks on them placed in the same anatomical positions, in the same order.

The operator will then have two images on the screen. On the upper half of the screen to the right will be the skull scan and to the left will be the average face surface scan.

D. The next step is to select the appropriate soft tissue thickness table measurements according to body build, if information is available.

Very often this information is not available, thus an average (Normal) soft tissue thickness is preferred which corresponds to the race and age of the

skull. From the [Main menu] of the facial reconstruction program the operator will select [Tissue Type]. (Appendix 9, Figure 97)
The soft tissue thicknesses used to locate the face surface over the skull may be selected from one of the six standard sets provided (Rhine et al., 1984) or the user could incorporate appropriate soft tissue thickness data.

This option has the following items:
[Normal male]
[Fat male]
[Thin male]
[Normal female]
[Fat female]
[Thin female]

E. Once the soft tissue type has been selected, the following step is to place the landmarks over the two scans. To do this the operator must select from the [Main menu] the option [Peg adjustment] or [Adjust peg markers]. This menu allows the user to select and move each peg on each data set. The pegs markers should be placed at defined anatomical landmarks and must be compatible on both the skull surface and the face surface. The default tissue thickness at each peg position can also be adjusted. All adjustments must be made prior to performing the facial surface fitting [Apply face shift] option (as explained later).
There are two main types of peg map displays; the first shows the peg grid over the surface of the scans, allowing the locations of the pegs to be seen. However, this sort of map has the disadvantage that parts of the scan and therefore also of the peg map, is hidden from view. This makes it difficult to check that the pegs have been placed symmetrically on the two sides. To

help in judging symmetry, an unwrapped display of the peg map is shown below the two scans on the screen. (Appendix 9, Figure 98)
It is possible to display the two unwrapped maps on the full screen for comparison purposes. Thus allowing the operator better visualisation of the marker points and also of the grid as a whole or each landmark individually, thus enabling easy adjustment over the two scans located on the upper half of the screen.

Single keystrokes select between the options displayed on the screen:
(Appendix 9, Figure 99)
f- select face active for moving pegs
s- select skull active for moving pegs
o- two ordinary images
b- one big image
n- select next peg (The landmarks are numerated from N° 1-58). If the operators are working in peg marker N° 3, then the next peg would be N°4 and so on.
p- select previous peg. In the aforementioned example, the previous peg marker would be N° 2.
a- all peg active. This option allows the entire grid to be moved across the scan.
c- compare skull and face peg position (display both)
u- show unwrapped peg maps full screen
m- modify the thickness of tissue to be "grown" at the current peg position.
The cursor keys are used to move the currently active peg which is indicated by a different colour
The number of the currently active peg is shown on the screen.
The active peg set (skull or face) is also shown)
The peg numbering scheme is shown in Appendix 9, figure 83.

F. Once all the pegs have been placed in approximately the right locations according to the numbering scheme of the program; using their classical anatomically defined position it is useful to normalise the orientations and the positions of the two scans in order to make it easier to compare the position of the pegs on the two scans.

To perform this the user must select from the [main menu] the option [Align and distort].

This option registers the two scans into a matching orientation and then allows the adjustment process to be performed. The normalising options are particularly useful when trying to align the peg markers on the face and skull. It is of no benefit to normalise the scans without previously setting the peg markers in their correct locations. (Appendix 9, Figure 100)

Once the landmarks are in the correct locations, normalising orientations and positions will help to fine tune the peg positions.

The align and distort menu has the following items: (Appendix 9, Figure 102)

[Normalise orientations]: This option rotates the face data to match the orientation of the skull data. (Appendix 9, Figure 101 A)

[Normalise position]: This shifts the face data to match the location of the skull data. (Appendix 9, Figure 101 B)

[Normalise scale]: This option re-sizes the face data to match the size of the skull data. (Appendix 9, Figure 101 C)

[Complete alignment]: This operation sequentially applies all of the first three operations at the top of this menu.

G. The complete alignment can be checked using from the [Main menu] the option [view control menu] in order to superimpose the facial image translucently over the skull allowing a simple visual comparison. This function may be performed through the option [show mixed image]. (Appendix 9, Figure 103).

For a better visualisation of images the program has an option called [show large image] which doubles the image size to fill the screen. To perform it the user must select from the [Main menu], the option [view control menu] and into this click the option [show large image].

H. The peg location information, for either the skull scan or face scan, should be saved to disk file if the user needs to keep them for future use. The saving process allows the user to save time and energy in a future facial reconstruction if the same facial or skull surface scan is to be used again. (Appendix 9, Figure 104)

I. The last step consists of applying the option [Face shift]: this performs the facial surface adjustment and must be preceded by a [complete alignment].

All adjustments of pegs positions, tissue thicknesses, etc., should be finalised before applying this option. This process takes about 15-20 minutes. Appendix 9 : (Figures 105 A, B, C, D, 106, 107A and B, 108 A and B)

J. The adjusted facial data set can be saved to a user nameable file. From the [File menu] the user must click [save face data] option. This process takes about 15-20 minutes.

From the [Main menu] another important function is the rotation of the image. To perform this the user must select the item [View control menu]. The menu allows interactive orientation of the three dimensional surface data in various ways. Among its option are the following:

1. [Set absolute menu]

This allows one of six orthogonal views to be selected

[Anterior view] frontal face view

[Top view] look down on head

[Bottom view] look up from below

[Posterior view] back of head view

[Right lateral] look at subject or skull's right side

[Left lateral] look at subject or skull's left side

2. [Rotate object by keyboard]

This option allows the user to select a new viewpoint. It uses the keyboard cursor pad to rotate the object to the current view.

The up cursor key rotates the object upwards. Similarly for down, left and right rotations.

The [Pg up] key rotates the object clockwise.

The [Home] key rotates the object anticlockwise.

The [Insert] key allows the angle increment (in degrees) to be set.

The [Esc] key returns the user to the [view menu].

APPENDIX 4

APPENDIX 7
HISTORICAL FIGURES

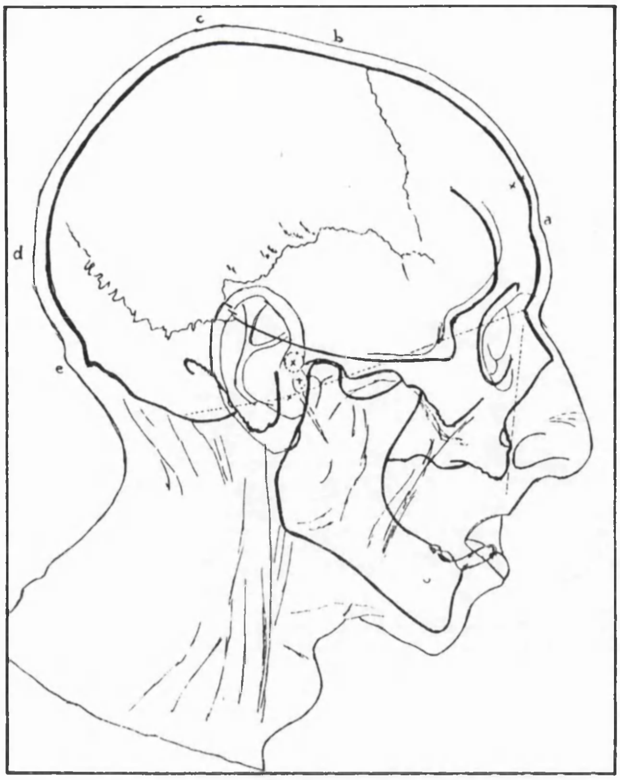


FIGURE 1(a)
Superimposition drawing by Welcker showing the skull and face of Immanuel Kant
(Welcker, 1883: Taf V)
(Reprinted in Iscan and Helmer, 1993: 33)

FIGURE 1(b)
Superimposition drawings by Welcker to illustrate that one of the presumed skulls of Schiller was not genuine. Superimposition technique was performed using line drawings of the skull overlaid on drawing from two busts existing of him.
(Welcker, 1888: 38: figures 4, 5 and 6 respectively)

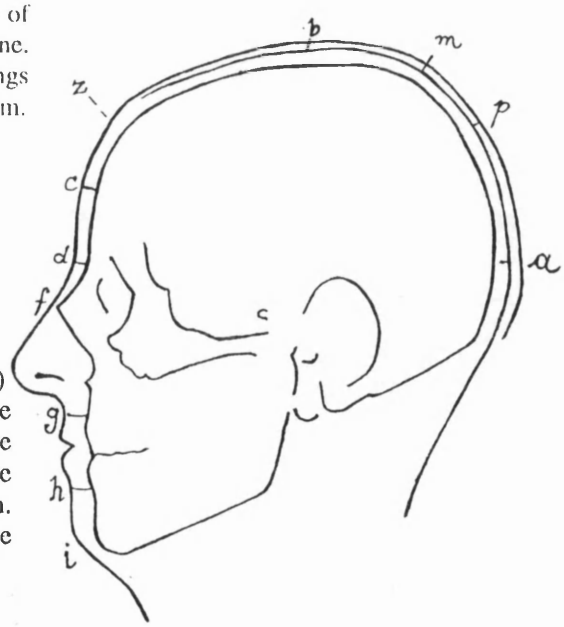


FIGURE 1(c)
Superimposed drawing of another skull presumed to be Schiller's and Schiller's bust, (the same used in the three orientations of the first skull shown in Figure 1(b)). The drawings showed the authenticity of the skull in question. Lines and letters in the superimposition indicate soft tissue thickness data reported by Welcker, 1883.
(Welcker, 1888, Taf II)

FIGURE 2(a)
Portrait of Sir Thomas Browne by Allix (currently in The National Portrait Gallery) with a superimposed craniostatic drawing of his skull. The fit of the skull shows a passable portrait.
(Pearson, 1926: Plate II)

FIGURE 2(b)
Portrait of Sir Thomas Browne (currently in The Royal College of Physicians). The superimposition to illustrate that the artist has idealised the forehead to emphasise intellectuality.
(Pearson, 1926: Plate II)
(Tildesley, 1923: Plate II: Figure3)

FIGURE 3(a)
Superimposition drawing of the skull of George Buchanan superimposed on one of several existing portrait of him, which Pearson, determined not to be authentic. This portrait is called Earl of Buchanan's Titian, St. Andrews.
(Pearson, 1926: Plate XXIX left)
(Reprinted in Krogman and Iscan, 1986: 425)

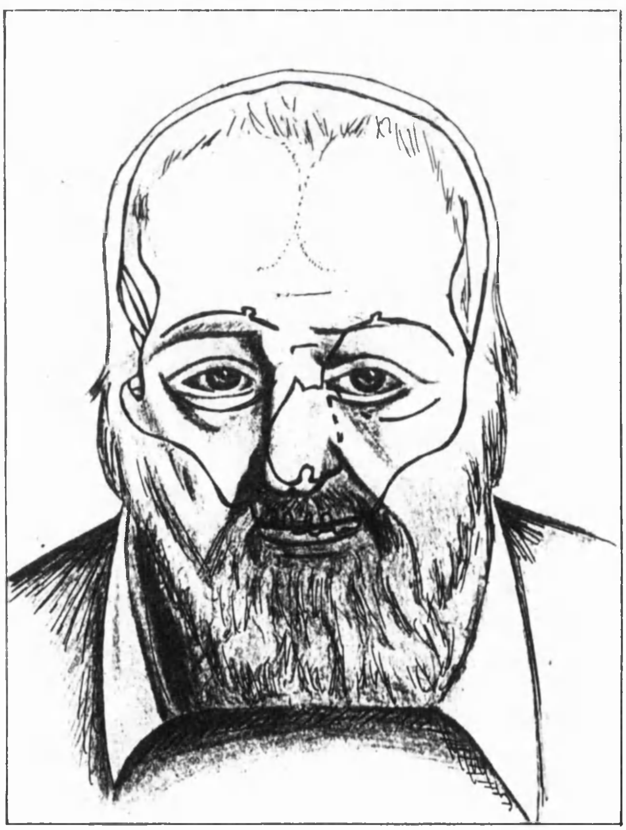


FIGURE 3(b)
Superimposed drawing of the skull of George Buchanan and Mr. Sowersby's portrait to illustrate that the portrait fitted with the skull.
(Pearson, 1926: Plate XXIX, right)
(Reprinted in Krogman and Iscan, 1986: 425)

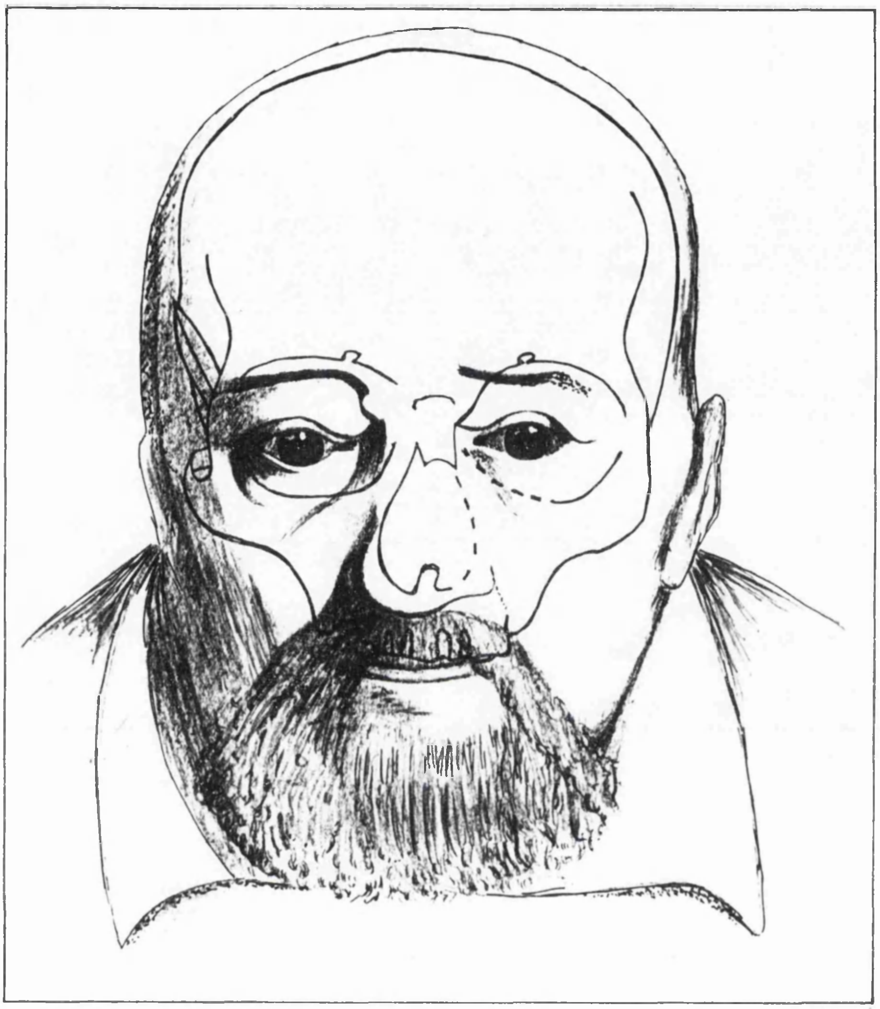


FIGURE 3(c)

The portrait of George Buchanan (Royal Society of London) with a superimposed craniostatic drawing of his skull which Pearson considered one of the best of portraits existing of him to illustrate its fitting with George Buchanan's skull.
(Pearson, 1926: Plate XXX)

FIGURE 4
Superimposition of a contour drawing of Jeremy Bentham's mummified head fitted to an authentic portrait of him.
(Pearson, 1926: Plate I)

FIGURE 5(a)
Craniostatic drawing of the genuine skull of Henry Stewart, Lord Darnley, superimposed on one of the five existing portraits of him. This portrait is by Lord Bolton fitted with the outline of the skull.
(Pearson, 1928: Plate XXVII)

FIGURE 5(b)
Superimposition of a Craniostatic drawing of the skull of Henry Stewart, Lord Darnley fitted to a portrait of him. From the Duke of Devonshire's Picture of Darnley with Mary (See Plate XIII)
(Pearson, 1928: Plate XXIX)

FIGURE 5(c)
Lord Darnley and Mary, Queen of Scots, from the Picture at Hardwicke Hall.
By kind permission of His Grace the Duke of Devonshire.
(Pearson, 1928: Plate XIII)

FIGURE 6
Craniostatic drawing of the skull of Robert The Bruce, King of Scotland, fitted to Harding's engraving of the Jamesome picture, indicating that the picture is not a true portrait, but has some faint traditional basis.
(Pearson, 1924: Plate XI)

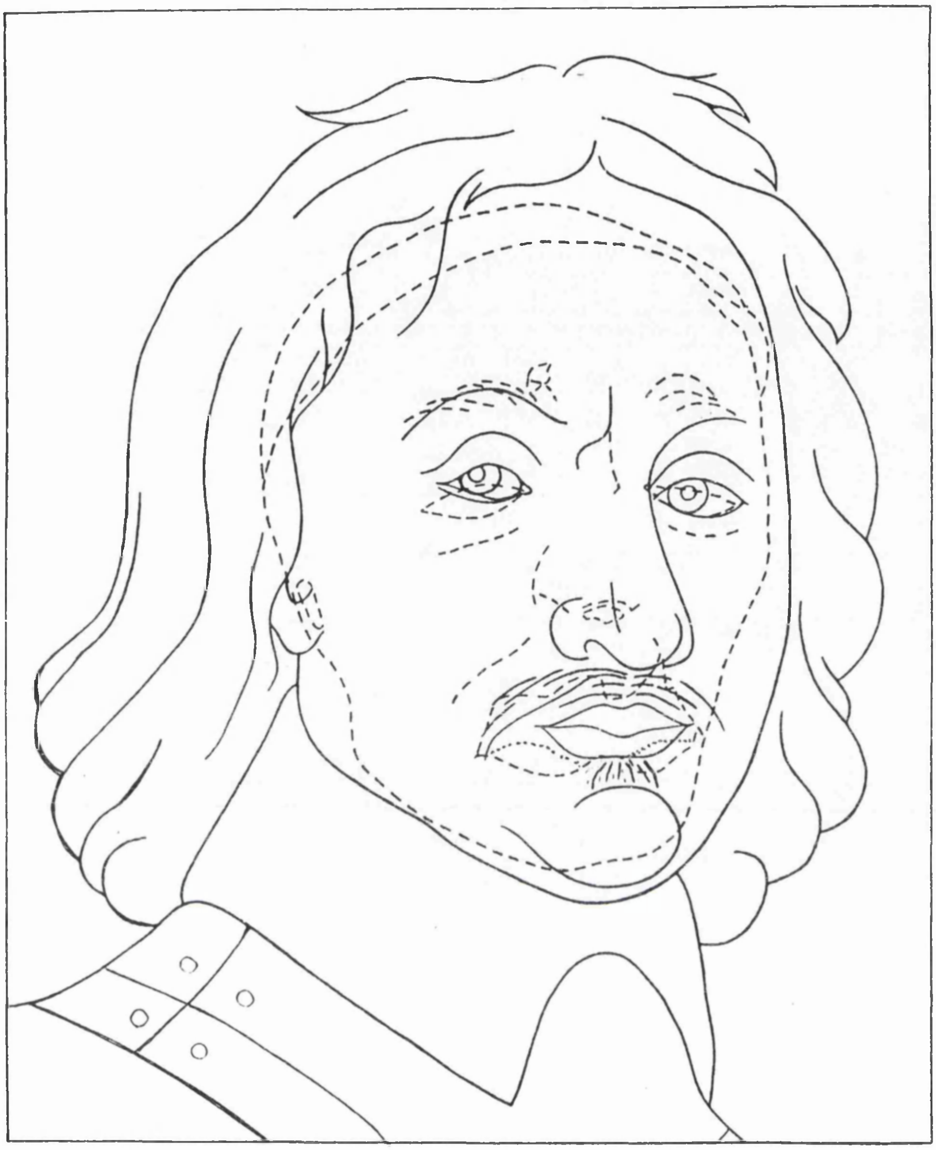
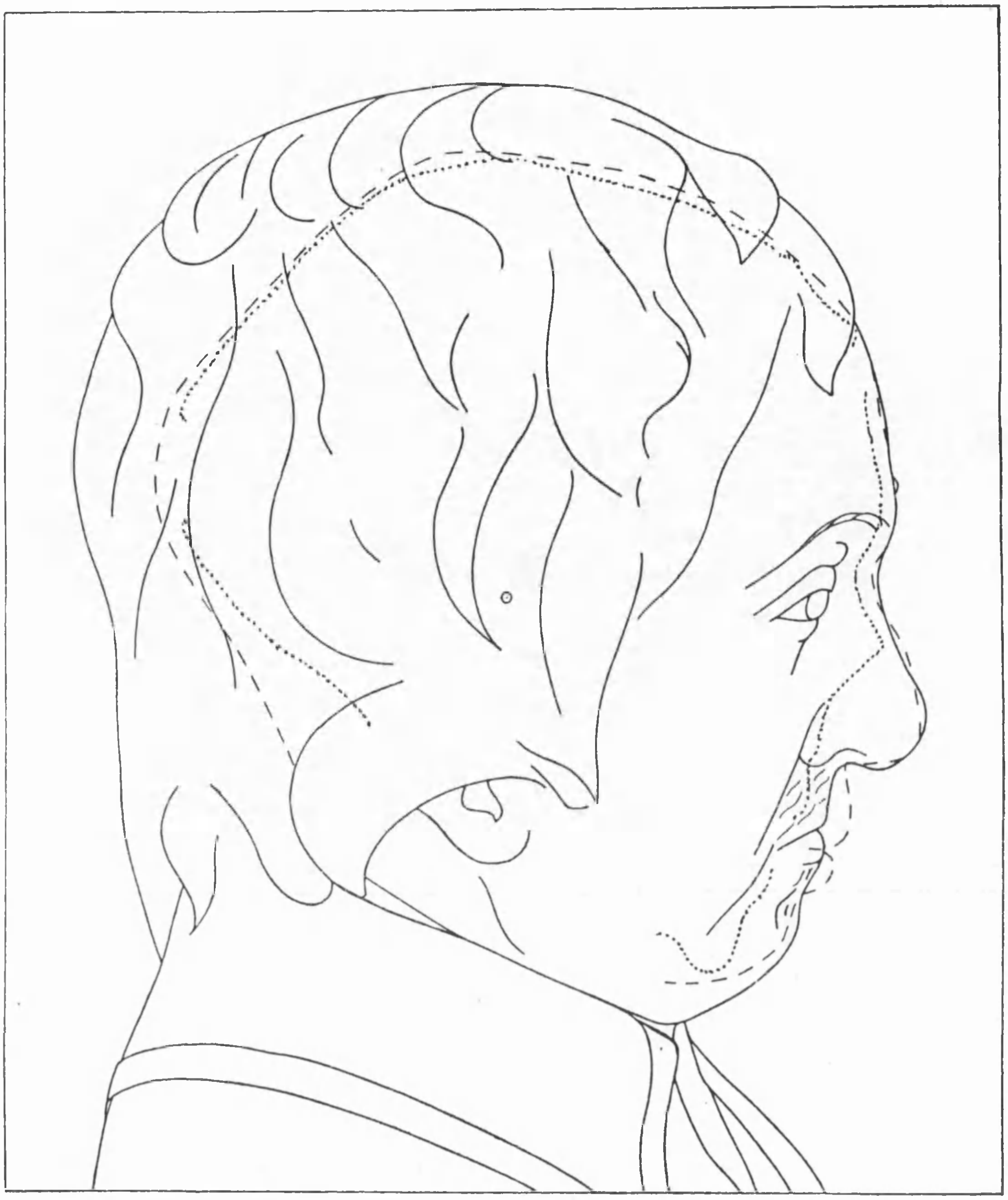


FIGURE 7 (a)
Superimposition of a craniostatic drawing of the "Wilkinson head" fitted to a portrait of Oliver Cromwell. This portrait is by Walker in the Tangye Collection at London Museum.
(Pearson and Morant, 1934: Plate LIII)



Bone Boundary................... **Flesh allowance _ _ _ _ _**

FIGURE 7(b)

Right profile of the King's College, Cambridge Bust (See Plate LXXXI) fitted with (a) bone profile and (b) flesh allowance of the Wilkinson Head. (Pearson and Morant, 1934: Plate C1)

FIGURE 7(c)
The bust of Cromwell in the Library,
King's College, Cambridge.
Right Profile.
(Pearson and Morant, 1934: Plate LXXXI)

FIGURE 8
Dr Buck Ruxton (1899-1936)
(Blundell and Wilson, 1937)

"Ruxton Case"

Leading dates:
1935

Night of 14-15th September: Mrs Ruxton and Miss Mary Rogerson murdered at 2 Dalton Square, probably shortly after midnight.
29th September: Remains found at Gardenholme Linn, Moffat.
12-13th October: Ruxton is charged with the murder of Mary Rogerson and arrested.
5th November: Ruxton is charged with the murder of Mrs. Ruxton.

1936

2nd March: First day of trial at Manchester Assizes.
13th March Buck Ruxton convicted and sentenced to death.
12th May: Execution of Buck Ruxton at Strangeways Prison, Manchester.

(Blundell and Wilson, 1937)

FIGURE 9

A. Studio portrait of Mrs. Isabella Ruxton. This photograph is called "Portrait A" in the comparison of the skulls with the portraits. The portrait shows a tiara found at 2 Dalton Square, Lancaster, and used by Professor Brash in fixing size of life size enlargements.
(Glaister and Brash, 1937, p:147, figure 106)
(Reprinted in Blundell and Wilson, 1937)
(Reprinted in Harvey, 1976, p: 83, figure 32)
(Reprinted in Iscan and Helmer, 1993, p: 38, figure 11)

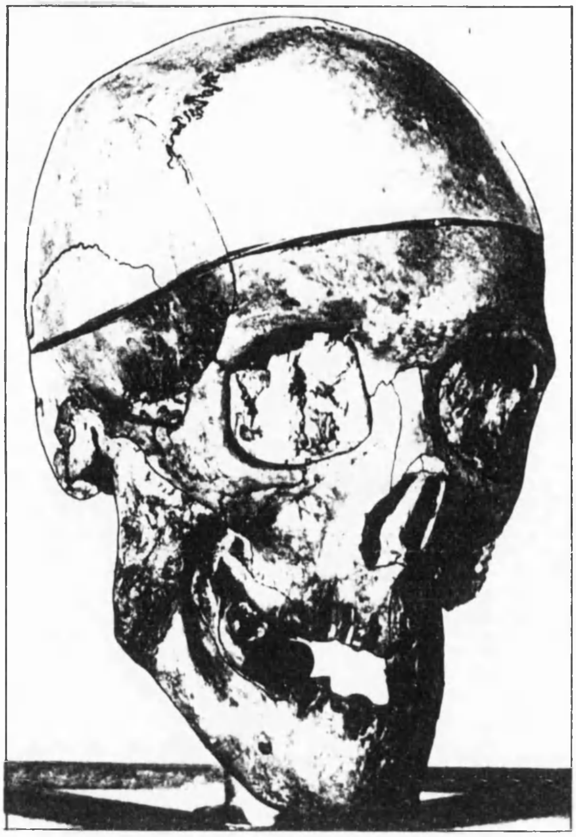
B. Photograph of Mrs. Isabella Ruxton. Original size. This portrait is called "Portrait B"

C. Photograph of Miss Mary Rogerson, standing at gate in a Morecambe street. This gate was used by Professor Brash to obtain life size enlargement of it. This portrait is called "Portrait C". Original size.

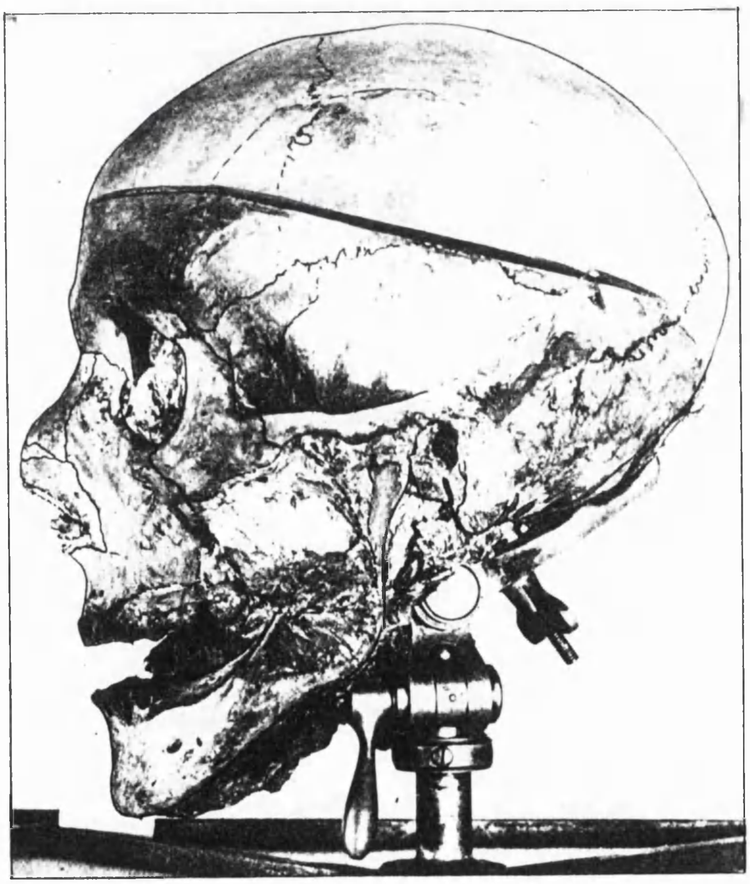
D. Photograph of Miss Mary Rogerson, standing in street at Morecambe. Original size. This portrait is called "Portrait D".

(Glaister and Brash, 1937, p: 147, figures 107, 108 and 109 respectively)

FIGURE 10



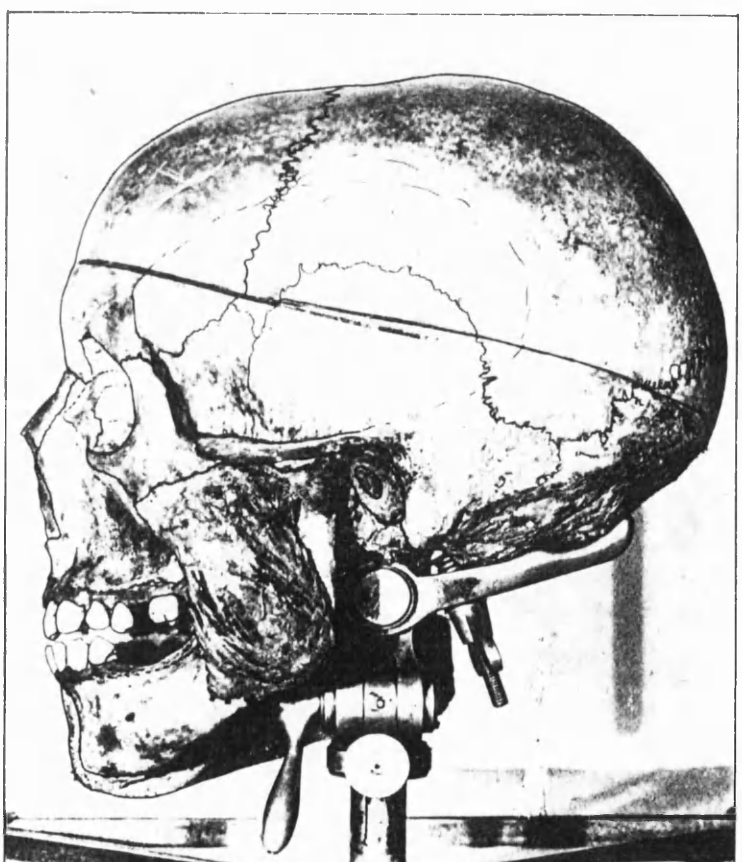
A. Skull N° 2 mounted in the Photograph A Position.
(Glaister and Brash, 1937, p: 149, figure 111)



B. Skull N° 2 mounted in the Photograph B Position.
(Glaister and Brash, 1937, p: 151, figure 113)

FIGURE 11

A. Skull N° 1 mounted in the Photograph A Position.
(Glaister and Brash, 1937, p: 149, figure 110)



B. Skull N° 1 mounted in the Photograph B Position.
(Glaister and Brash, 1937, p: 151, figure 112)

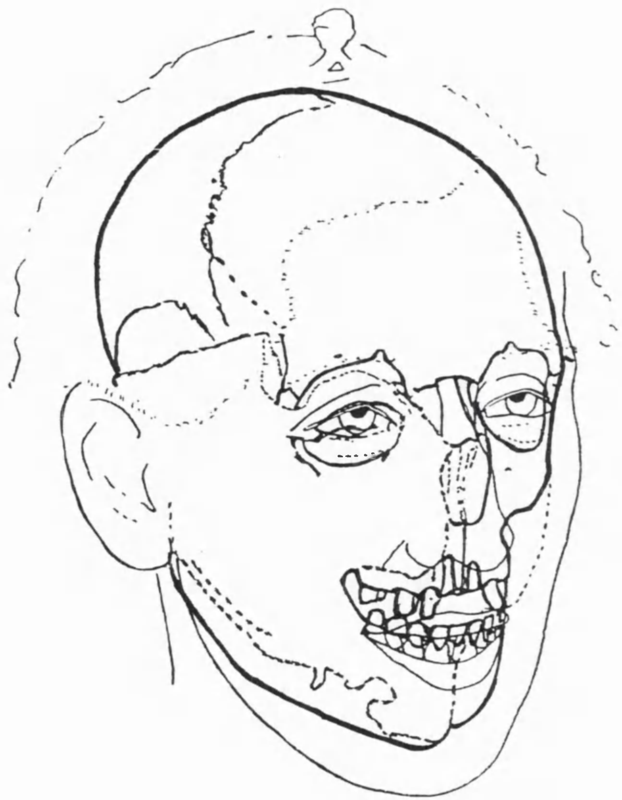
FIGURE 12 A

A1. Mrs. Ruxton: Positive of "Portrait A".

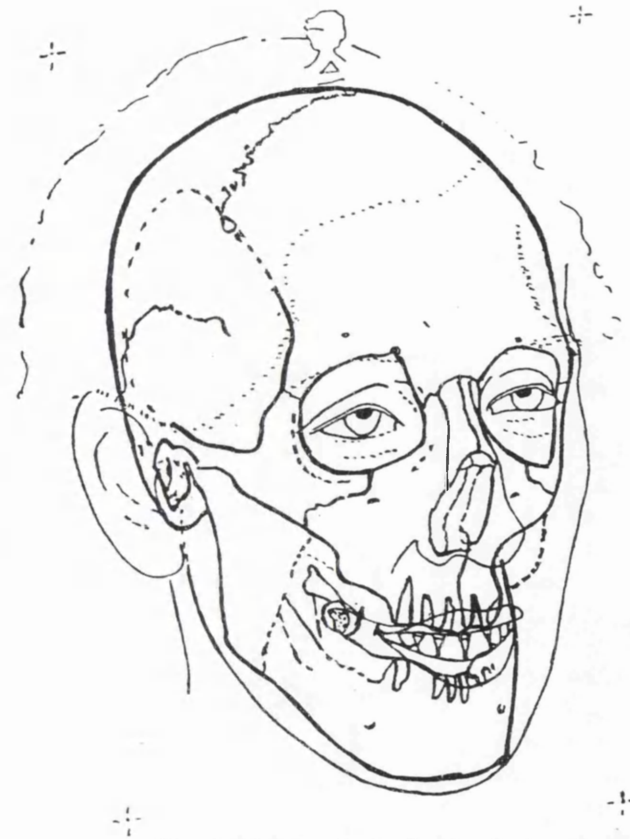
A2. Negative of skull in the "Photograph A"

A3. Mrs. Ruxton: Positive "Portrait A" and skull N° 2. Negative in "A" Position photographically superimposed.
(Glaister and Brash, 1937, p: 162-163, figures 122, 123 and 124 respectively)
(Reprinted in Blundel and Wilson, 1937)
(Reprinted in Harvey, 1976, p: 83, figure 32)

FIGURE 12 B



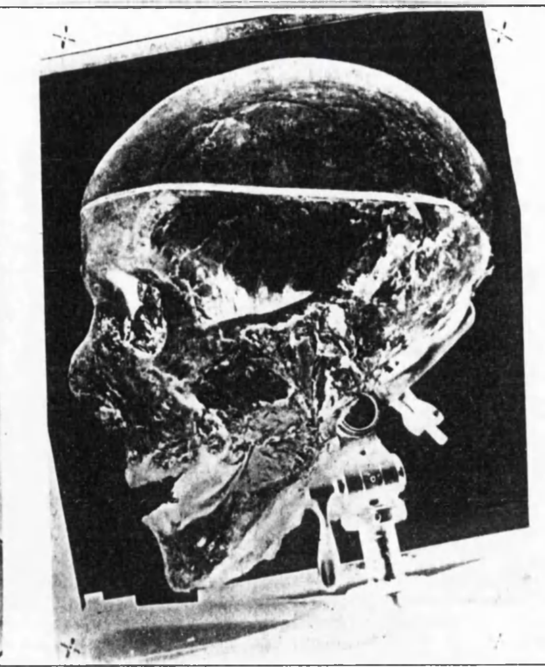
B1. Outlines of skull N° 1 in the "Photograph A". "They do not correspond".



B2. Outlines of skull N° 2 in the "Photograph A". "They appear to correspond well".
(Glaister and Brash, 1937, p: 153, figures 114 and 115)
(Blundell and Wilson, 1937)

FIGURE 12 C

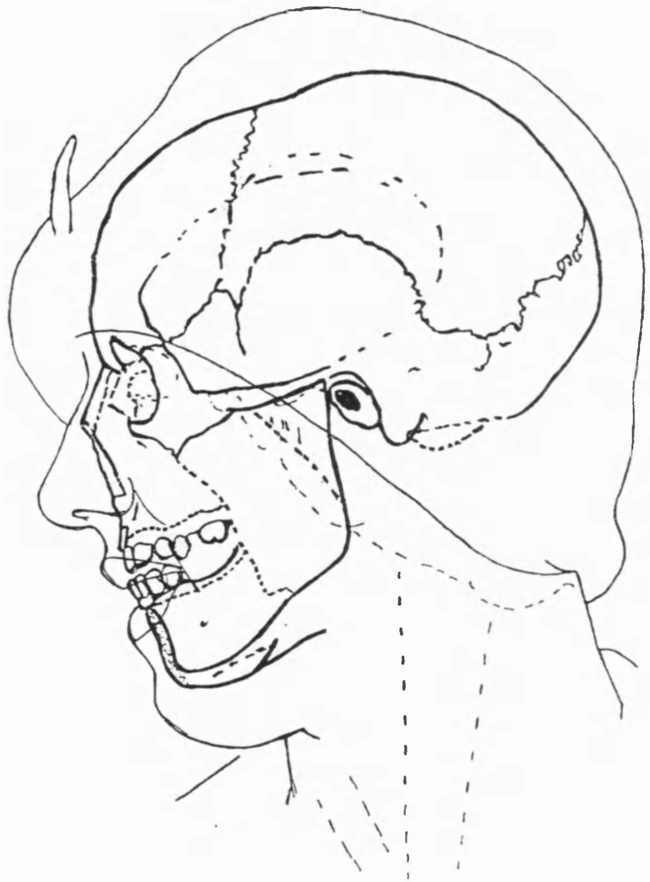
C1. Mrs. Ruxton. Positive of "Portrait B" with registration marks transferred from the superimposed outlines.



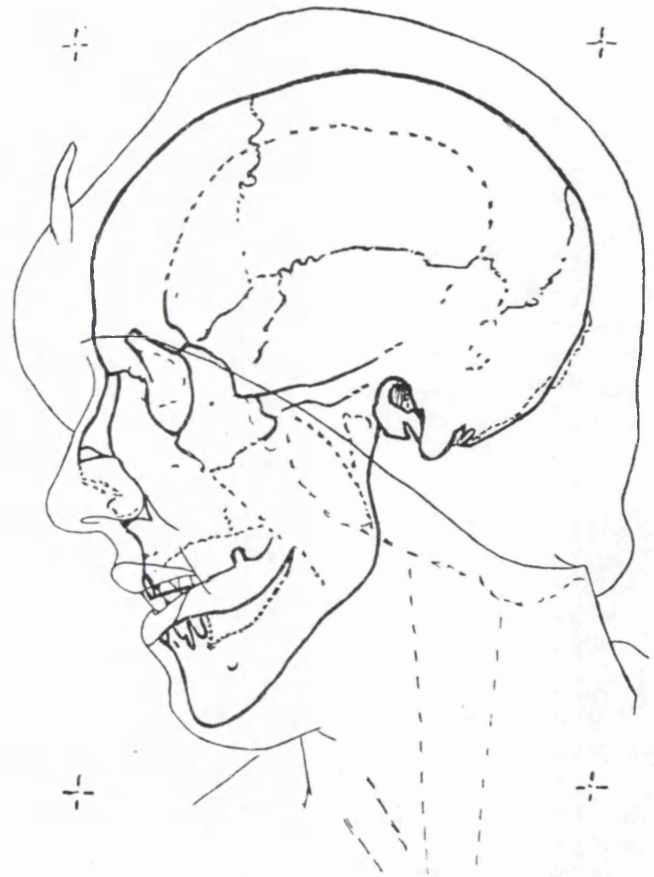
C2. Skull N° 2 in the "Photograph B" Position.

C3. Mrs. Ruxton: Positive "Portrait B" and skull N° 2. Negative in "B"Position photographically superimposed.
(Glaister and Brash, 1937, p: 166-167, figures 125, 126, 127 respectively)

FIGURE 12 D



D1. Outlines of skull N° 1 in the "Photograph B" Position. "The facial outlines do not correspond".



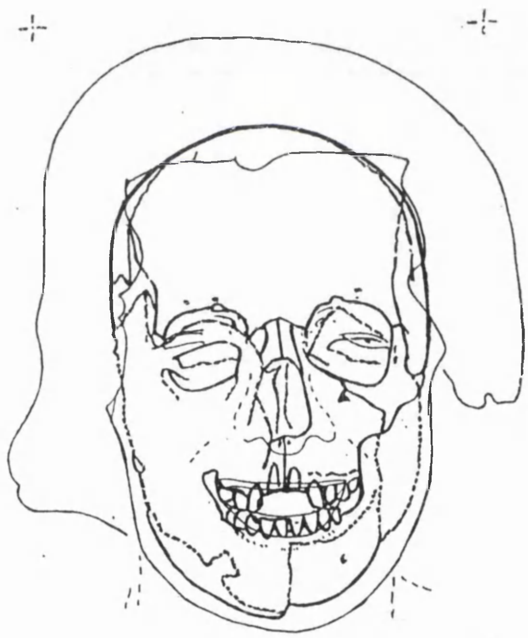
D2. Outlines of skull N° 2 in the "Photograph 2" Position. "The facial outlines appear to correspond well".

(Glaister and Brash, 1937, p: 155, figures 116 and 117)

FIGURE 12 E

E1. Mary Rogerson: Positive Portrait C and skull N° 1. Negative in C position, photographically superimposed.

E2. Mary Rogerson: Positive Portrait D and skull N° 1. Negative in D position, photographically superimposed.
(Glaister and Brash, 1937, p: 168-169, figures 128 and 129)



E3. Outlines of skull N° 1 in the "Photograph C" Position superimposed on outlines of Mary Rogerson's "Portrait C". "The outlines seem to correspond".

E4. Outlines of skull N° 2 in the "Photograph C" Position superimposed on outlines of Mary Rogerson's "Portrait C". "The outlines do not correspond".
(Glaister and Brash, 1937, p: 157, figures 118 and 119)

FIGURE 13
Outlines of the casts of the feet showing their relatives dimensions.
A-A/ A1-A1= greatest breadth
B-B/ B1-B1= greatest length
B1-B2=probable length of part removed from left foot of Body N° 2.
(Glaister and Brash, 1937, p: 141, figure 101)

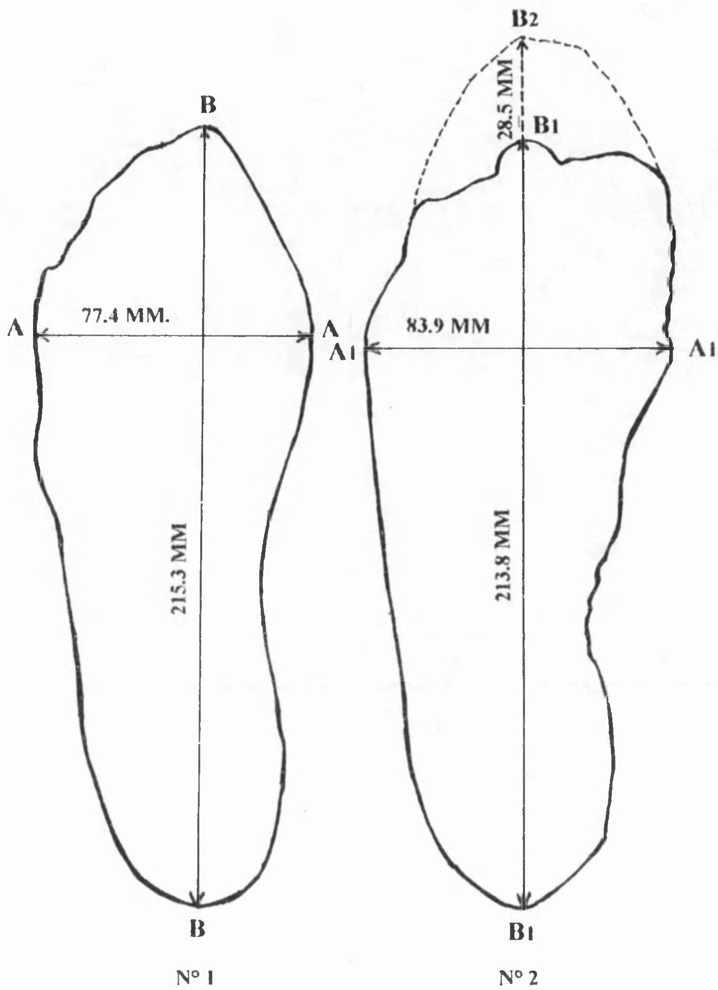


TABLE N° 3 Comparison of casts and shoes.

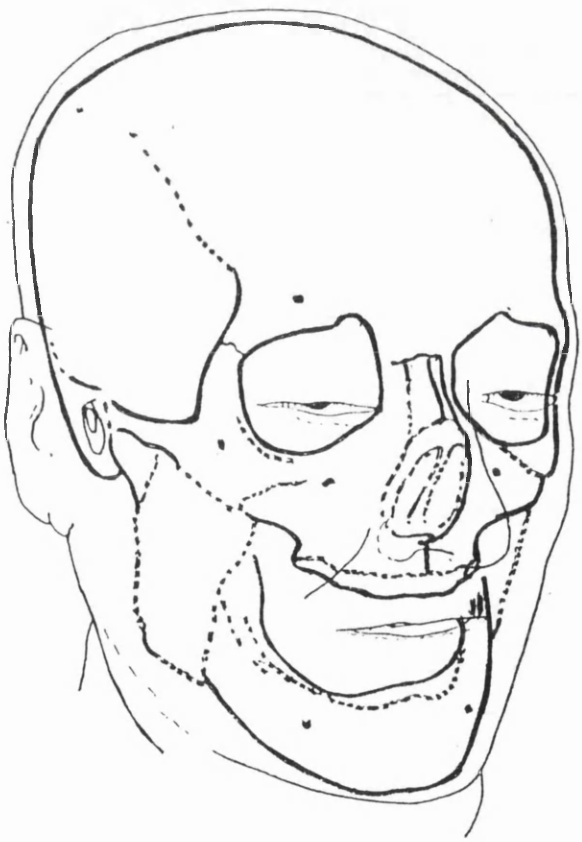
Feet and shoes	Maximum length	Maximum Breadth	Remarks
Foot N° 1 Mary Rogerson's shoe	215.3 mm 220.1 mm	77.4 mm 78.6 mm	After preservation. Inside measurements.
Foot N° 2 Allowance for mutilatioı Probable original measurement Mrs Ruxton's Shoe	213.8 mm 28.5 mm 242.3 mm 245.3 mm	83.9 mm 2.0 mm 85.9 mm 86.0 mm	As found, after preservation Removal of toes and bunion Inside Measurements.

This table shows the general correspondence between the measurements of the feet and the inside measurements of the shoes.
(Glaister an d Brash, 1937, p: 140, Table XIV)

FIGURE 14 A

A1. Head of Anatomical Subject (Female, 84), photographed in the same position as the Head in Mrs. Ruxton's "Portrait A".

A2. Skull of the same Anatomical Subject photographed in the "A" Position.
(Glaister and Brash, 1937, p: 257, figures 163 and 164)

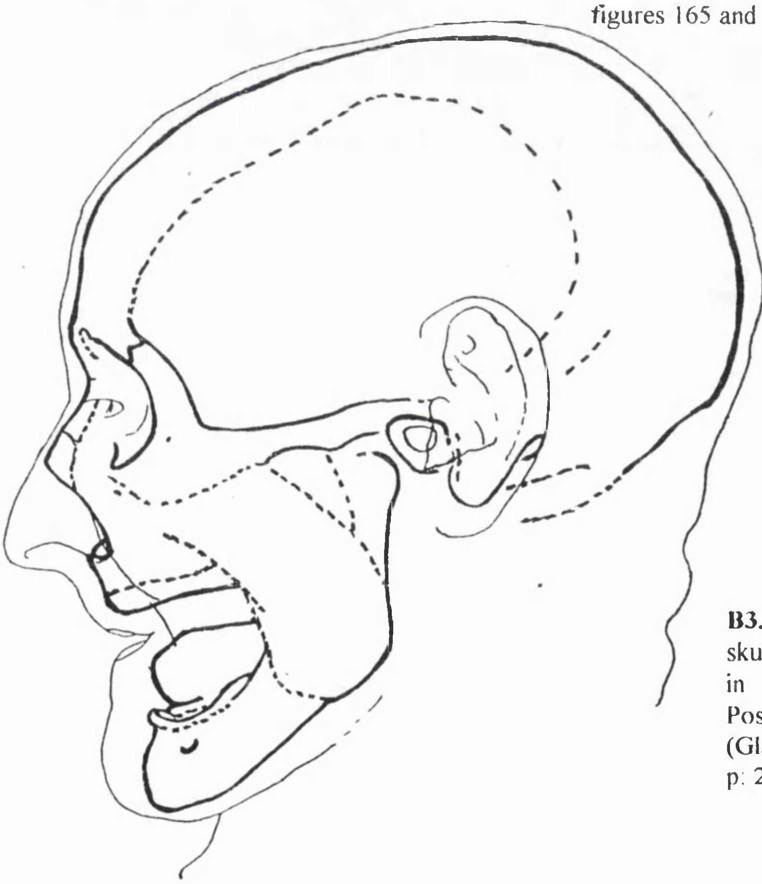


A3. Outlines of Head and of skull of Anatomical Subject in the "Photograph A" Position superimposed.
(Glaister and Brash, 1937, p: 259, figure 167)

FIGURE 14 B

B1. Head of Anatomical Subject (Female, 84) photographed in the same position as the Head in Mrs. Ruxton's "Portrait B".

B2. Skull of the same Anatomical Subject photographed in the " B" Position.
(Glaister and Brash, 1937, p: 258, figures 165 and 166)



B3. Outlines of Head and of skull of Anatomical Subject in the "Photograph B" Position.
(Glaister and Brash, 1937, p: 259, figure 168)

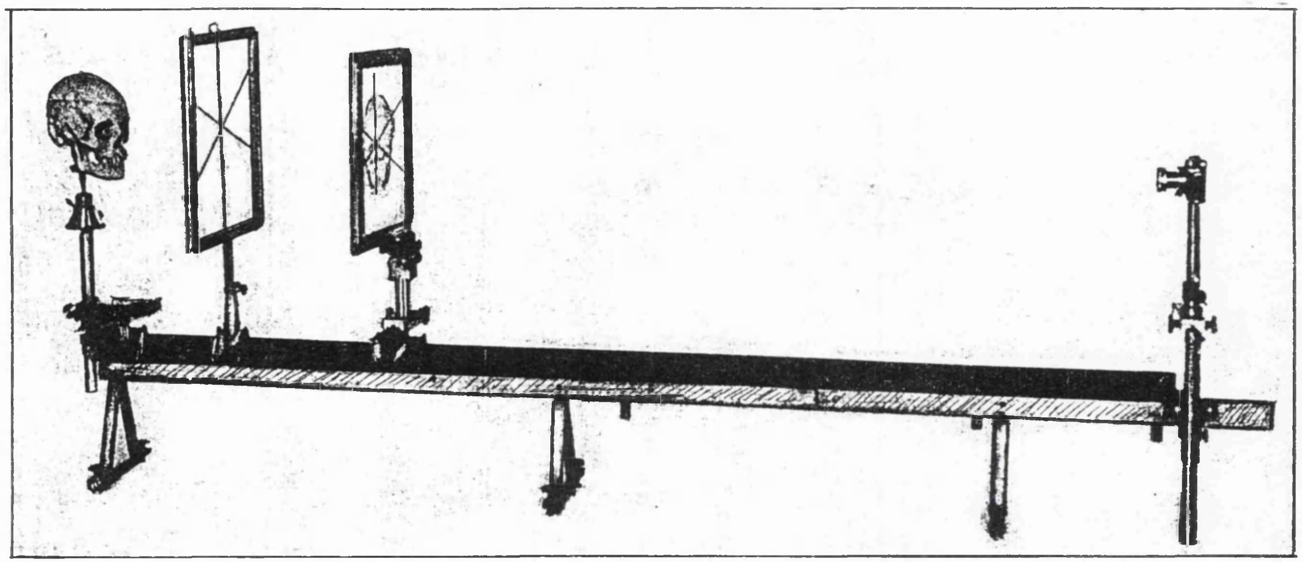


FIGURE 15
Optical apparatus of Grüner and Reinhard (1959)
(Iscan and Helmer, 1993, p: 38, figure 12)

FIGURE 16
This photograph shows the appropriate cephalometric landmarks used by Grüner's technique (Step 1)
(Iscan and Helmer, 1993, p: 38, figure 13)

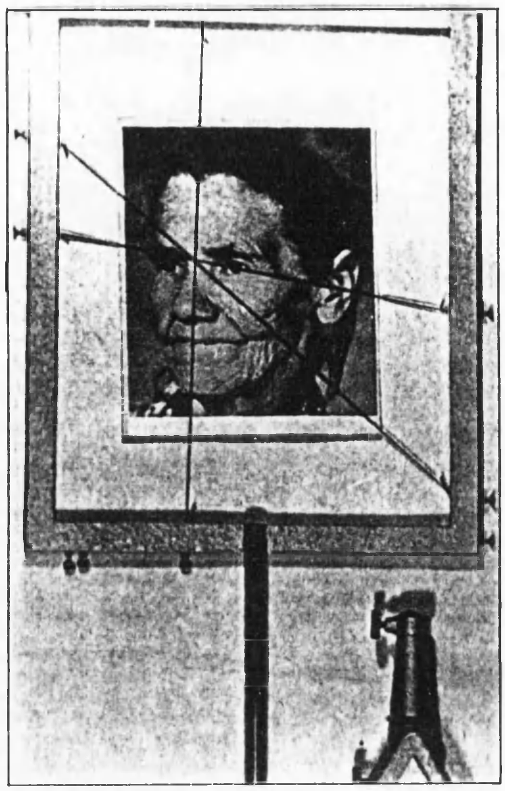


FIGURE 17
This photograph shows the placement of photograph on the Grüner and Reinhard apparatus. (Step 2)
(Iscan and Helmer, 1993, p: 39, figure 14)

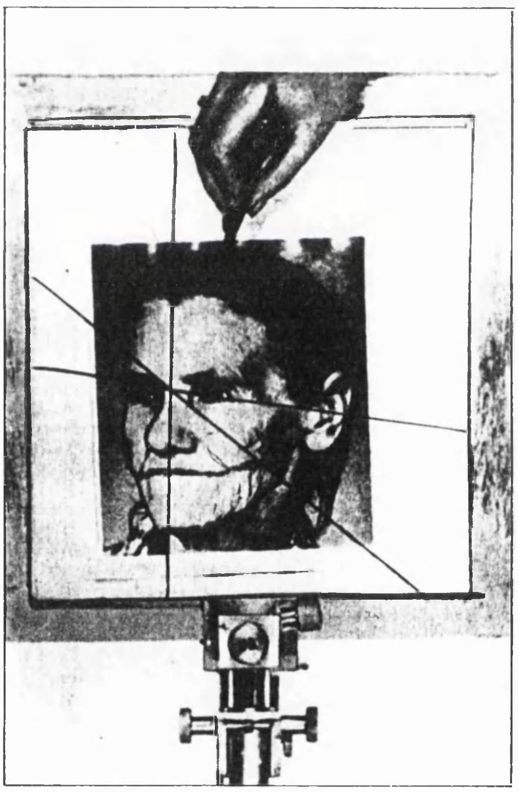


FIGURE 18
This photograph illustrates drawing outlines of the head and guidelines used by Grüner's technique. (Step 4)
(Iscan and Helmer, 1993, p: 39, figure 15)

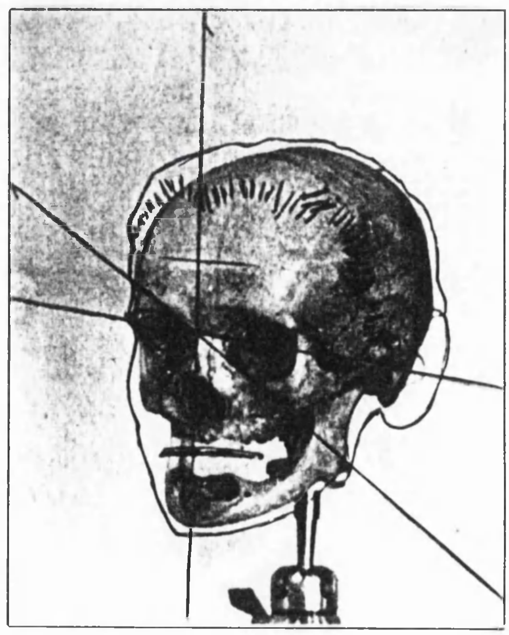


FIGURE 19
This photograph shows positioning of the skull on the drawings used by Grüner's technique. (Step 5)

FIGURE 20

This photograph illustrates the double exposure of the skull and photograph used by Grüner's technique.
(Step 6b)
(Iscan and Helmer, 1993, p: 40, figure 17)

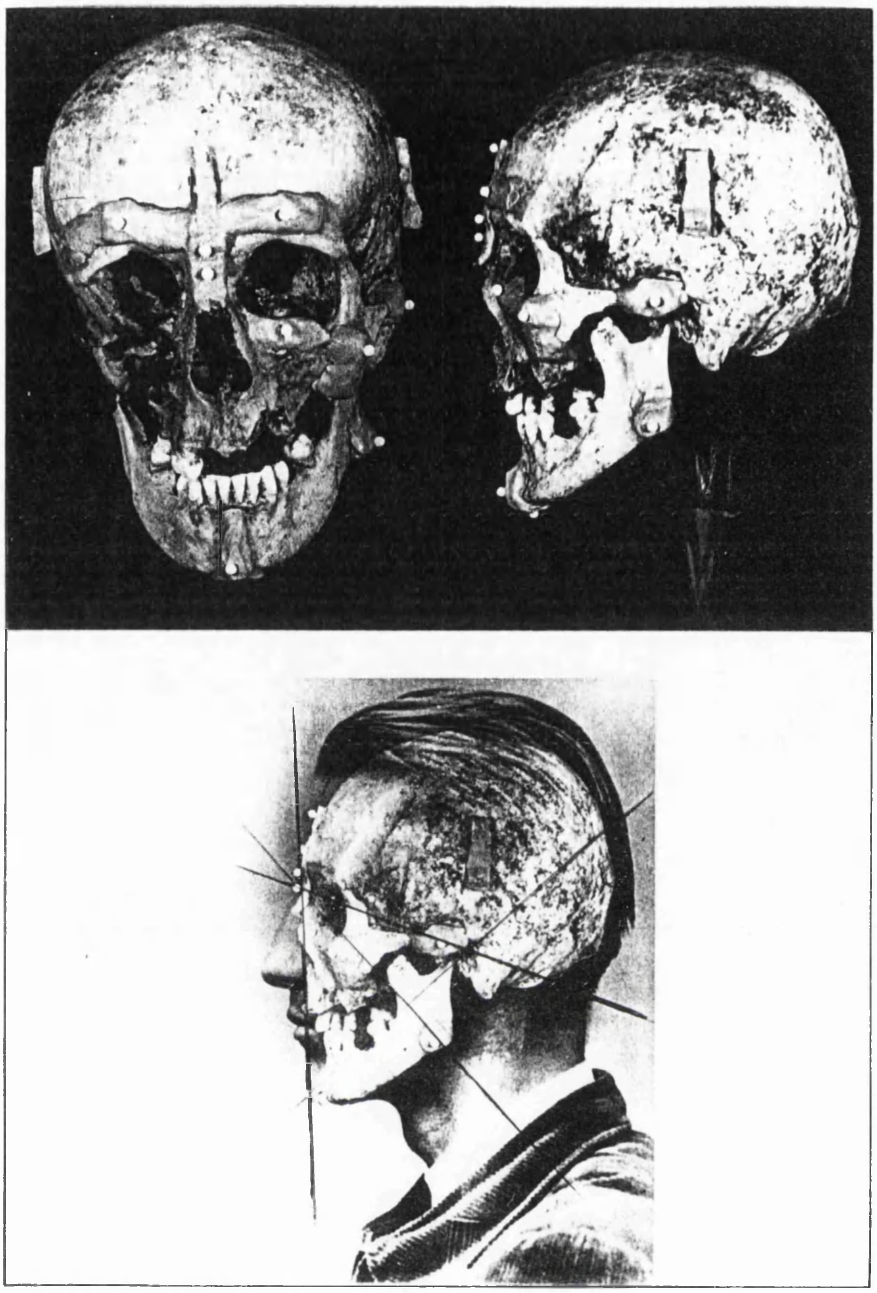


FIGURE 21

This set of photographs illustrates the second procedure used to produce a correct photographic enlargement for superimposition. (The use of classical landmarks.) In this case the landmarks were marked at the marking points with a corresponding layer of plasticine or wax.

(Iscan and Helmer, 1993, p: 41, figure 18)

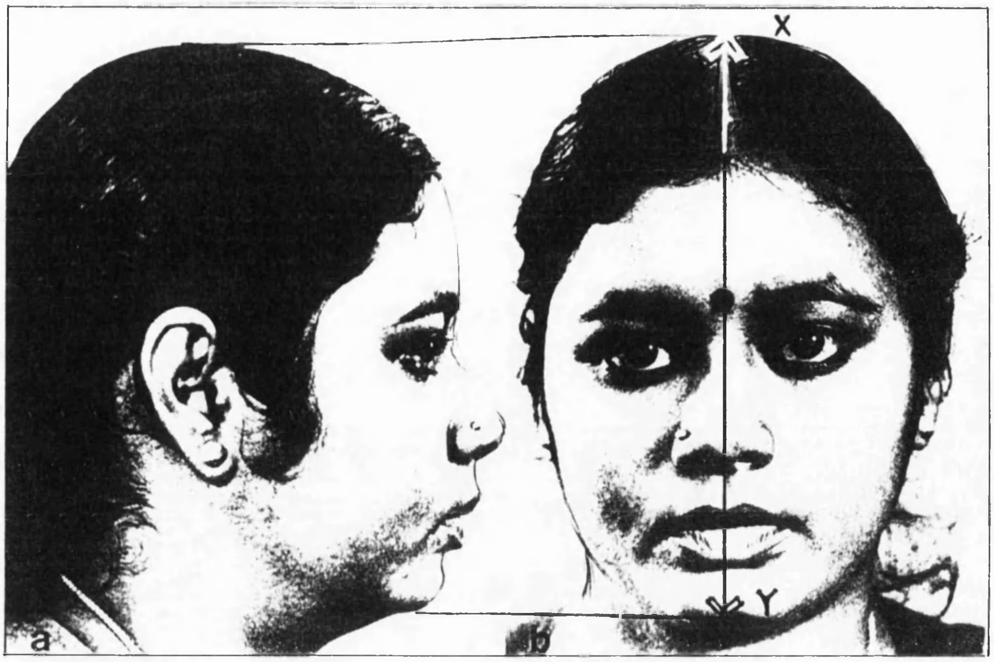


FIGURE 22a
Lateral view of the erect posture of the head.

FIGURE 22b
Frontal view of the erect posture of the head
(Iscan and Helmer, 1993, p: 110, figures 11 a and b)

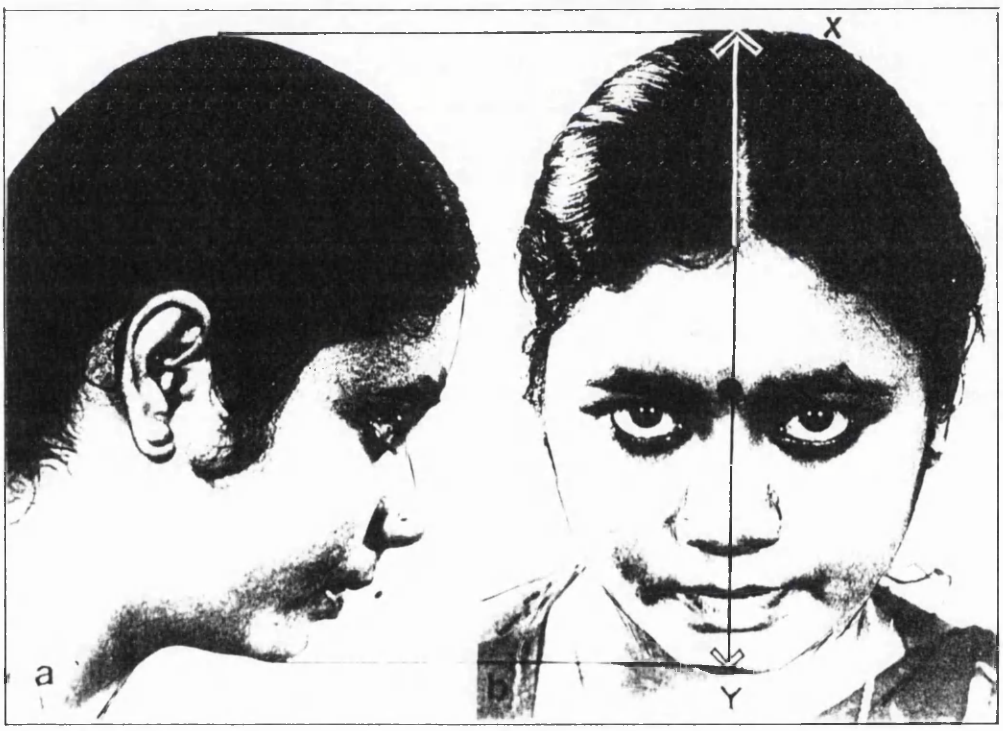


FIGURE 23a
Lateral view of the forward tilted head.

FIGURE 23b
Frontal view of the forward tilted head.
Figures 23a and b and 24 a and b illustrate the factor flexion or extension discussed in the text that in opinion of Sekharan is one of the most important factors to be considered in the posture of the face in a photograph.
(Iscan and Helmer, 1993, p: 110, figures 12 a and b)

FIGURE 24a
Lateral view of the backward tilted head.

FIGURE 24 b
Frontal view of the backward tilted head.
(Iscan and Helmer, 1993, p: 112, figures 13a and b)

FIGURE 25
Frontal view of the laterally tilted head. This photograph illustrates the factor lateral flexion considered by Sekharan in the posture of the face in a photograph. In this case show right lateral flexion.
(Iscan and Helmer, 1993, p: 113, figure 15)

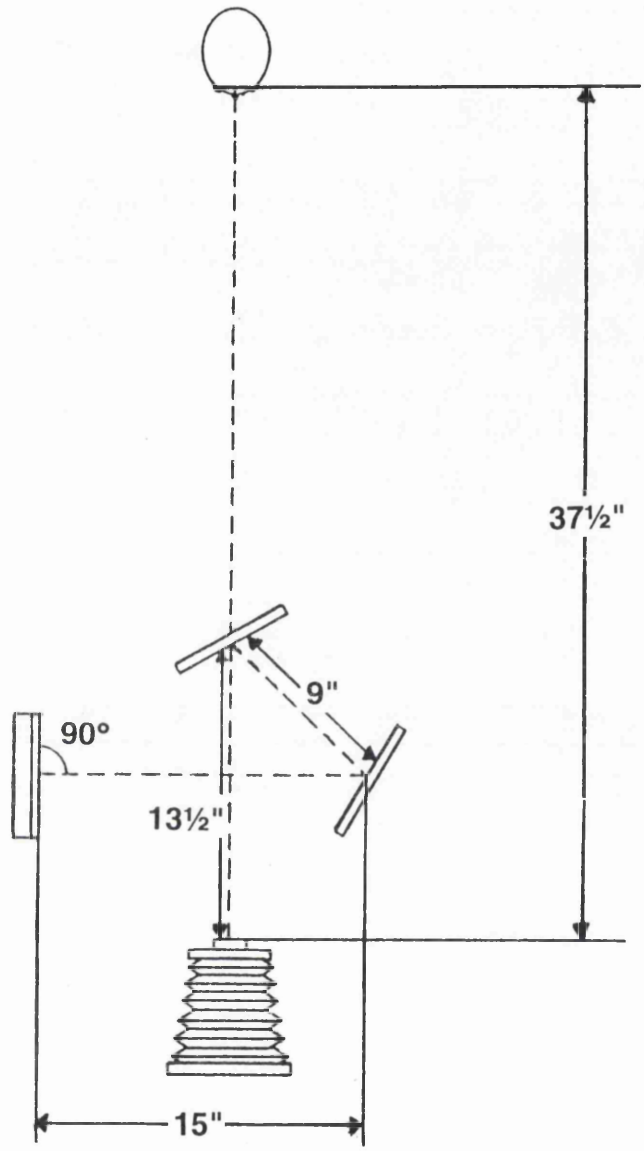


FIGURE 26
Graflex 4 x 5 camera with a 135 mm lens at f-4.5 was mounted directly in front of the skull at a distance of 95.25 cm (37.5 in.)
(Dorion's technique step 2)
(Dorion, 1983, p: 728, figure 2)

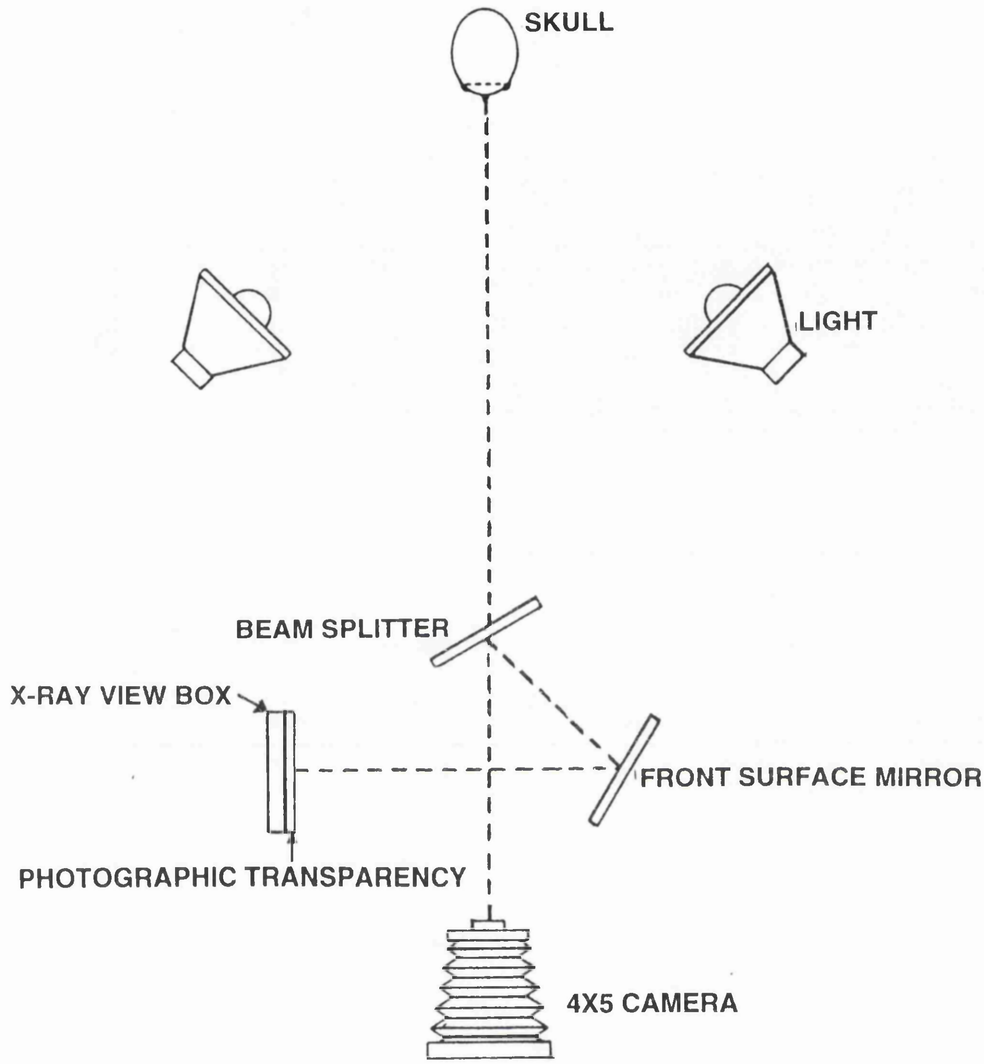


FIGURE 27
A beam splitter and front surface mirror were arranged so as to reflect the image of the subject's photographic transparency
(Dorion's technique step 2)
(Dorion, 1983, p: 729, figure 3)

FIGURE 28
Superimposition of transparencies and tracings of skull Z7 with photograph of Victim 1, giving a positive identification.
This photograph shows the following features of the dentition:
1. Outline of the labial surface of right maxillary canine (piece 13)
2. Outline of the labial surface of right mandibular canine (piece 43)
3. Outline of the distolabial angle of the right maxillary lateral incisor (piece 12)
4. Outline of the distoincisal angle of the right mandibular lateral incisor. (piece 42)
5. Outline of the labial surface and cuspal margin of the left maxillary canine. (piece 23)
6. The cross-bite of the right maxillary and mandibular lateral incisors (pieces 12 and 42).
The distance between the cuspal tips of the maxillary canines (pieces 13 and 23) was not used as an identifying feature because it had been used to establish the magnification factor for the enlargement.
(McKenna et al, 1984, p: 792, figure 2)

FIGURE 29
Superimposition of transparencies and tracings of skull Z6 with a photograph of Victim 2, giving a probable identification. The superimposition resulted in registration of several features of the facial skeleton with those of the photograph of the victim's face, as can see in table 4)
(McKenna et al, 1984, p: 793, figure 3)

FIGURE 30
Superimposition of transparencies and tracings of skull Z_6 with photograph of Victim 3, giving a positive elimination. The photograph of Victim 3 was enlarged so that her two central incisors fitted the corresponding space on skull Z_6. Superimposition of the transparencies demonstrated that skull Z_6 could not have belonged to Victim 3.
(McKenna et al, 1984, p: 794, figure 4)

FIGURE 31
Superimposition of transparencies and tracings of skull Z_{20} with photograph of Victim 3, giving a positive identification. Superimposition resulted in exact registration of the following features of the dentition:
1. Outline of the labial surface of the left maxillary lateral incisor (piece 22)
2. Angulation of piece 22
3. Sockets of the remaining maxillary incisors with the position of the cervical contour of the anterior teeth in the antemortem photograph.
(McKenna et al, 1984, p: 795, figure 5)

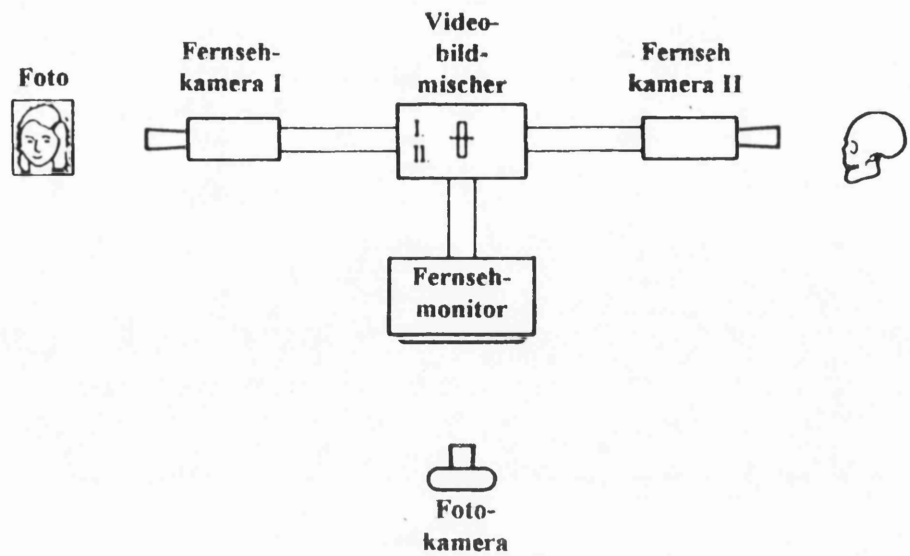


FIGURE 32
Schematic drawing of Grüner and Helmer's video superimposition apparatus
(Iscan and Helmer, 1993, p: 42, figure 19)

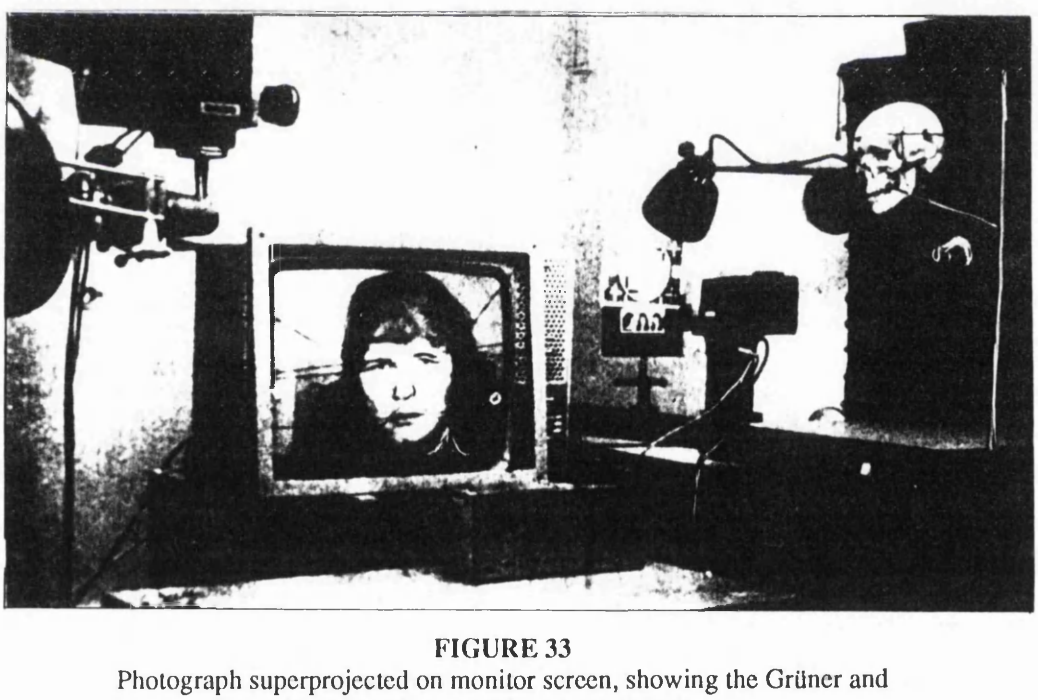


FIGURE 33
Photograph superprojected on monitor screen, showing the Grüner and Helmer video superimposition technique
(Iscan and Helmer, 1993, p: 42, figure 20)

FIGURE 34
Josef Mengele aged 27 years
(Helmer, 1987, p: 1633, figure 8)

FIGURE 35
Skull in position as in comparative photograph in Figure 34, and marked with soft tissue layer markers.
(Helmer, 1987, p: 1634, figure 9)

FIGURE 36
Video Superimposition of the skull and of the comparative photograph.
(Helmer, 1987, p: 1635, figure 10)

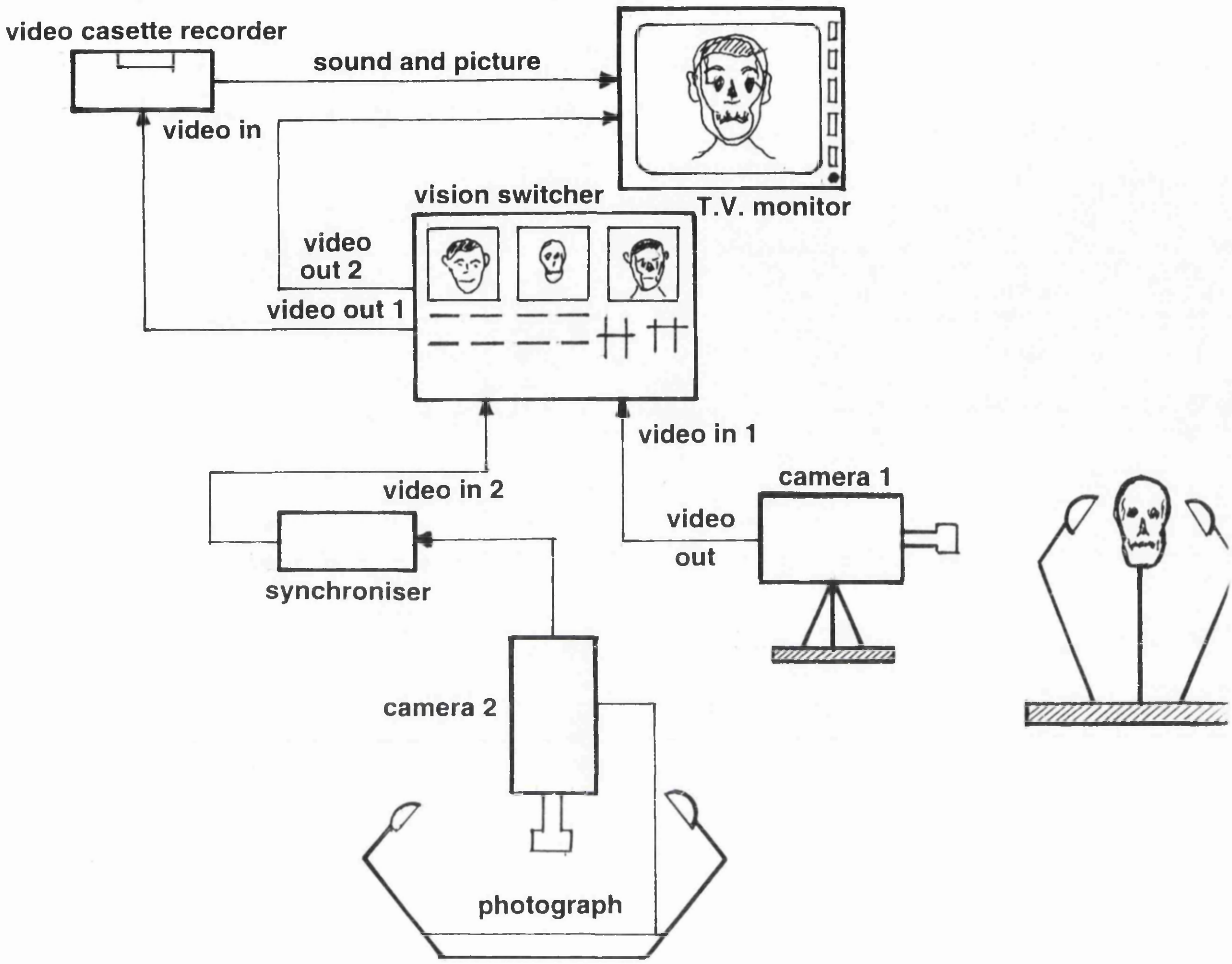


FIGURE 37
Scheme for cranio-facial Video-Superimposition
(Brown, 1977, p. 60, figure 1)

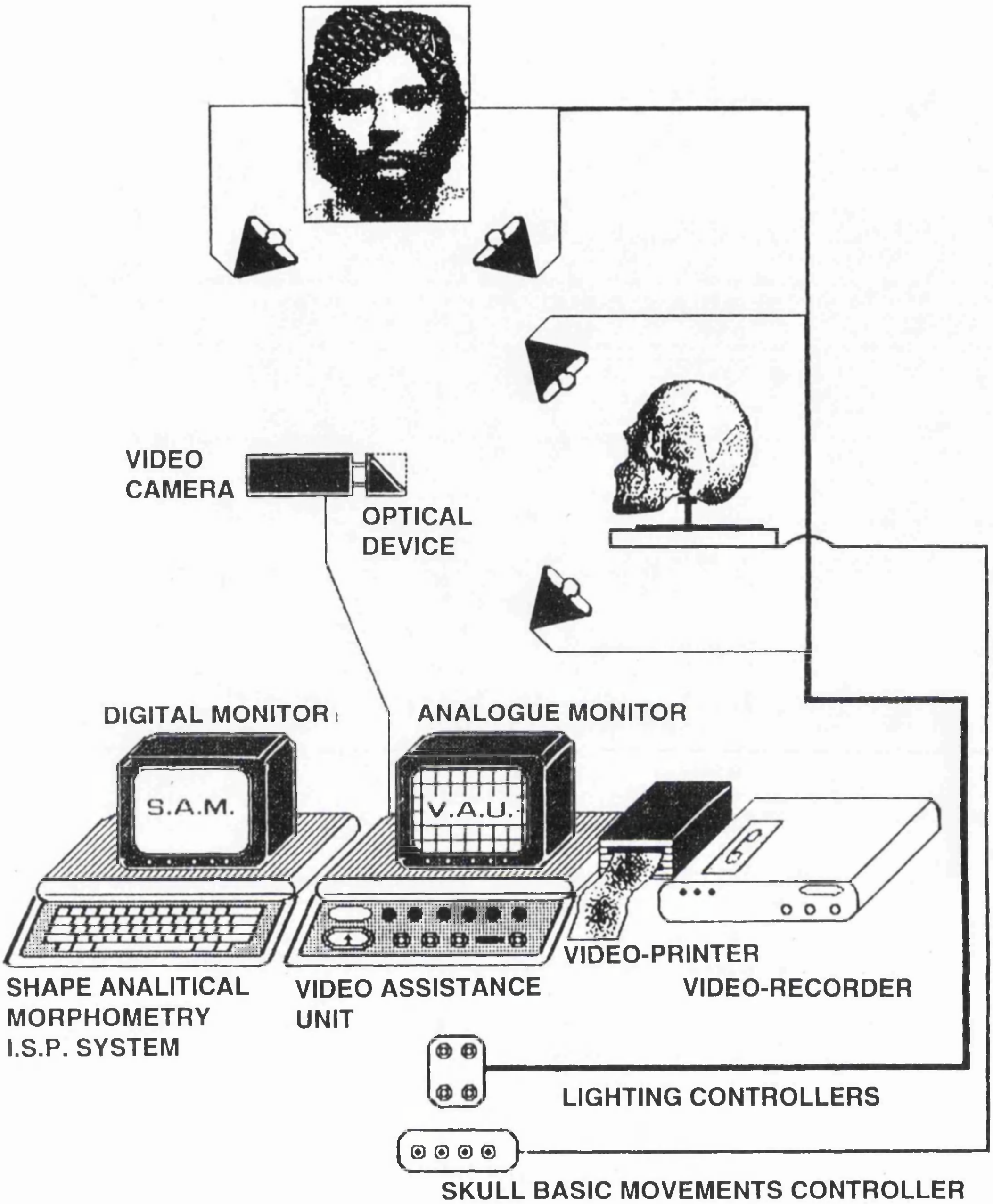


FIGURE 38
Diagram of S. A. M. Forensic super-imposition workstation.
(Pesce Delfino et al, 1986)
(Iscan and Helmer, 1993, p: 133, figure 1)

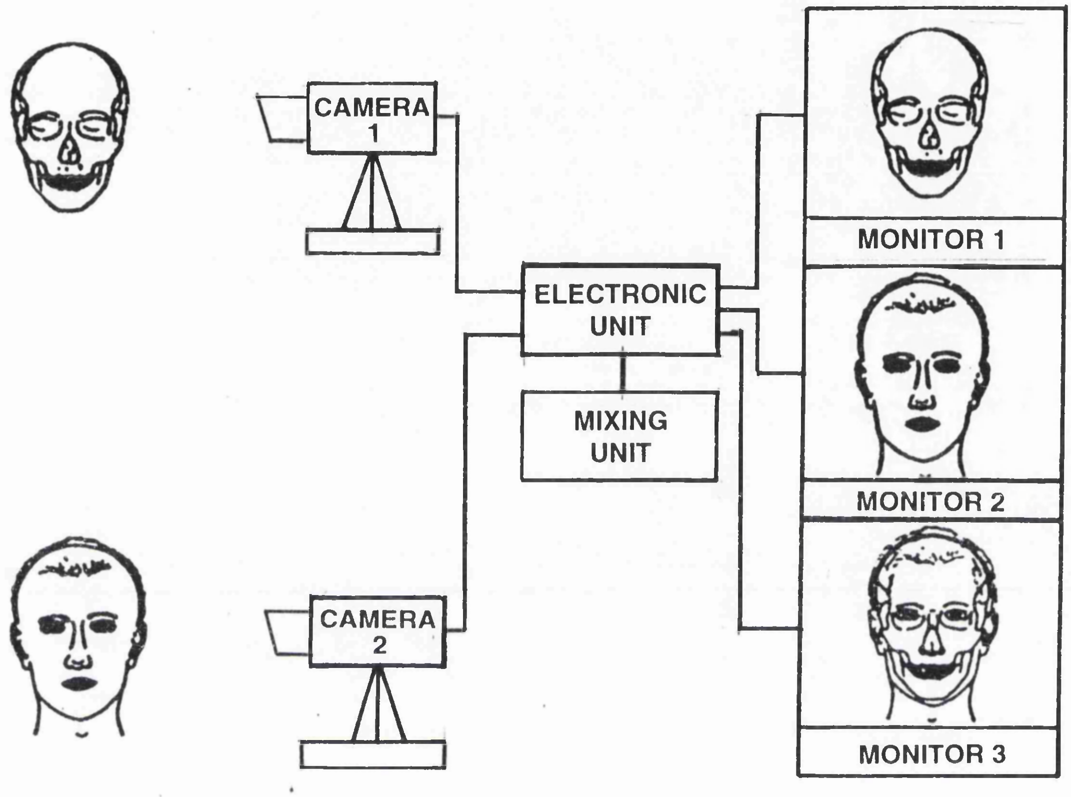


FIGURE 39
Schematic view of the set up of the video comparison apparatus, consisting of two video-tubes 1 and 2, electronic and mixing units, and three monitors. (Iten, 1987, p: 174, figure 1)

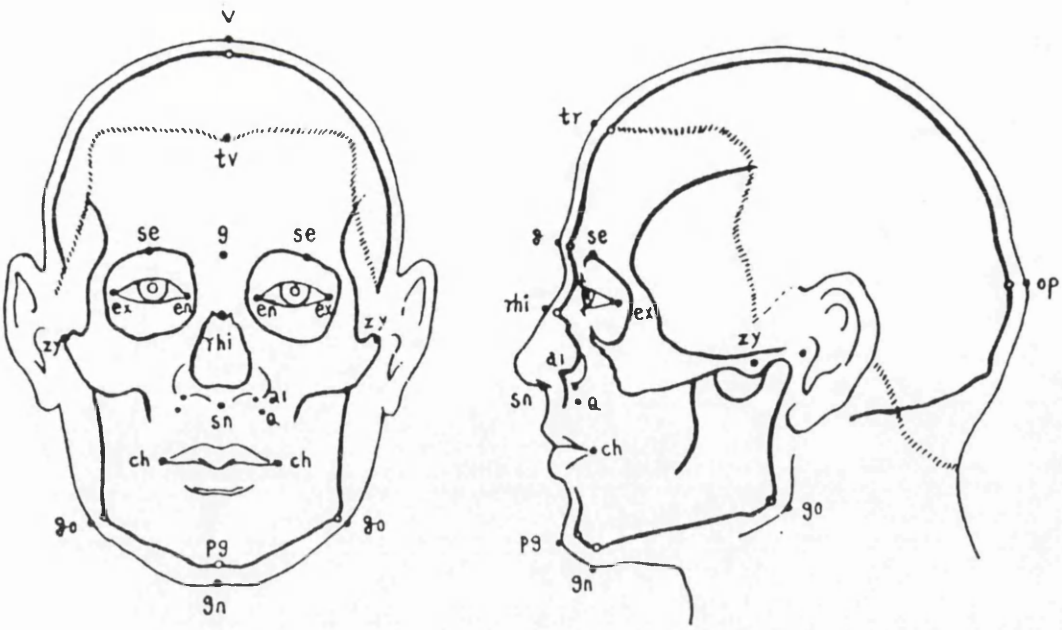


FIGURE 40
Landmarks on the skull and face selected by Chai et al. for a standard identification system for superimposition
(Chai et al., 1989, p: 1344, figure 1)
(Reprinted in Iscan and Helmer, 1993, p: 172., figure 1)

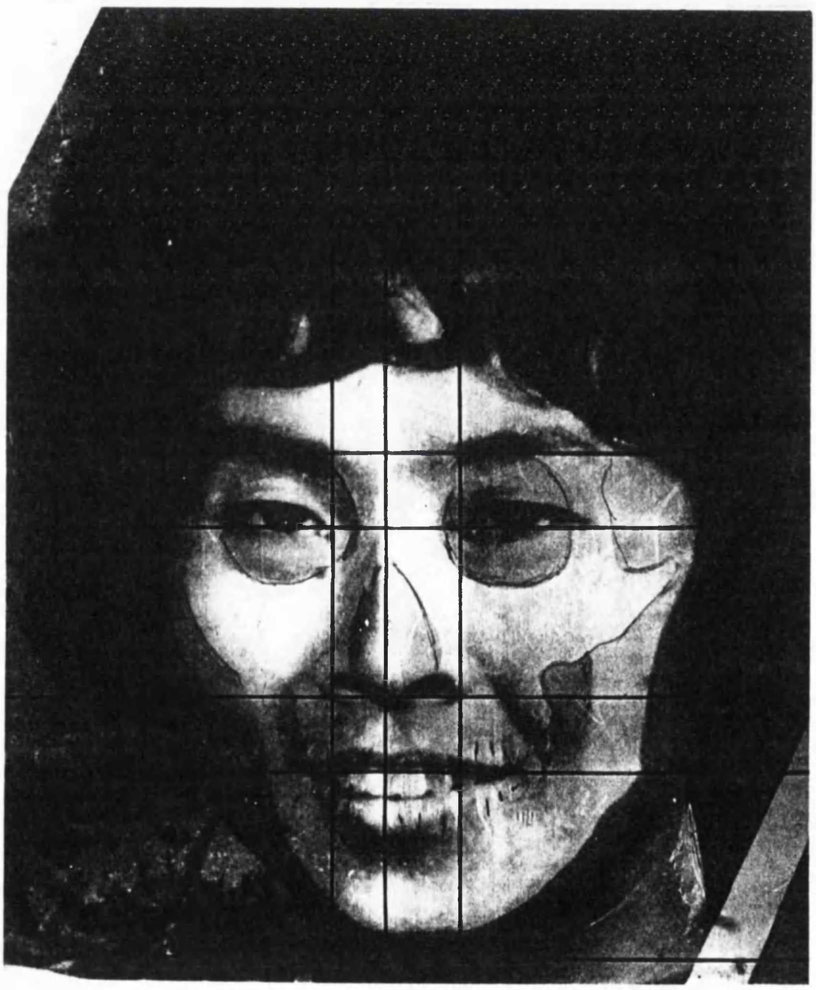


FIGURE 41
The eight determining lines used by Chai et al for a standard identification system for superimposition.
(Iscan and Helmer, 1993, p: 176, figure 4)

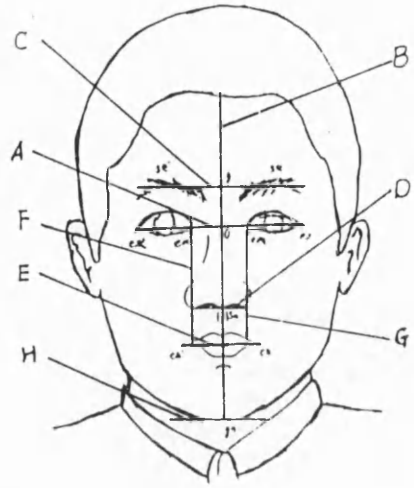


FIGURE 42A
Diagram illustrating marking lines on the face, same as illustrated in figure 41.
A: line ex'-ex, B: front central line g-gn, C: line se'-se, D: line sn, E: line ch'-ch, F: vertical line en'-eh', G: vertical line en-eh, H: line-gn.
(Chai et al., 1989, p: 1345, figure 2)

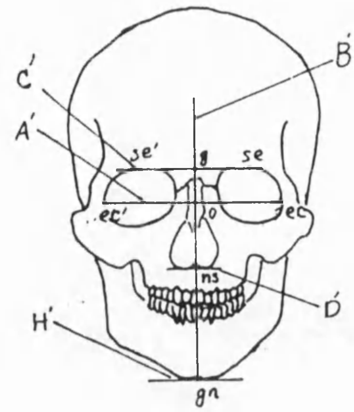


FIGURE 42B
Diagram showing determining lines on skull: A': line ec'-ec, B': front central line g-gn, C': line se'-se, D': line-ns, H': line -gn.
(Chai et al, 1989, p: 1345, figure 3)

TABLE N° 5
Examining lines on the Face and Skull Images

Face Image		Skull Image
Glabella line		Upper orbit tangent
Central line		Central line
Gnathion line		Gnathion tangent
Ectocanthion line		Line between junctures of external orbit
Subnasale line		Piriform aperture lower tangent
Cheilion line		Mouth line
Vertical line through left endocanthion		Left canine
Vertical line through right endocanthion		Right canine

(Iscan and Helmer, 1993, p: 176, table 2)

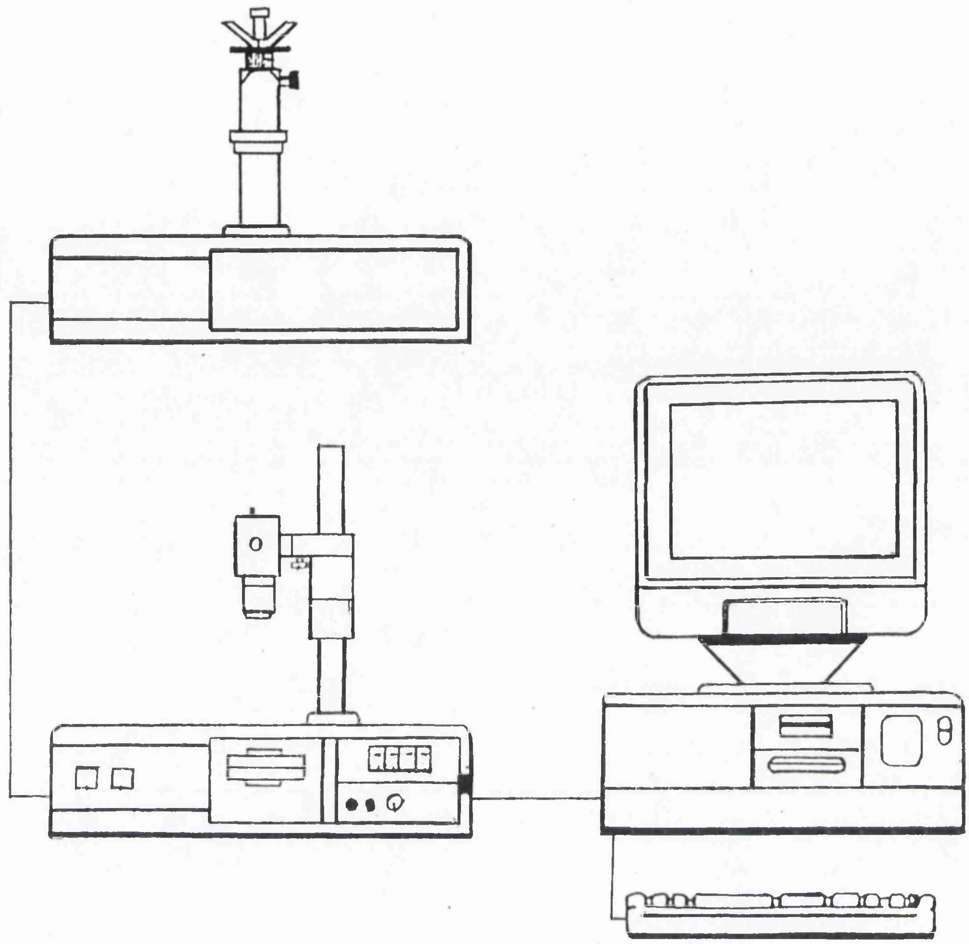
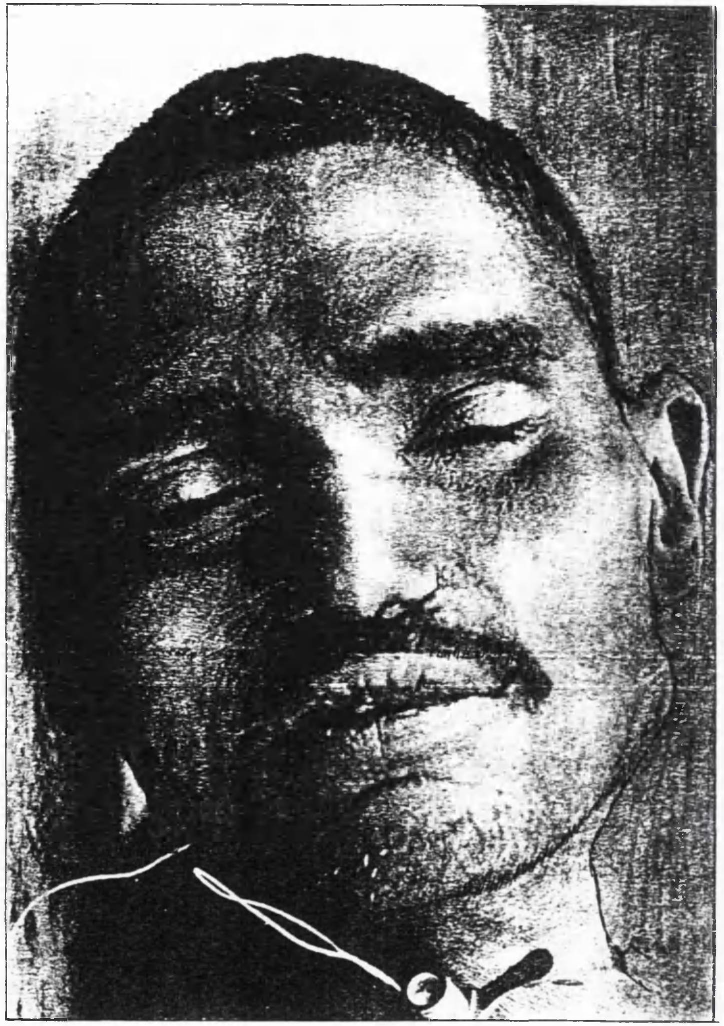


FIGURE 42 C
Schematic diagram of TGLA-213 System
(From User's guide of the system, 1994, p: 17)



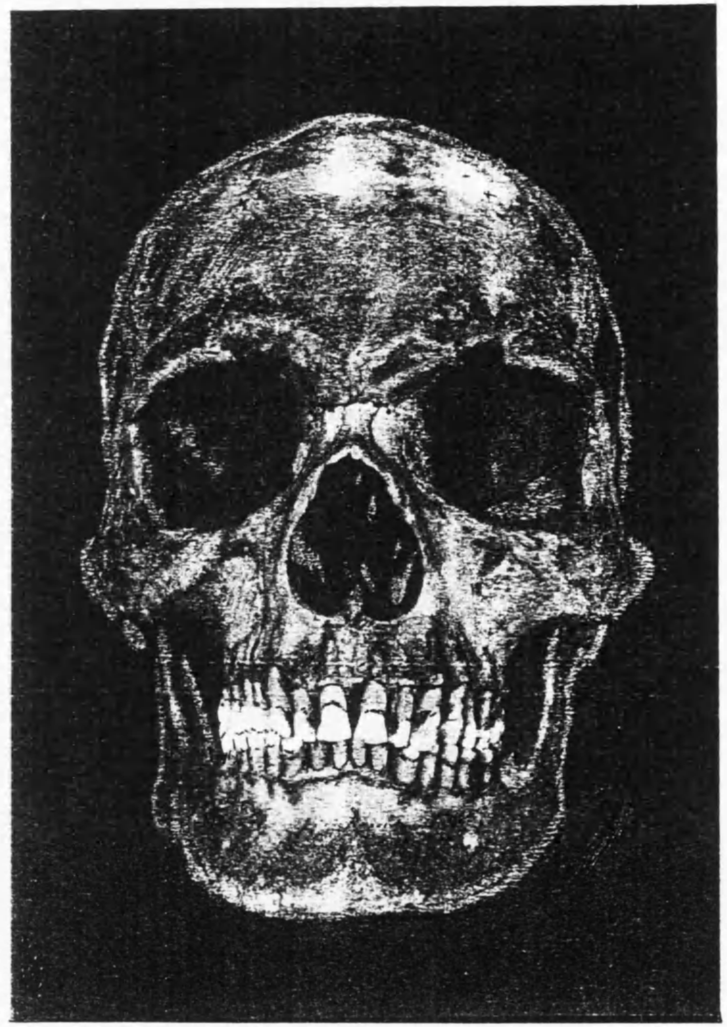


FIGURE 43A

Photographs illustrating The Egyptian criminal head and his skull.
(Pearson and Morant, 1934, "The Wilkinson head of Oliver Cromwell and its relationship to busts, masks and painted portraits." Biometrika Vol. xxvi, p: 269-378, Plate I)

FIGURE 43B
Diagram illustrating superimposed facial tracings from Derry's photographs of an executed Egyptian criminal and his skull to show the manner in which the original skull fits its actual face.
(Pearson and Morant, 1934, Biometrika, Vol. xxvi, p: 269-378, Plate II)
(Reprinted in Stewart, 1979, p: 272, figure 81)

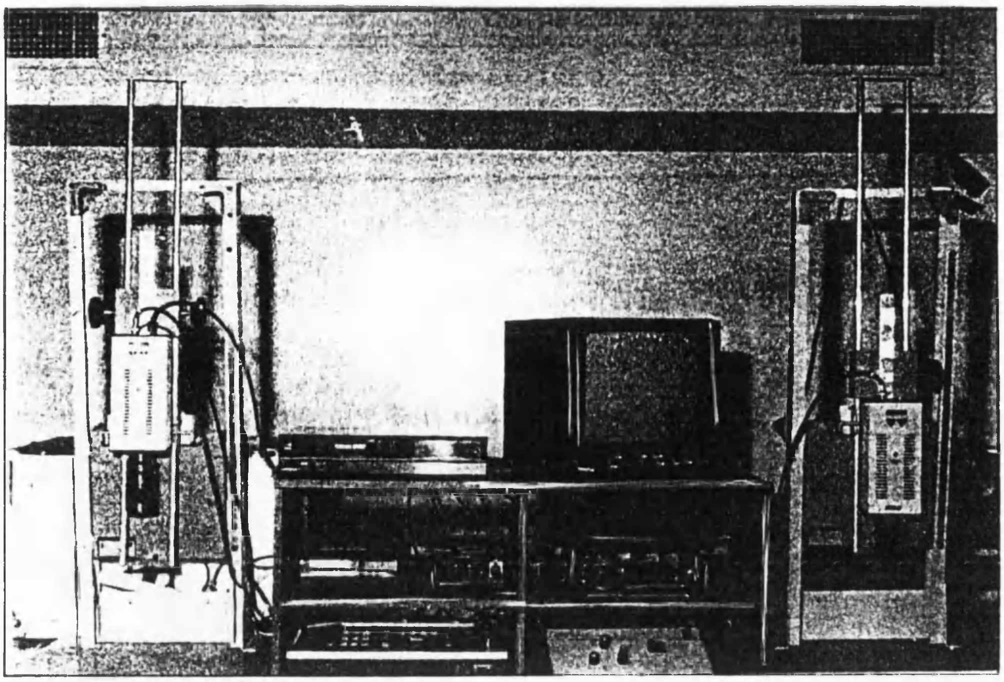


FIGURE 44
Video-Superimposition equipment used by Austin-Smith et al.
(Austin-Smith et al., 1994, p: 449, figure 1)

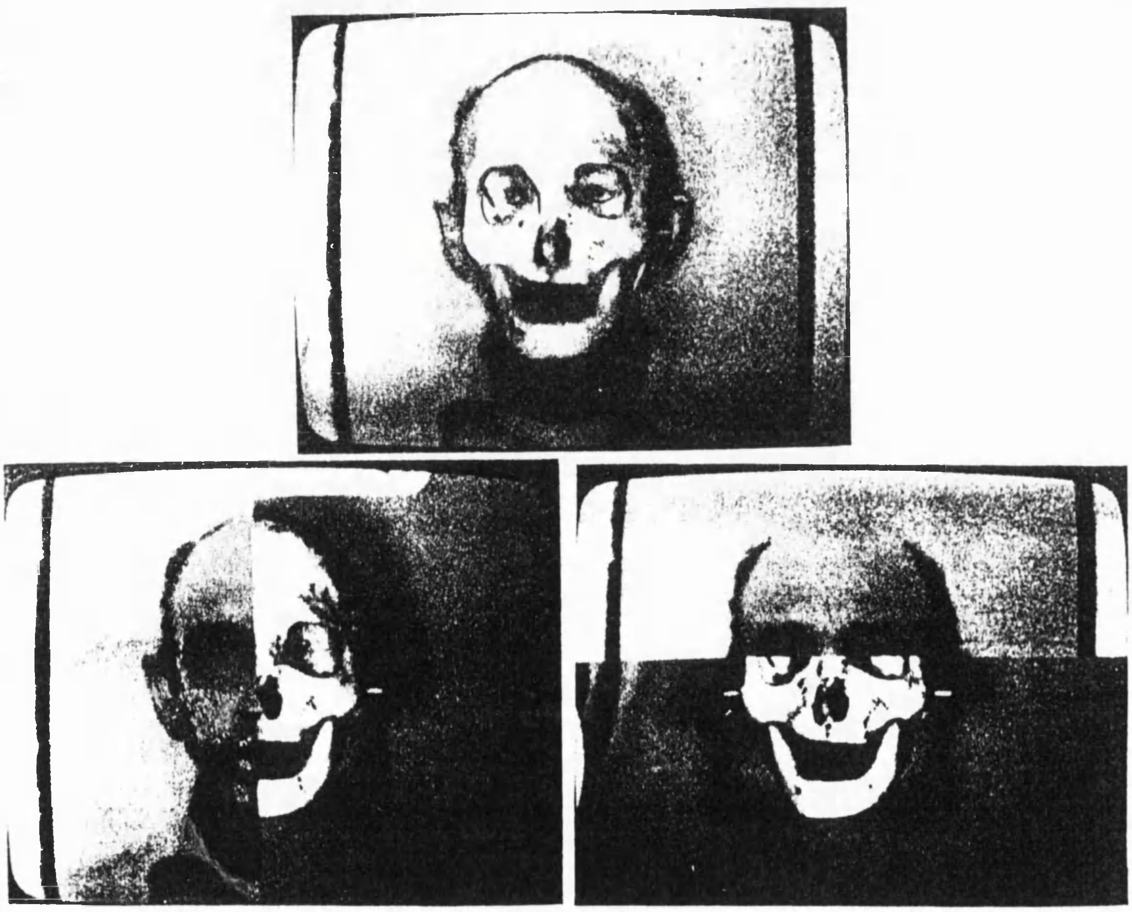


FIGURE 45
Photographs illustrating an example of "good match" according to the criteria used by Austin-Smith et al., Top: superimposed view. Bottom: Vertical and Horizontal wipes.
(Austin-Smith et al., 1994, p: 449, figure 2)

FIGURE 46
Diagram showing the frontal view of J. S. Bach' skull.
(His, 1895a, p: 382, figure 1)

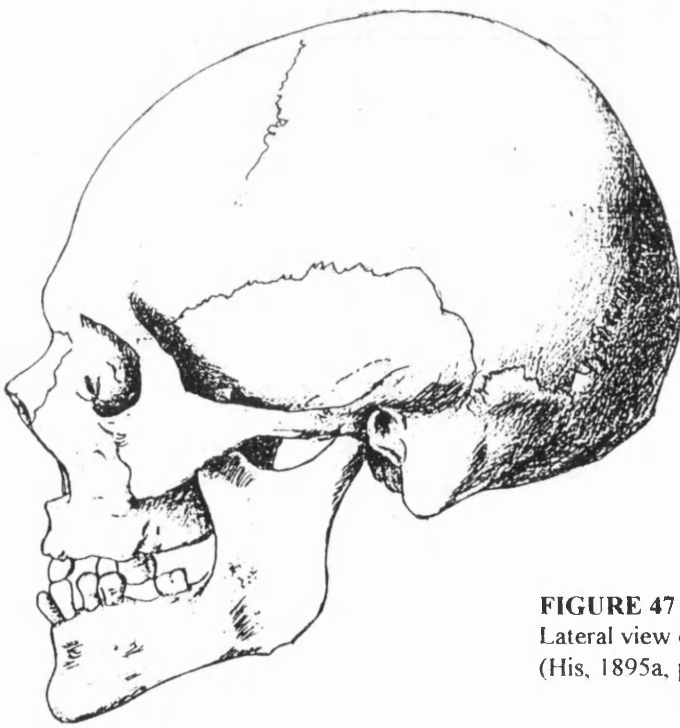


FIGURE 47
Lateral view of J.S. Bach' skull
(His, 1895a, p: 382, figure 2)

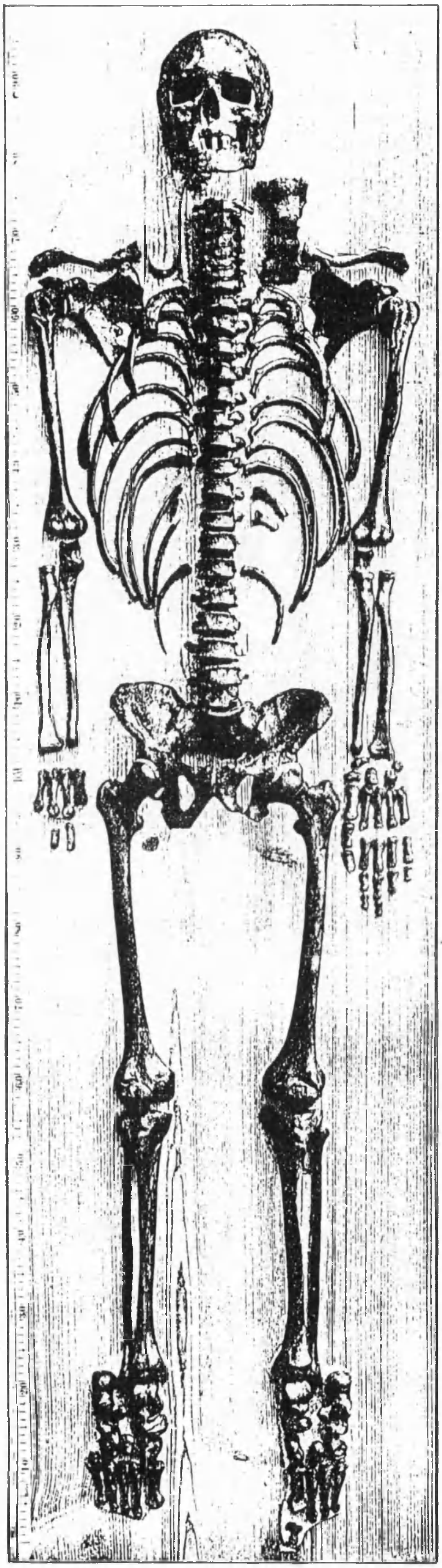


FIGURE 48
Skeleton of J. S. Bach
(His, 1895a, p: 420)
(Reprinted in Iscan and Helmer, 1993, p: 31, figure 3)

FIGURE 49
Facial Reconstruction of J. S. Bach. The sculptor Seffner applied His' method, using a plaster cast of the skull.
(His, 1895a)
(Reprinted in Iscan and Helmer, 1993, p: 30, figure 1)

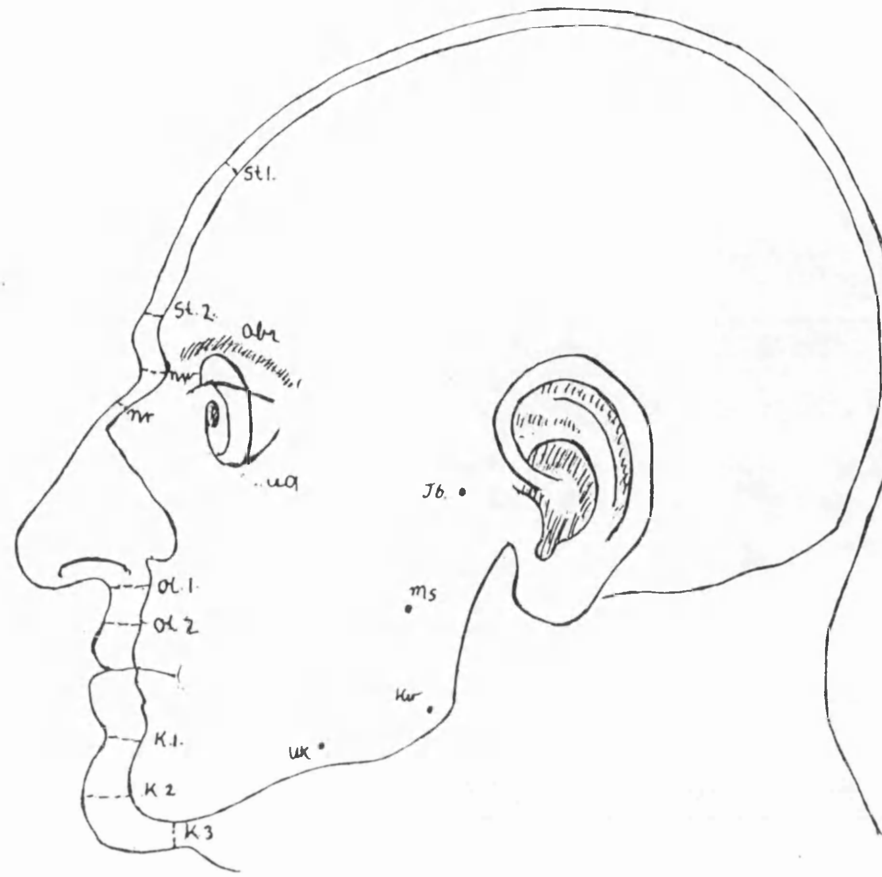


FIGURE 50
Lateral diagram illustrating the locations of soft tissue thicknesses (15) measured by His.
(His, 1895a, p: 405, figure 15)
(Reprinted in Krogman and Iscan, 1986, p: 433, figure 11.18)

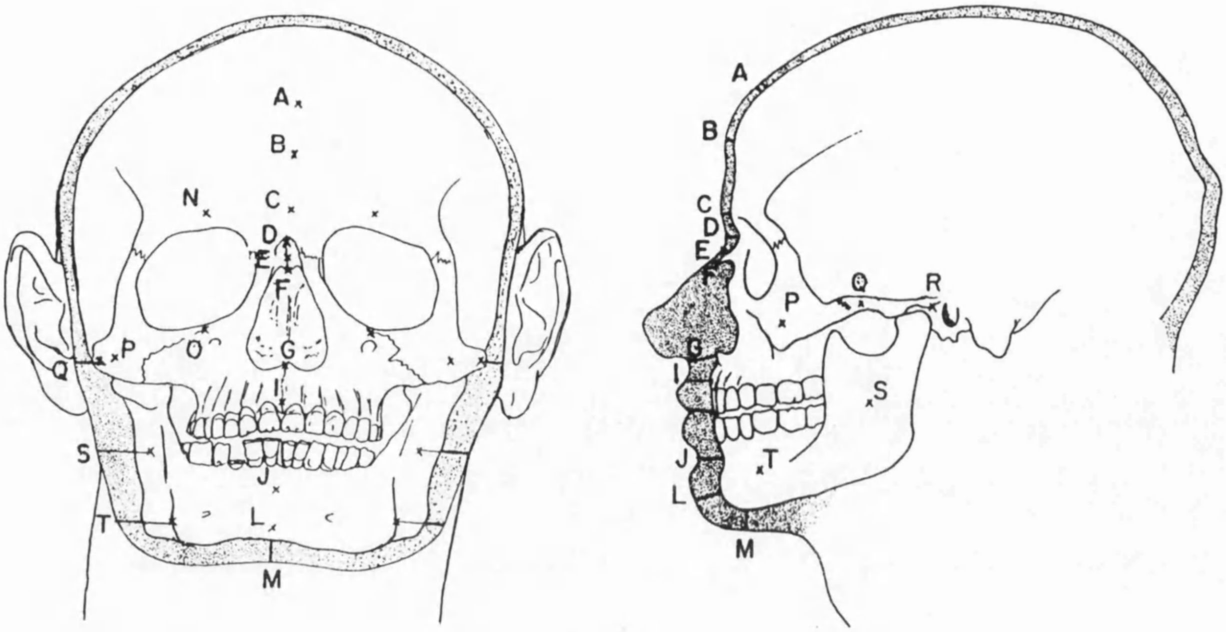


FIGURE 51
Frontal and lateral diagrams showing the sites of 18 soft tissue thickness points from the study by Kollmann and Büchly.
(Modified from Kollmann and Büchly, 1898, Plates VII and VIII)
(Reprinted in Stewart, 1979, p: 262, figure 77)

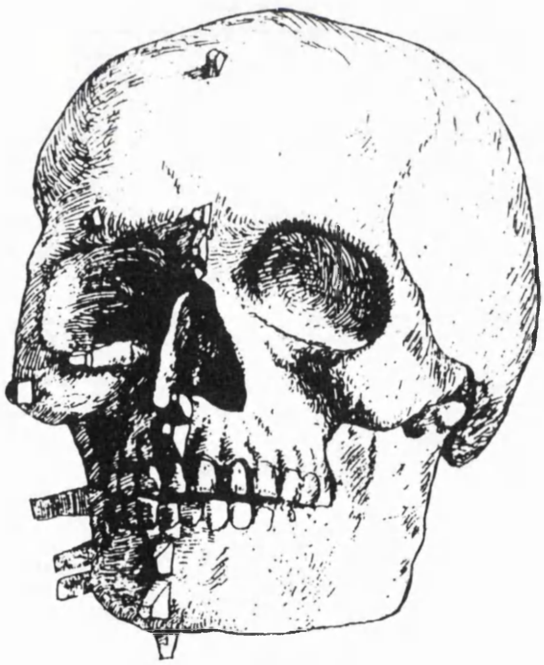


FIGURE 52
Skull drawing with clay "cones" showing the locations of soft tissue thickness in place at some of the points shown in figure 51.
(Kollmann and Büchly, 1898, p: 338, figure 2)
(Reprinted in Stewart, 1979, p: 263, figure 78)

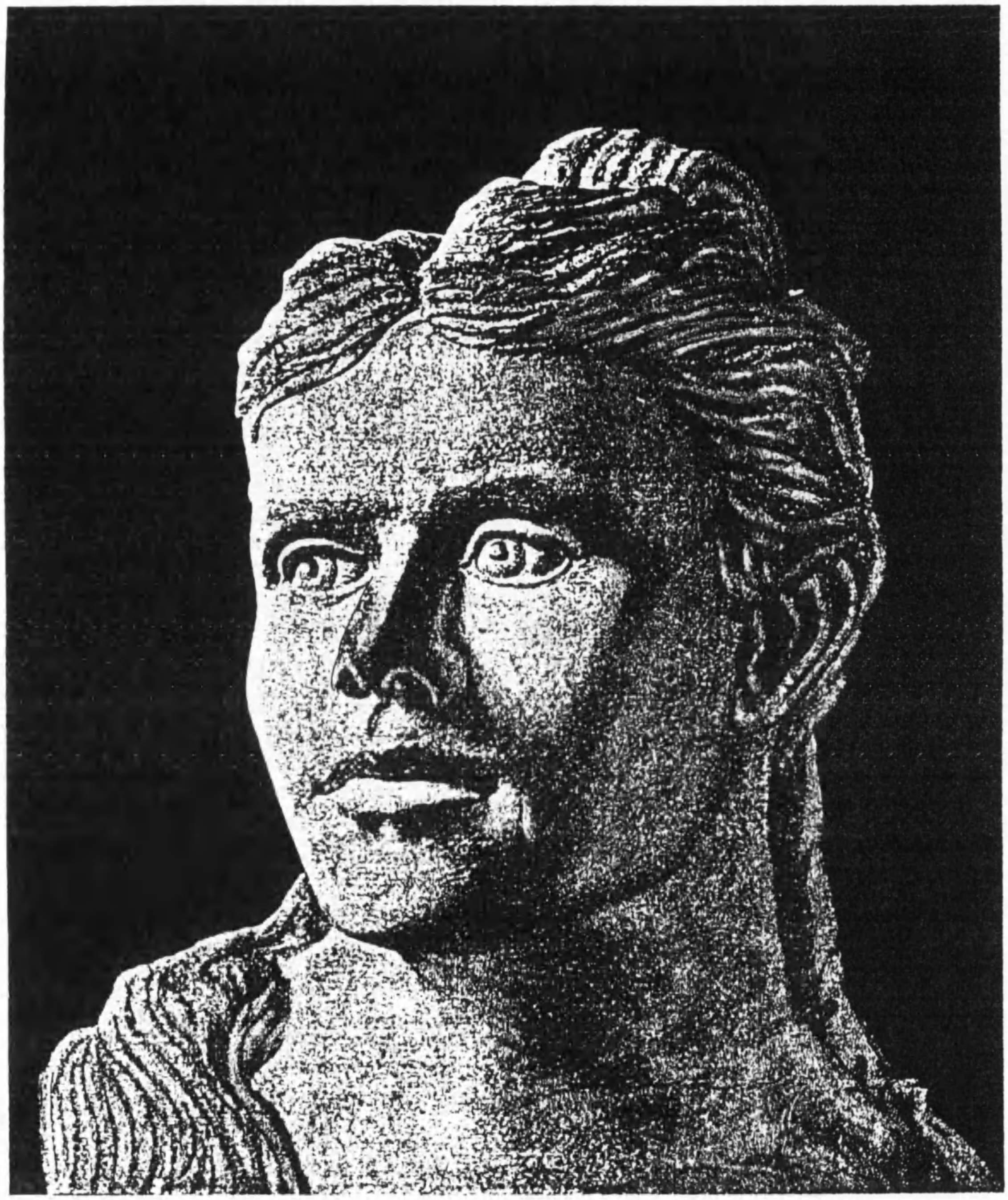


FIGURE 53
Facial Reconstruction on the skull of a young woman, from the Stone age, exhumed in Auvernier.
The three dimensional facial reconstruction was performed by Büchly.
(Kollmann and Büchly, 1898, p. 337, figure 1)

FIGURE 54
Three dimensional facial reconstruction and comparison with existing portraits of J. S. Bach were combined to produce this marble bust of J. S. Bach. The bust and three dimensional facial reconstruction shown in figure 49 were sculpted by Seffner.
(His, 1895a)
(Reprinted in Iscan and Helmer, 1993, p: 31, figure 2)

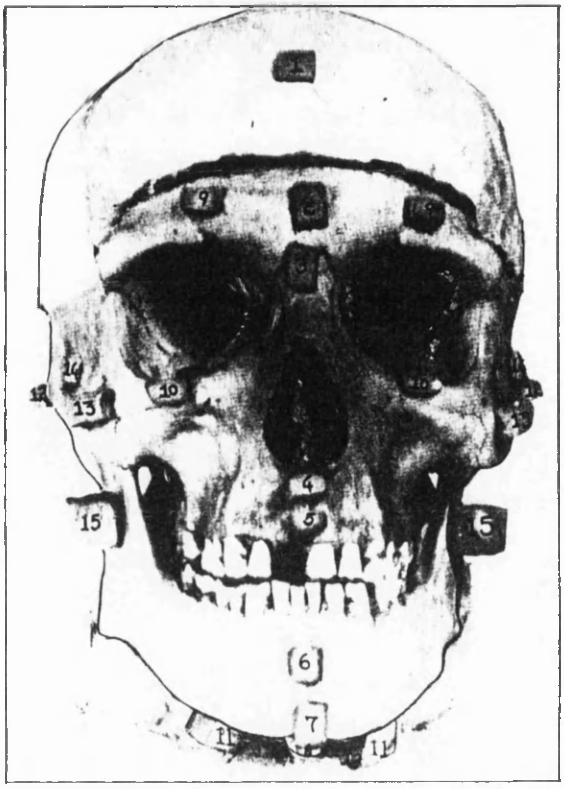


FIGURE 55A
Frontal view of skull with blocks of clay to tissue thickness at selected sites.
(From Krogman, 1943, figure 13)
(Reprinted in Krogman and Iscan, 1986, p: 442, figure 11.22)

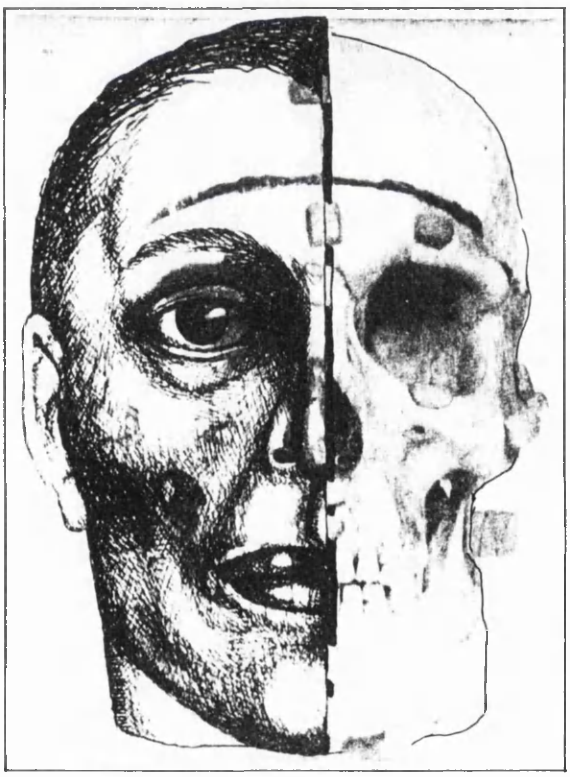


FIGURE 55B
Facial view of subject of figure 55A with soft tissues drawn in on the right half.
(From Krogman, 1943, figure 14)
(Reprinted in Krogman and Iscan, 1986, p: 443, figure 11.23)

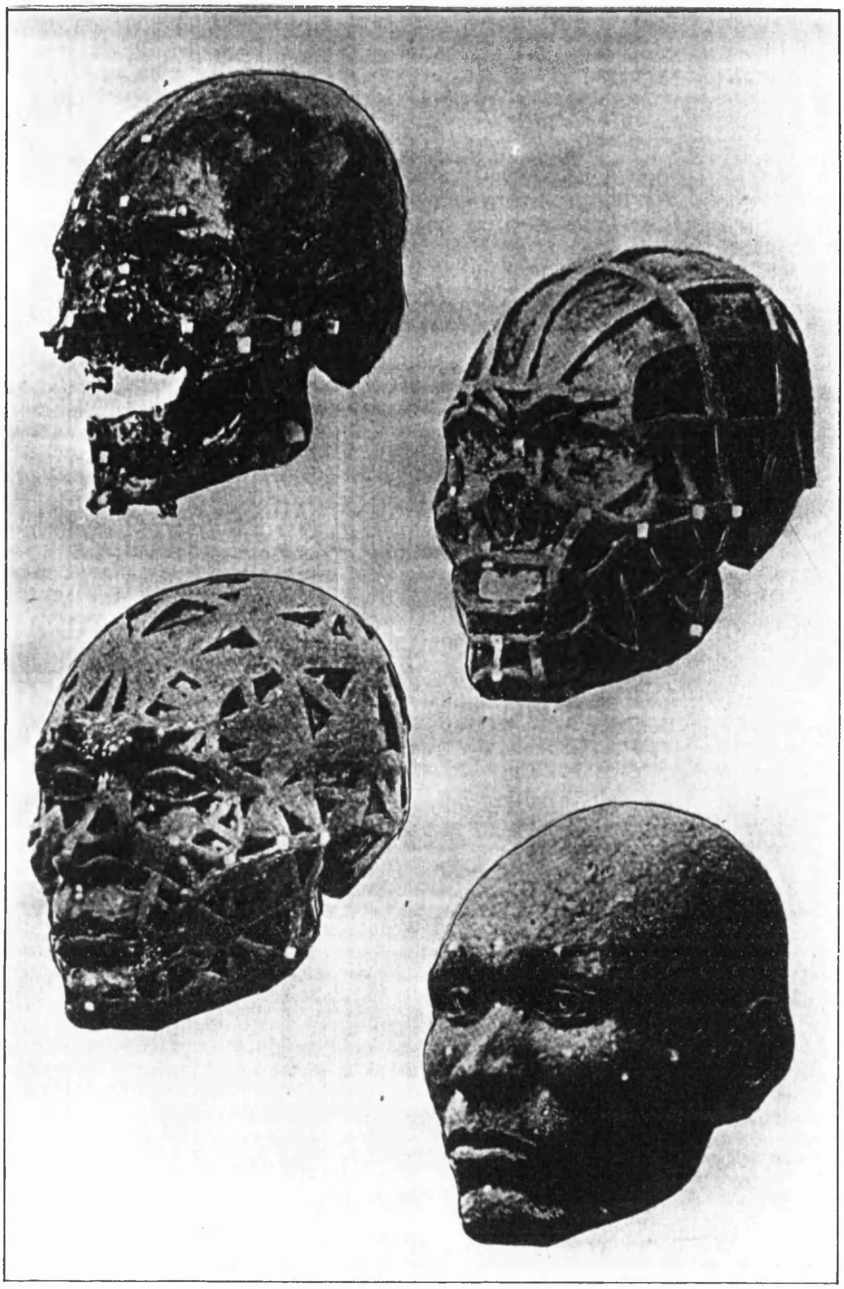


FIGURE 56
Four stages in a three dimensional facial reconstruction of a skull. The lower jaw has been firmly attached to the skull and the missing teeth restored. Blocks proportional to the soft tissue thickness at specific points were attached. By connecting the blocks with bands of clay, a latticework of the facial surface is built up, and the features were modelled in, to produce the final reconstructed face. The stages represent "The American school".
(From Stewart, 1954, figure 124)
(Reprinted in Krogman and Iscan, 1986, p: 444, figure 11.24)

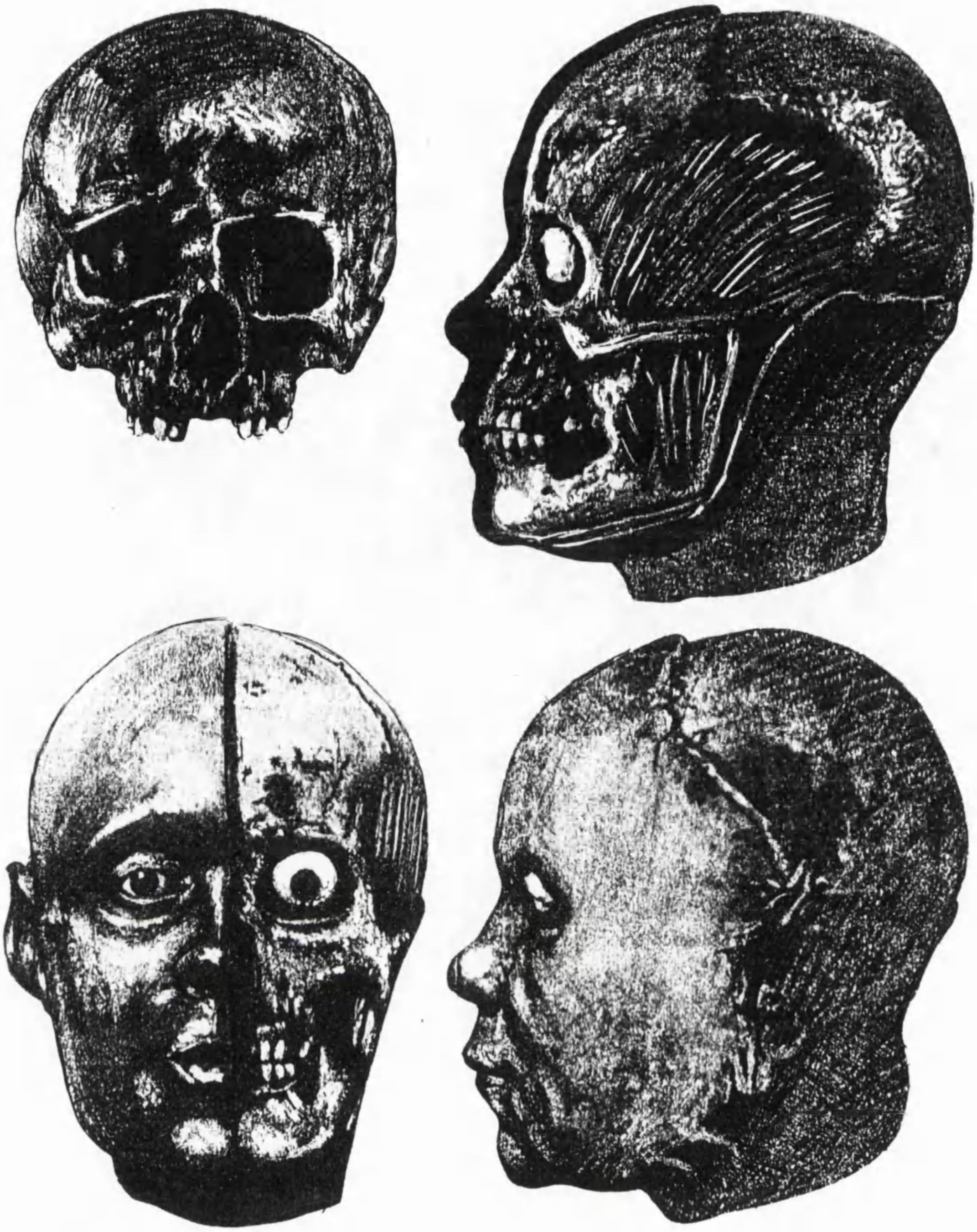


FIGURE 56 A
Stages of facial reconstruction using Gerasimov's method. The method was developed and used in Eastern Europe and has two phases- the reconstruction of the head itself and then the modelling of the facial mask. The first stage involves the reconstruction of the most important masticatory and neck muscles with those of the shoulder, using their bony attachments as indicators of size and extent. Gerasimov's opinion with regard to this step is that: "there is no doubt that the masticatory muscles can be accurately reconstructed. They are highly individual in size, volume and shape so that their form can be in each particular case determined from the skull." The second step involves the modelling of the facial features, special training, experience and knowledge of the relationships between the underlying bone and soft tissues are required. The sculptor then applied more clay to the depth specified in tissue thickness tables to approximate the muscle, glands, major arteries, and the other structures according to the anatomy of the face. The final stage shows the final reconstructed face. The stages showed also represent the facial reconstruction performed on the skull of the first forensic case illustrated in Gerasimov's book "The face finder". (From Gerasimov, 1971)

FIGURE 56 B

The comparison of the finished facial reconstruction of the skull of a twenty-two years old female (on the left) with a photograph of Valentina Kosova taken six years before her disappearance on the right showed a great resemblance between them, thus her remains were identified and her murdered convicted. The facial reconstruction shown is the continuation and final step of the stages illustrated in figure 56A. The photographs illustrate the first forensic case illustrated in "The face finder" (From Gerasimov, 1971)

FIGURE 56 C
The comparison of the finished three dimensional facial reconstruction by Gerasimov on the skull of a thirty- two years old female (on the right) with a photograph of the missing dentist, representing the second forensic case illustrated in Gerasimov's book. A great likeness was observed, especially noticeable in the asymmetry of the eyes, and the droop of the right side of the face, presumably a result of facial paralysis.
(From Gerasimov, 1971)

FIGURE 57

Stages of Three dimensional Facial Reconstruction using a combined method by R. Neave.

FIGURES 57 B-C-D
Plaster cast with added clay simulating the basic musculature of the face.

FIGURE 57A
Plaster cast of skull with pegs and eyeballs in position. Plaster eyeballs were placed into the orbits and small holes drilled into the skull cast at specific anatomical points. Small wooden markers were cut to precise lengths and glued into the holes. The pegs corresponds to the average soft tissue thickness to be found at those locations.

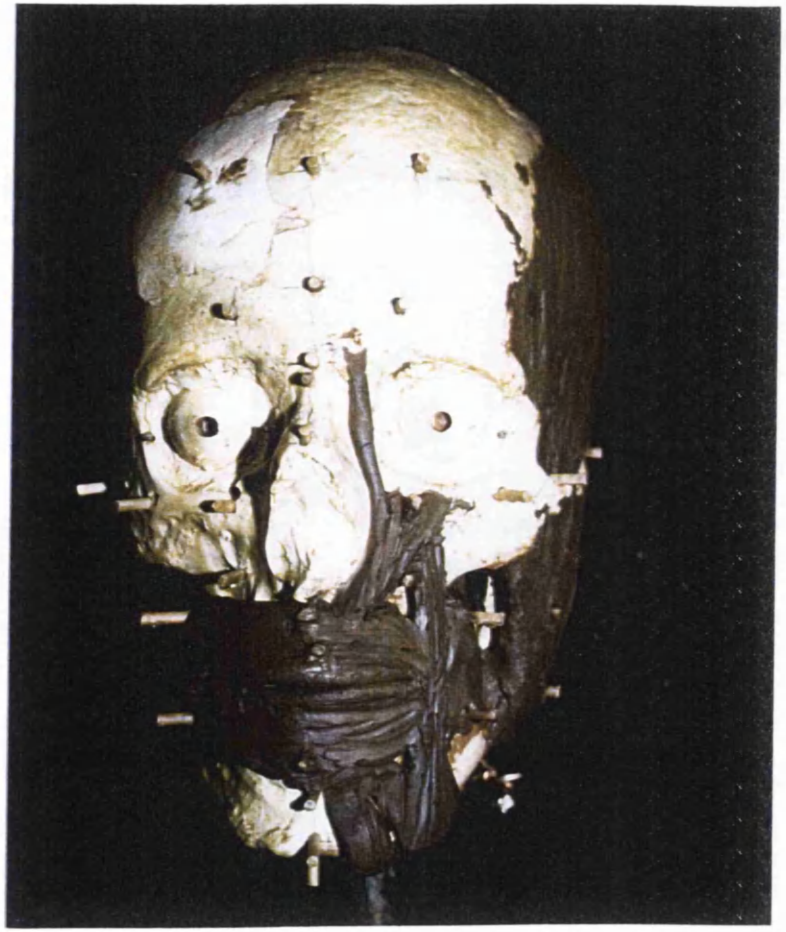


FIGURE 57 C

FIGURE 57 D
The eyelids were modelled over the solid globe, noting the position of the inner and outer canthus to ensure the correct angle of opening.

FIGURE 57 F

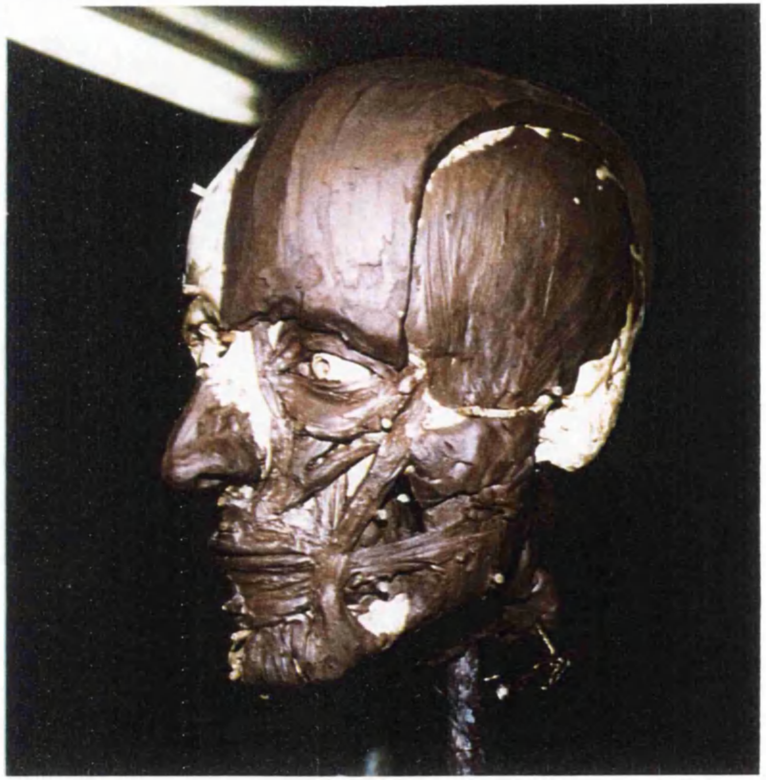


FIGURE 57 E and F
Layers of clay simulating subcutaneous tissue and skin were laid over the structure and allowed to take their natural form.

FIGURE 57 E
The nose is reconstructed by projecting the line from the nasal bone and another from the nasal spine. This guideline allows one to establish approximately the distance the nose projects from the surface of the skull.

FIGURE 57 G
The width of the nose is established by examining the piriform aperture. It is approximately 3/5 of the overall width between the alae. One of the most useful indications for the width of the mouth comes from the eyes. Neave has noted in about 97 % of cases studied that the distance between the medial limbus of the iris is the same as the width of the mouth. Details of the lips and mouth are impossible to establish with complete accuracy. The aforementioned guidelines combined with the shape of the mandible and maxilla, provides enough information for reasonable accuracy to be achieved, the width of the philtrum being equal to the distance between the centre point of the two upper front incisors.

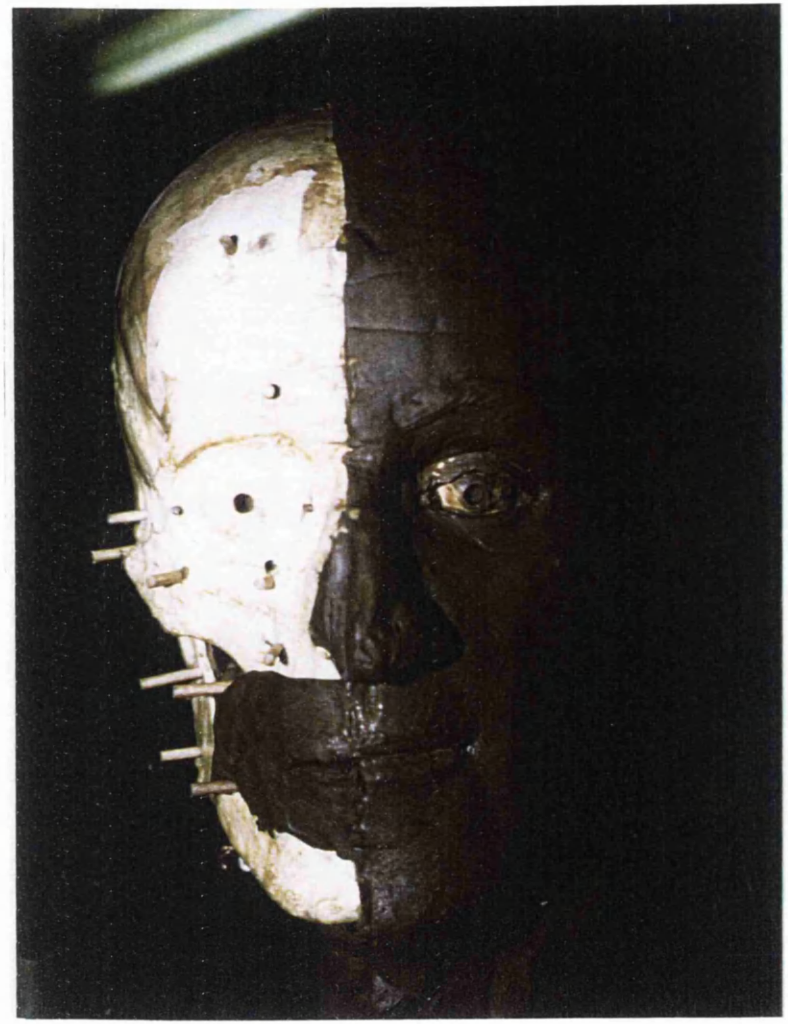


FIGURE 57 H
Final stage of reconstructed face on the left half. The reconstructed soft tissue at no point exceeds the level of the measuring pegs.

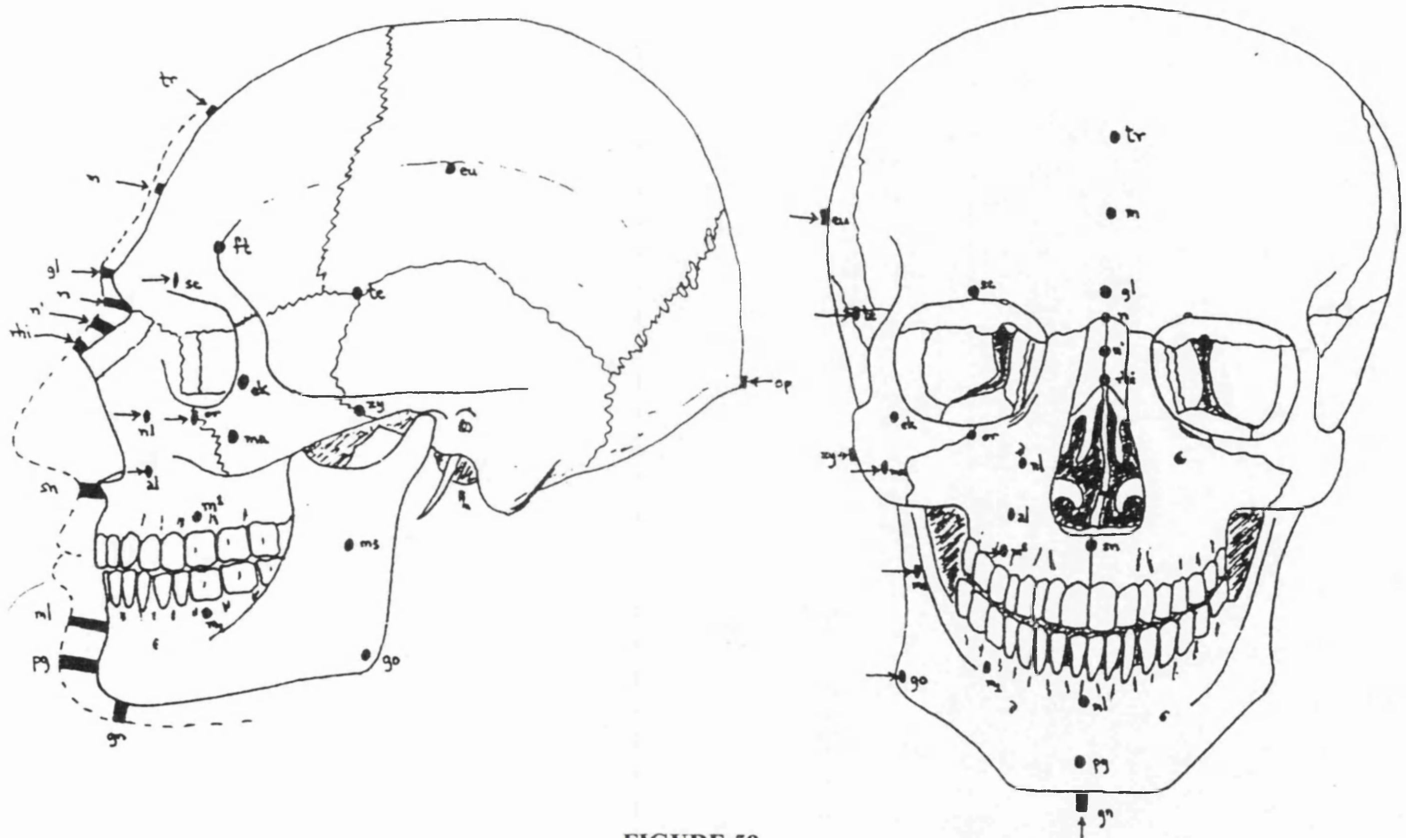


FIGURE 58
Frontal and lateral skull diagrams illustrating the soft tissue thickness points from the study by Suzuki (1948).
(Reprinted in Rhine and Campbell, 1980, p: 851, figure 2)

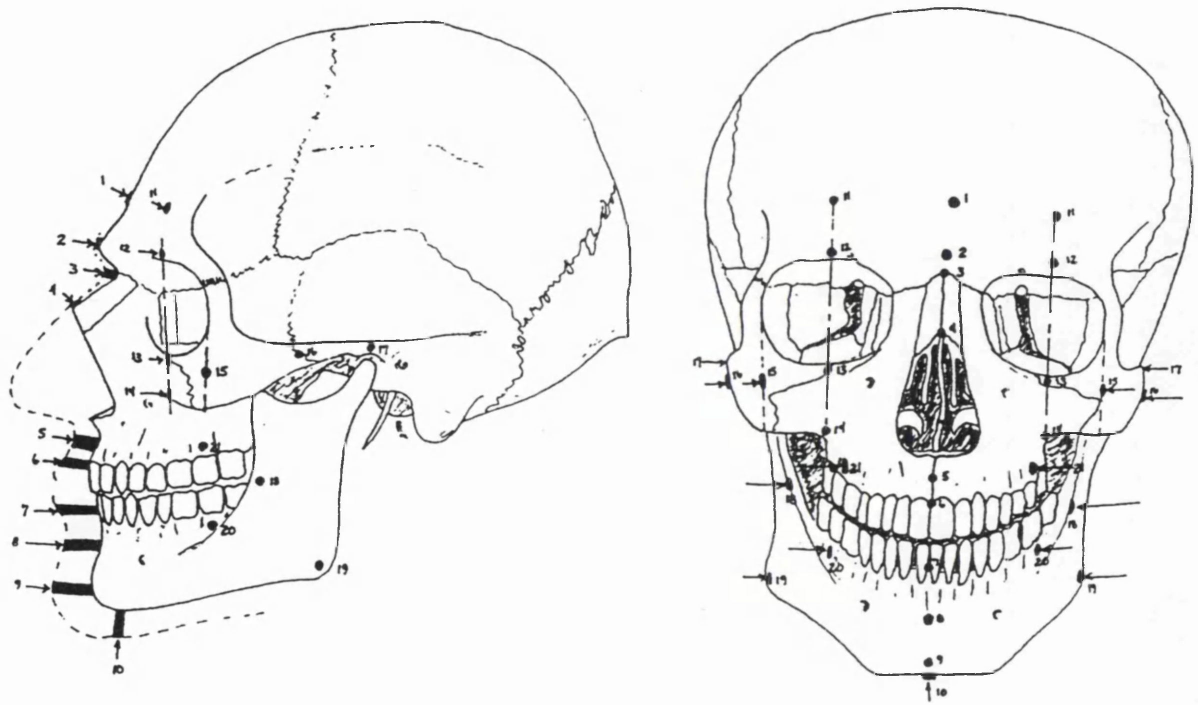


FIGURE 59
Frontal and lateral skulls diagrams showing facial soft tissue thickness points in American Black population. (From the study by Rhine and Campbell, 1980, p: 853, figure3)

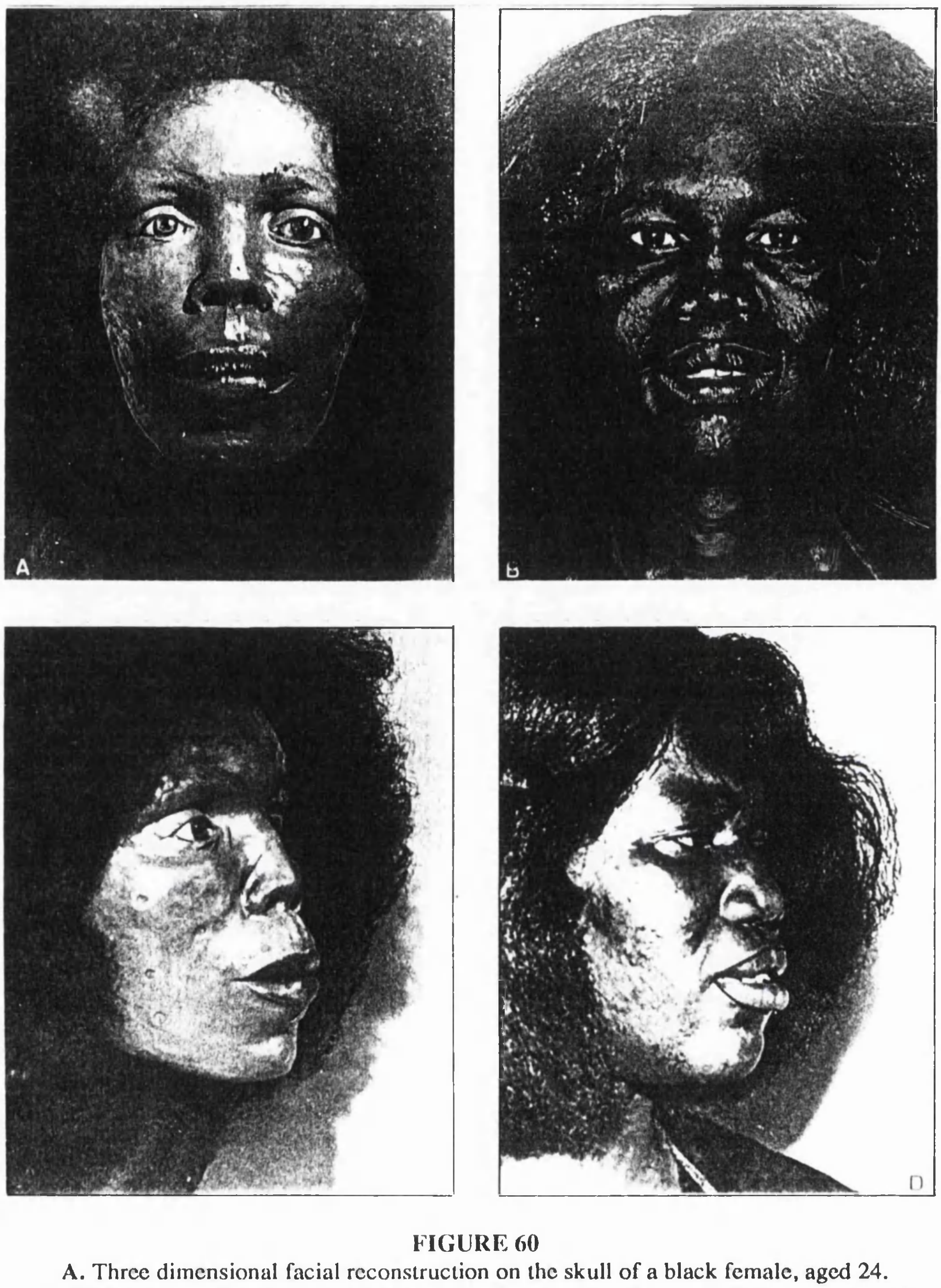


FIGURE 60

A. Three dimensional facial reconstruction on the skull of a black female, aged 24. **B.** Official law enforcement premortem photograph of the deceased. **C.** Lateral view of three dimensional facial reconstruction. **D.** Official law enforcement premortem photograph of the deceased. Lateral view.

Photographs illustrating Rathbun's research using the new data of facial soft tissue thickness in American black by Rhine and Campbell (1980).

(From Rathbun and Buikstra, 1984, p: 353, figure 24-1)

FIGURE 61
Photographs illustrating frontal and side views of skull of American Negro male, studied by Krogman for testing the accuracy of Facial reconstruction by sculpting in 1946.
(Krogman, 1946, p: 14)

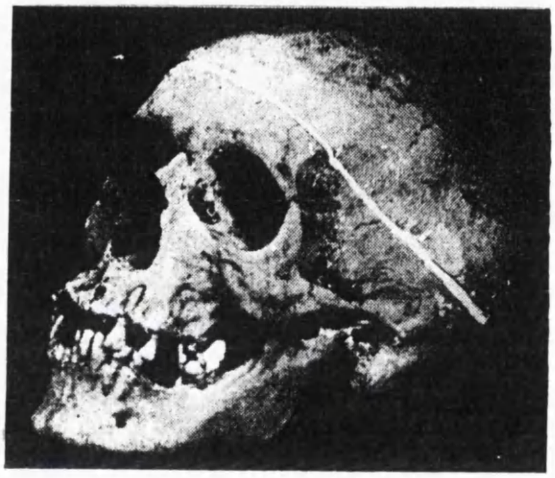


FIGURE 62
Comparison between photographs of an original head of an American Negro, male with the Facial reconstruction by sculpting from his macerated skull.

LEFT: Frontal and side views of the head of forty-five year old, Negro, male, selected by Krogman for testing Facial reconstruction technique by sculpting.

RIGHT: Frontal and side views of the Facial Reconstruction by sculptress Mc Cue of the individual shown on the left.
(From Krogman, 1946, p: 17)

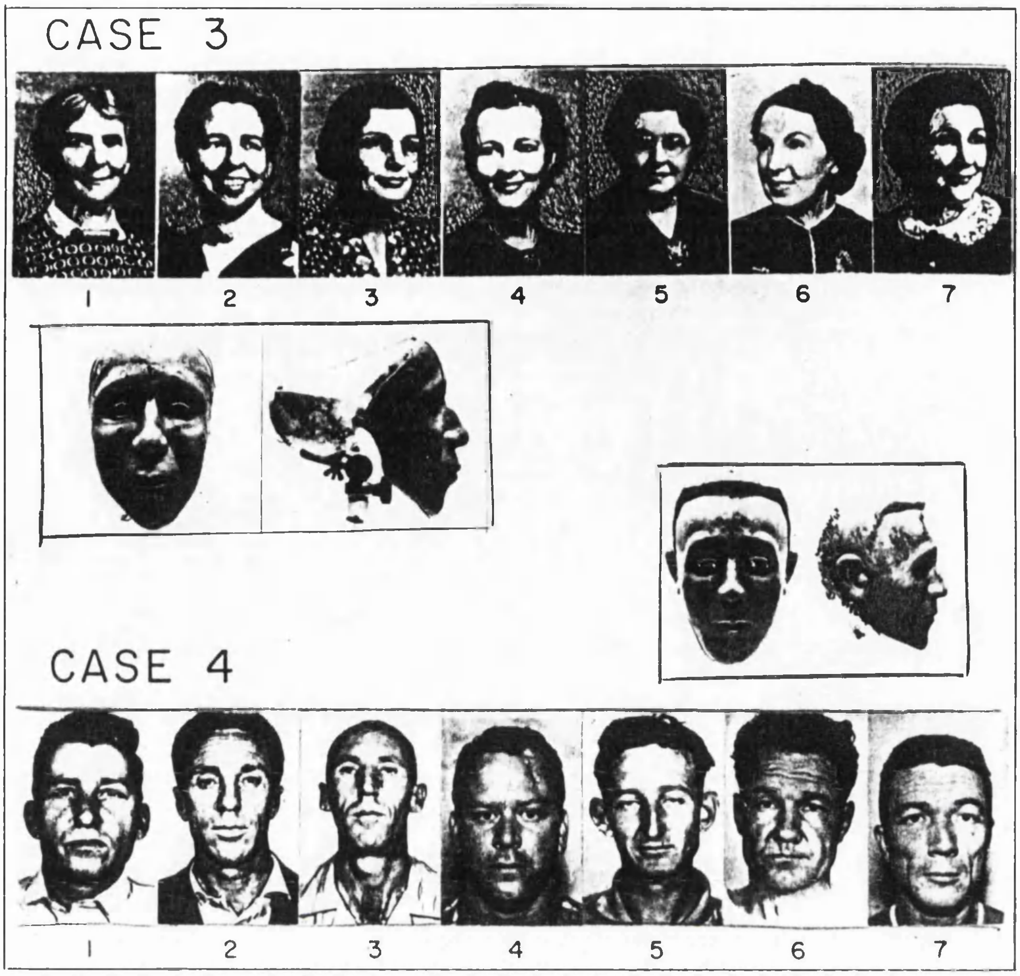


FIGURE 63
Poster used by Snow et al. (1970), when they tested likeness objectively in two cases of a face reconstructed on a skull. First, Gatliff performed the reconstruction using Krogman's method on the skull of two positively identified Caucasian individuals, a female, aged sixty-seven and a male, aged 36. Second, the authors made up posters in which each reconstruction appeared with a row of seven photographs of individuals of the same sex, and general age. One of them N° 2 being of the reconstructed individual.
(Snow et al. , 1970, p: 224, figure 2)
(Reprinted in Stewart, 1979, p: 269, figure 80)

TABLE N° 10

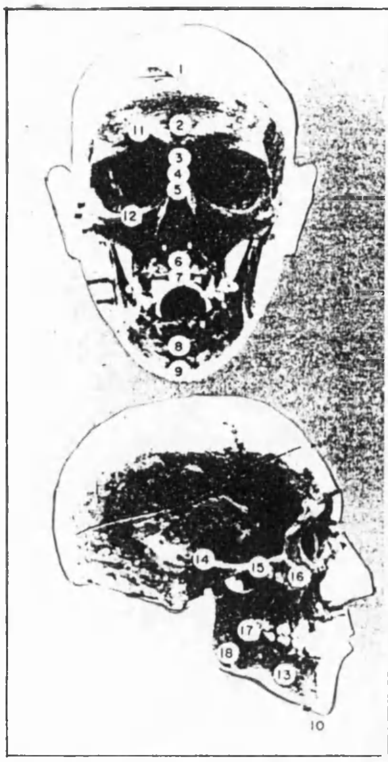
Results of the test used by Snow et al. (1970)

Number of correct identifications made by policemen, civilian males, and civilian females for the two facial reconstructions. (Probabilities are based on 2 x 2 Chi square analyses using N/7 for the number of chance-expected correct identifications.)

				Civilian			Civilian			All	
	Policemen			Males			Females			Subjects	
	N	Correct		N	Correct		N	Correct		N	Correct
Reconstruction											
Case 3	36	10		34	7		34	10		104	27[1]
Case 4	91	73[2]		76	39[2]		33	23[2]		200	135[2]
[1] $p < 0.05$ [2] $p < 0.005$											

(From Snow et al., 1970, p: 225, Table 1)-(Reprinted in Stewart, 1979, p: 270, Table XXXVII)

FIGURE 64
Comparison between Facial reconstruction with Photographs of identified persons.
Facial reconstruction by Gatliff on the skulls of two individuals positively identified by others means and their life photographs provided by comparison.
Photographs a and b compare the Facial reconstruction and photograph of an Indian, male, aged 26. Results from the viewers: Reconstruction was a reasonable likeness.
Photographs c and d compare Facial reconstruction and photograph of a white, female, aged 56 and a portrait taken approximately 25 years earlier. Results from the viewers: The resemblance was not impressive. The viewers expressed reservation about its accuracy.
(From Snow et al., 1970, p. 223, figure 1)



TISSUE THICKNESSES (in milimeters)		
	Male	Female
1	3.50	3.50
2	4.75	4.25
3	5.00	4.50
4	3.25	2.75
5	2.00	2.00
6	11.50	10.00
7	9.50	8.25
8	10.00	10.00
9	10.25	10.00
10	6.00	6.25
11	5.75	5.25
12	4.25	4.50
13	8.25	7.25
14	6.75	7.00
15	4.25	4.50
16	6.75	7.75
17	17.50	16.00
18	10.50	9.50

FIGURE 65
Diagram illustrating 18 facial soft tissue thicknesses sites selected and used by Gatliff (1979). Average soft tissue thickness from Kollmann and Büchly, (1898)
(From Gatliff and Snow, 1979, p:28, figure 2)

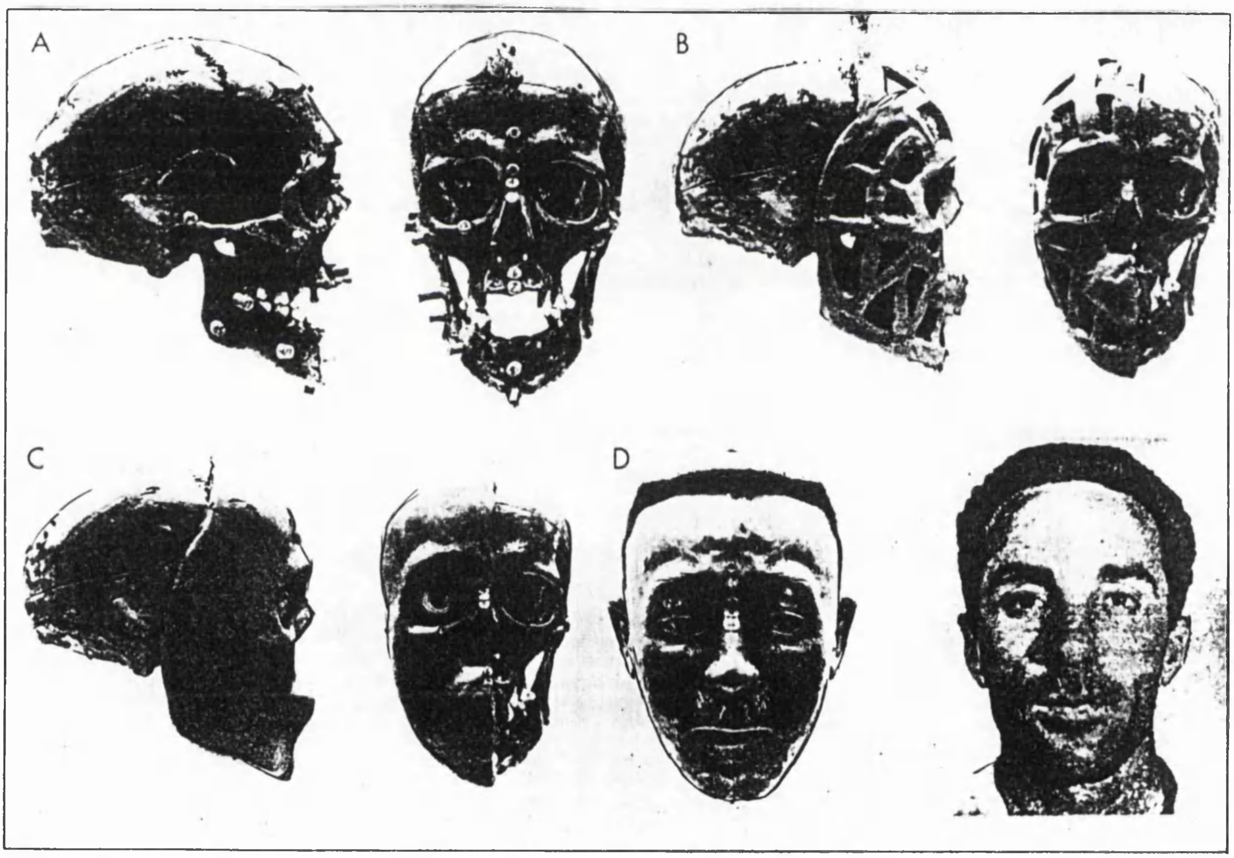


FIGURE 66
Stages of Facial reconstruction by sculpting used by Gatliff (1979). American school method of Facial reconstruction.
A. Attach tissue thickness blocks to skull at designated points. **B.** Connect blocks with strips of clay. **C.** Build up surfaces with clay and position eyeball. **D.** Model in facial features- compare reconstruction with photograph.
(From Gatliff and Snow, 1979, p: 28, figure 3)

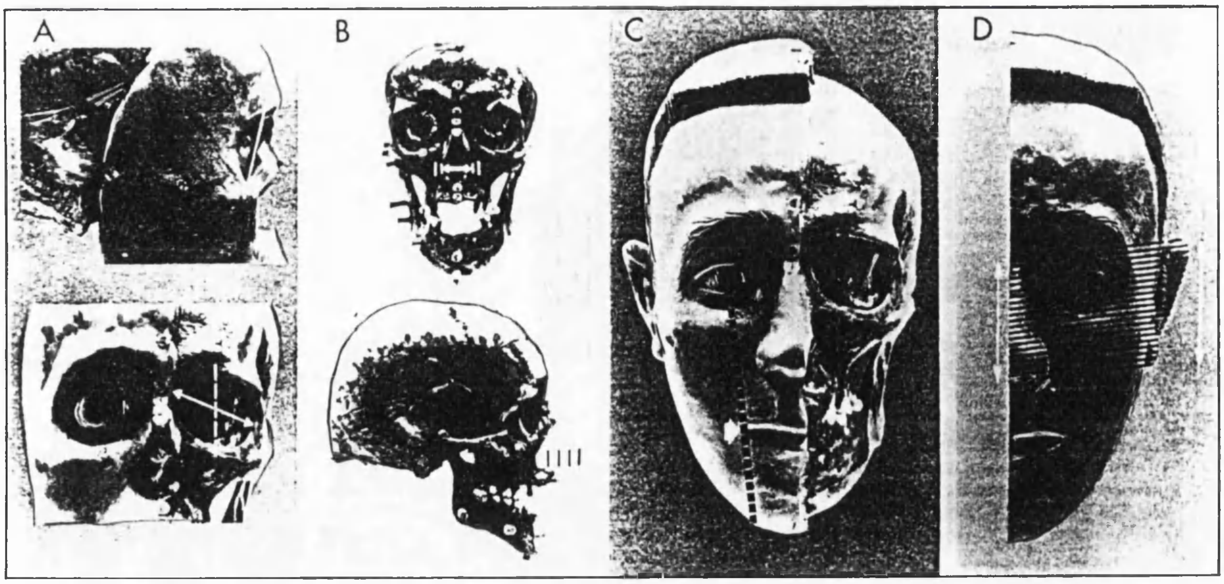


FIGURE 67
Stages of Facial reconstruction by sculpting used by Gatliff (1979)
Soft tissue features which have no necessary correlation with the underlying bone such as shape of eyelids, lower part of the nose, mouth width and lip thickness, ears.
A. Eye, the outer point of the cornea is approximately tangent to a line drawn from superior to inferior margins of the orbits; the apex of the cornea is at the juncture of two lines: one from the maxillofrontale to the ectoconchion- the other bisecting the orbit. **B.** Nose: Width is computed:
Blacks-nasal aperture +16 mm (8 mm each side);
Whites-nasal aperture + 16 mm (5 mm each side).
Projection is approximately three times the length of the nasal spine. **C.** Mouth, align with centres of sockets and widest points of chin. **D.** Ear, length (from top to bottom) roughly equal to nose length.
(From Gatliff and Snow, 1979, p. 29, figure 4)

1 **2** **3** **4**

FIGURE 68
Comparison between Facial Reconstructions and Photographs of the deceased at different ages, showing the strong resemblance between them.
Figures 68 (1) and (3) show the facial reconstruction of a white, female whose battered and partly cremated remains were found in an isolated woods in Central Oklahoma. Figure 68 (1) The artist's first reconstruction of the face does not take into account age lines. The age was estimated about sixty years. The woman had no dental treatment but did display a noticeable diastema between the two upper incisors. The reconstruction was modified to display age lines, dental treatment glasses and a grey wig as seen in figure 68 (3). The resemblance was striking enough that when the woman's brother was shown the photograph, he first had to be convinced that is was not an actual picture of his sister. Once she was identified, her aggressor was readily apprehended, tried and sentenced to prison for his murder. Later the authors were given photographs of the woman for her family as seen in figures 68 (2) and (4). Figure 68 (2) was taken several years prior to her death and resembles the unaged reconstruction. Figure 68 (4) was taken a year or two prior her disappearance, strongly resembles the second reconstruction as seen in figure 68 (3)
(From Gatliff and Snow, 1979, p: 29, figures 5 and 6)

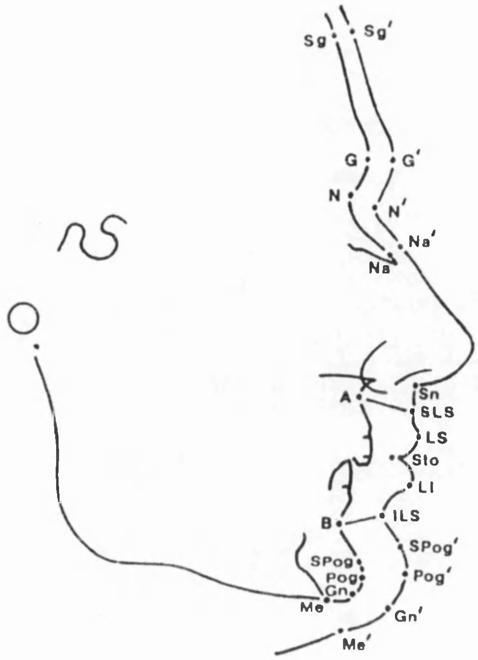


FIGURE 69

A.Cranial landmarks selected by George.: supraglabella (Sg), glabella (G), nasion (N), nasale (Na), Point A (A), Point B (B), suprapogonion (S Pog), pogonion (Pog), gnathion (Gn), menton (Me).

Cephalometric landmarks: supraglabella (Sg'), glabella (G'), nasion (N'), subnasale (Sn), superior labial sulcus (SLS), labrale superius (LS), stomion (Sto), labrale inferius (LI), inferir labial sulcus (ILS), suprapogonion (SPog'), pogonion (Pog'), gnathion (Gn'), menton (Me')

(From George, 1987, p: 1307, figure 1)

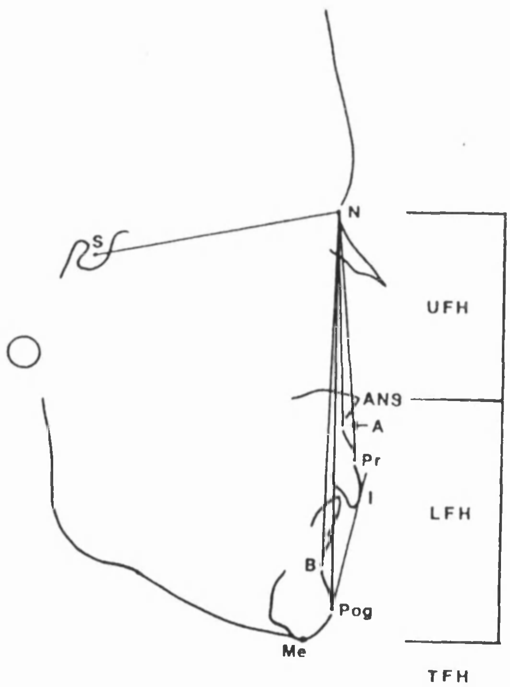


FIGURE 69 B

Reference points for cephalometric analysis: upper facial height (UFH), lower facial height (LFH), total facial height (TFH), sella (S), nasion (N), anterior nasal spine (ANS), Point A (A), prosthion (Pr), inciso point (I), Point B (B), pogonion (Pog), menton (Me).

(From Geoge, 1987, p: 1309, figure 3)

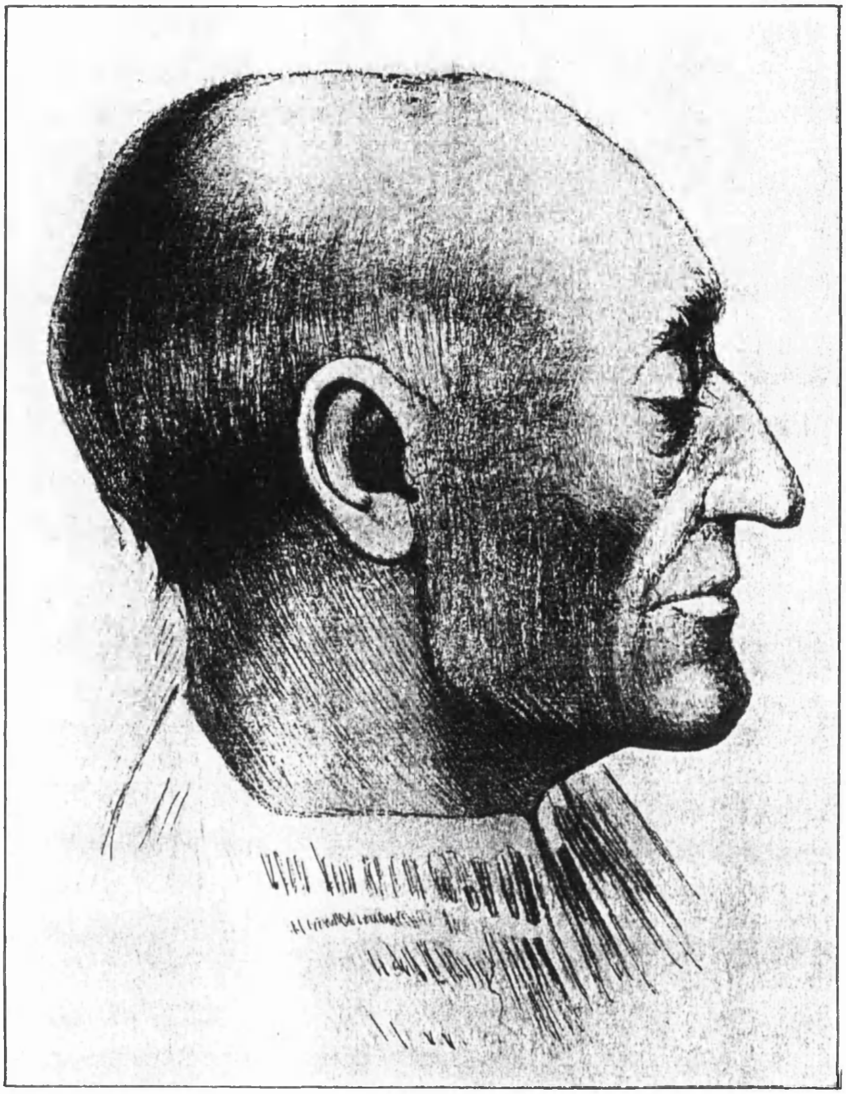


FIGURE 70
Two- dimensional Facial Reconstruction from the skull of
Bishop James Kennedy by J. T. Murray.
(From Stewart, 1979, p: 259, figure 76)

FIGURE 71

A. Comparison of the life photograph of a girl, aged twenty years, taken by The Police six months before her death (July 1975) with a Two-dimensional facial reconstruction by Police artist Cherry under directions of Dr. L. Angel.
(From Cherry and Angel, 1977, p: 14-15, figures 3 and 1)
(Reprinted in Stewart, 1979, p: 256, figure 75)

FIGURE 71 B
Frontal view of skull of the subject showed in figure 71 A.
(From Cherry and Angel, 1977, p: 14-15, figure 2)

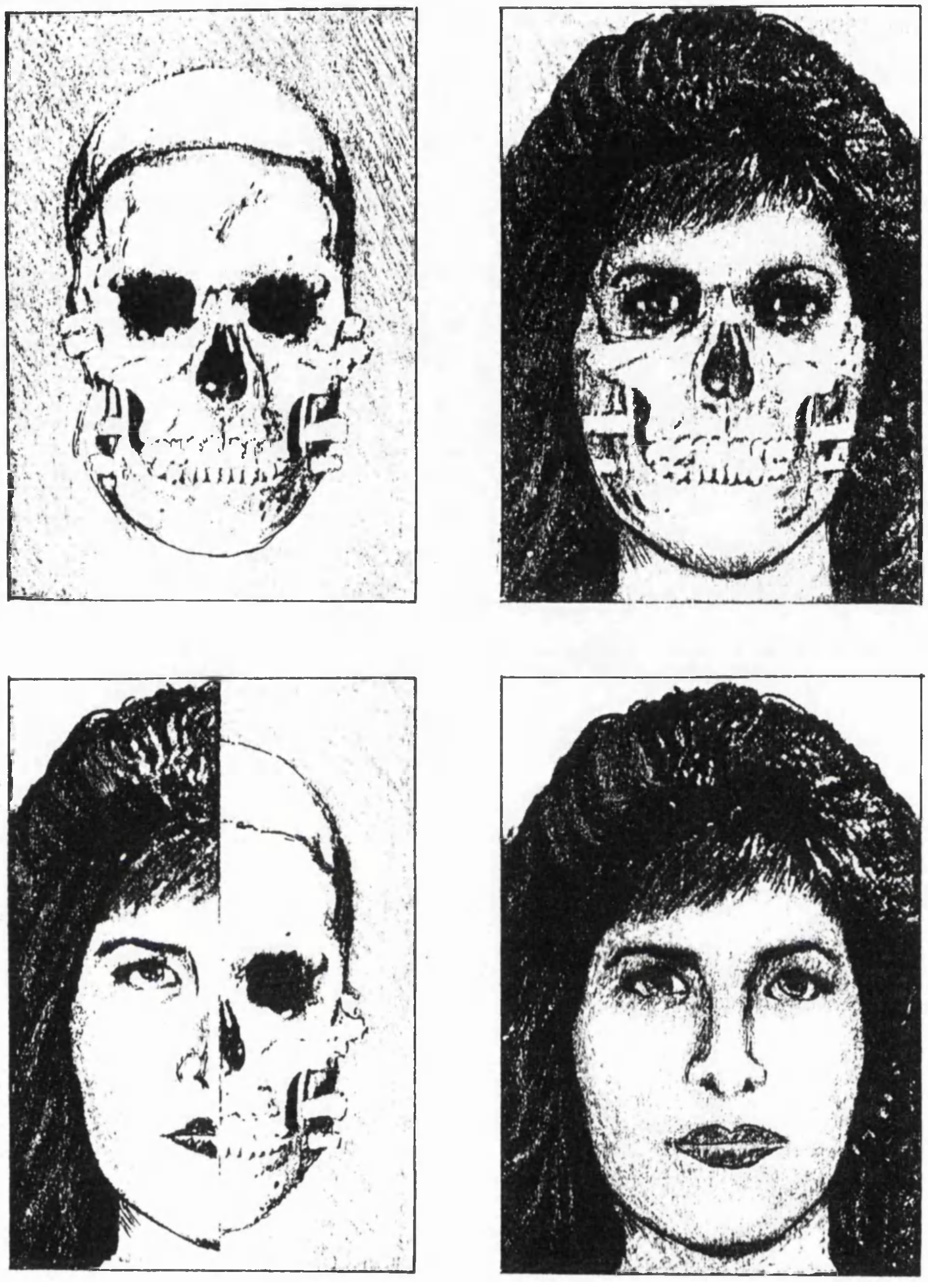


FIGURE 72

Computer -assisted facial reconstruction from the North Carolina skull.
(All the images are computer generated)
(From Ubelaker and O'Donnell, 1992, p: 159, figure 1)

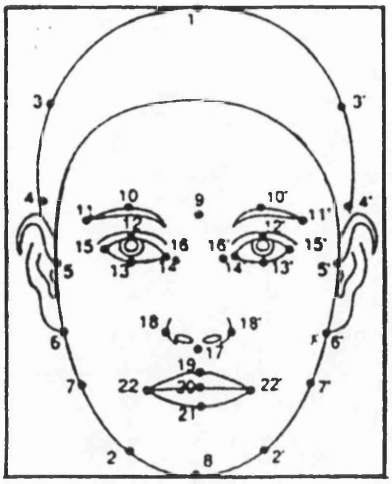


FIGURE 73 A
Diagram illustrating cephalometric landmarks used as vertices for mapping.
(From Evenhouse et al., 1992, p: 24, figure 4)

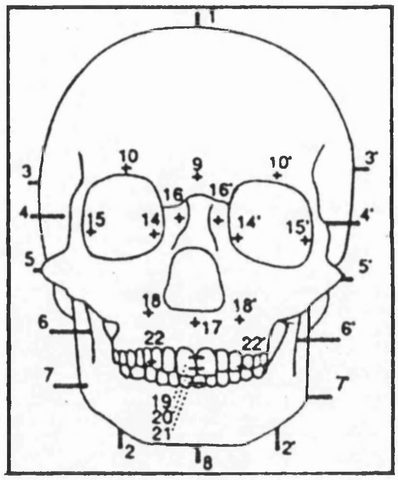


FIGURE 73 B
Diagram illustrating craniometric landmarks, assumed to be homologues to like numbers in figure 73 A.
(From Evenhouse et al., 1992, p: 24, figure 5)

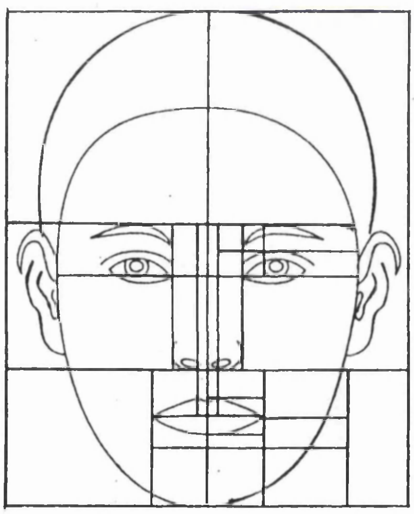


FIGURE 73 C
Diagram showing standard facial proportions of the young adult face from Farkas (1981) (From Evenhouse et al., 1992, p: 23, figure 2)

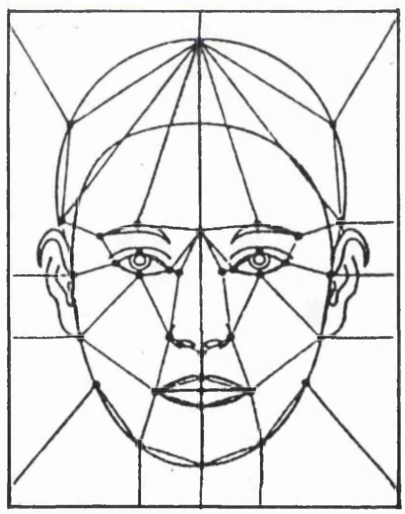


FIGURE 73 D
Polygonal mesh used to warp image. (From Evenhouse et al., 1992, p: 24, figure 6)

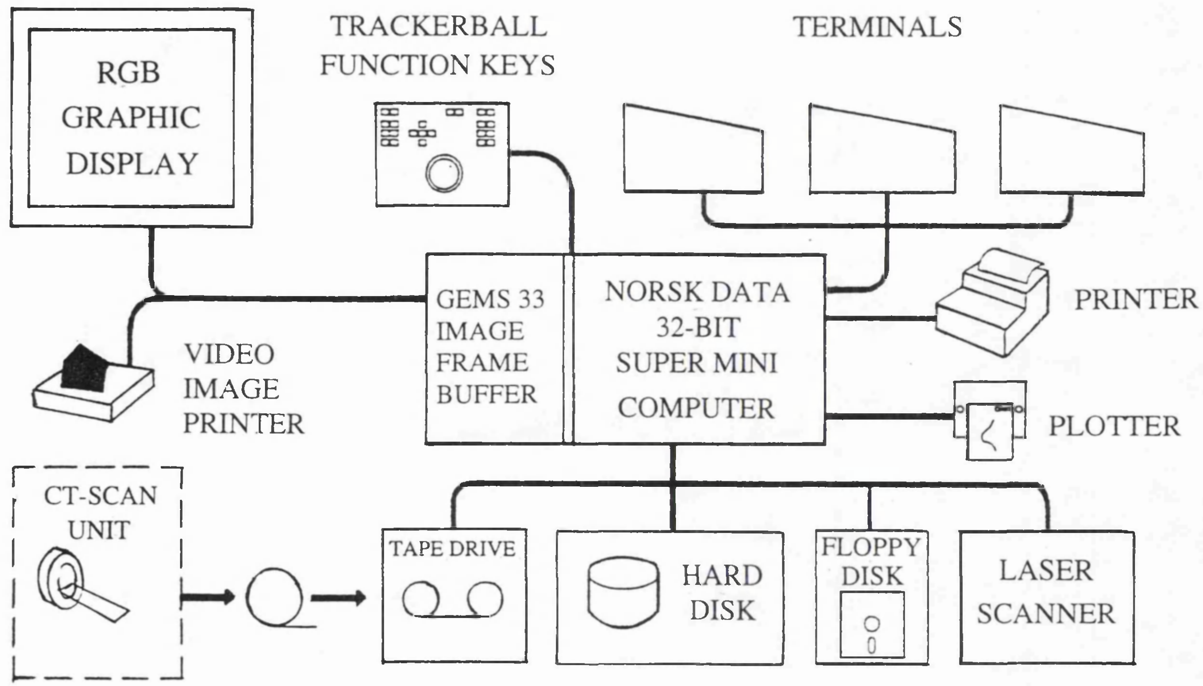


FIGURE 74
Diagram illustrating the computer system used for planning facial surgery.
(Moss et al., 1988, p: 470, figure 1)

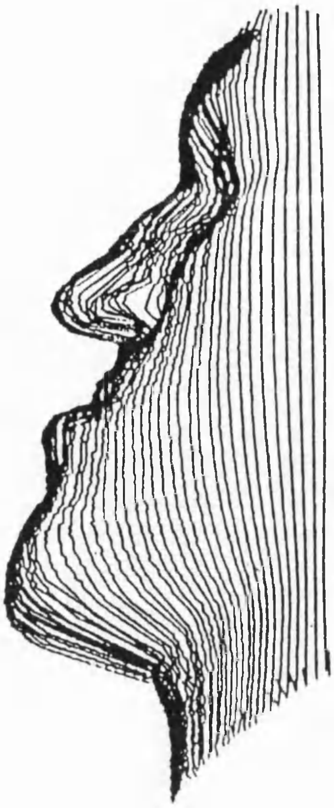


FIGURE 75 A
Diagram showing a set of projected profiles from the laser scanner of the patient before surgery. (Moss et al., 1987, p: 249, figure 1)

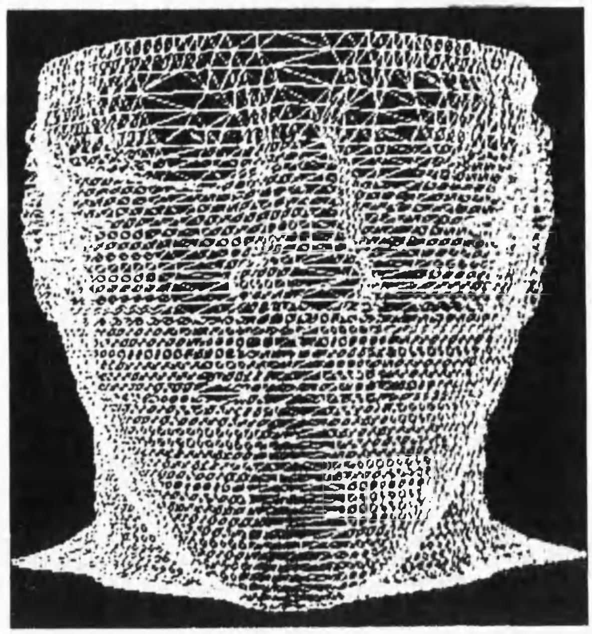


FIGURE 75 B
A facetted image of the patient shown in figure 75 A, generated from CT scans before surgery containing 10.210 facets. (From Moss et al., 1987, p: 250, figure 2a)

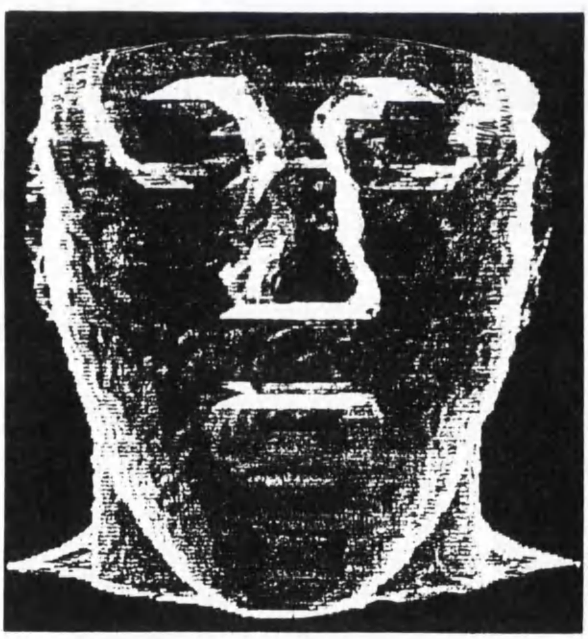


FIGURE 75 C
The same image from figure 75 B with simple flat shading of the facets, which took 4 seconds to shade and is illuminated from 45 degrees below the horizontal plane.
(From Moss et al., 1987, p: 250, figure 2b)

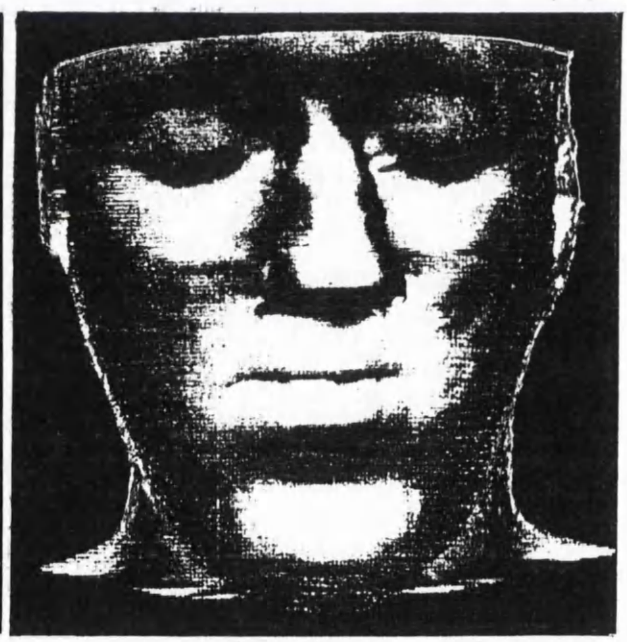


FIGURE 75 D
The same image from figures 75 A, B, C realistically shaded using phong shading to produce a smooter surface.
(From Moss et al., 1987, p: 250, figure 2c)

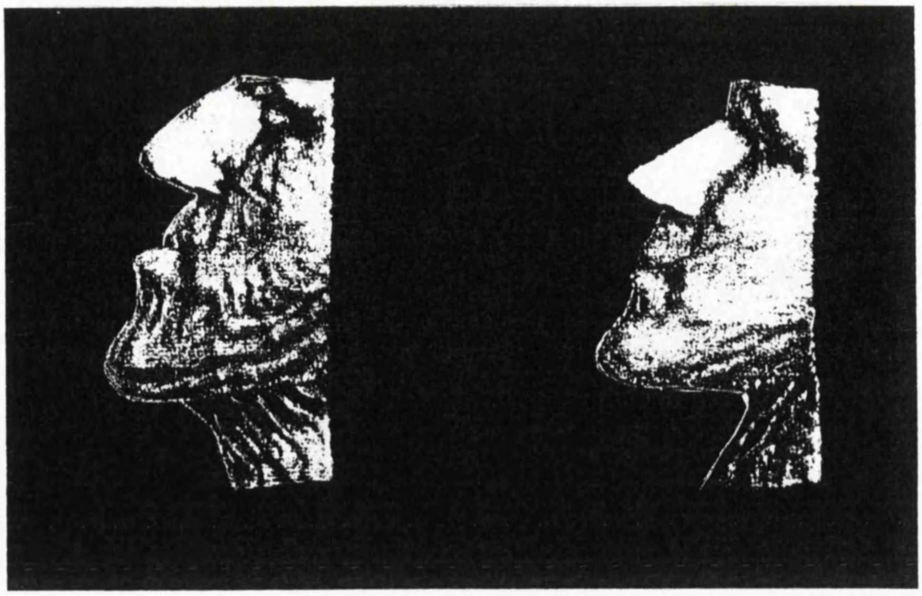


FIGURE 76
A phong shaded image of the same patient from laser scan data before and after surgery. The after image on the right has been produced from smoothed laser data.
(From Moss et al., 1987, p: 251, figure 3)

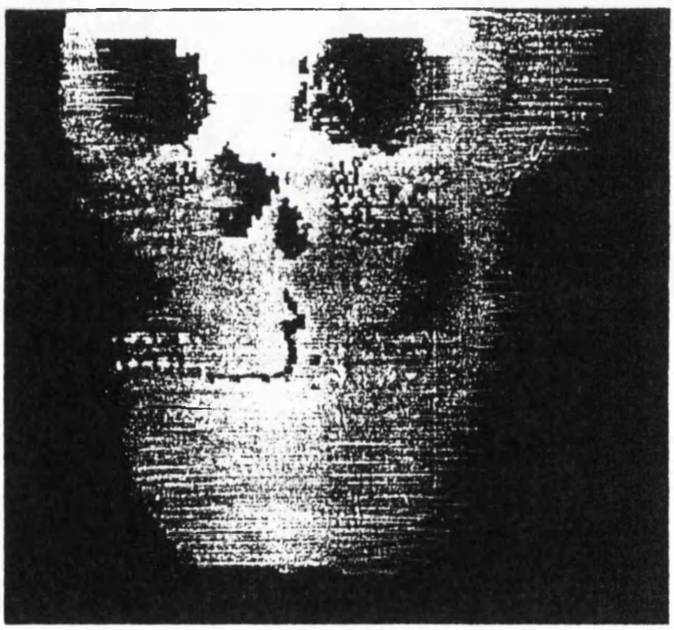


FIGURE 77
An image of the patient's skull generated using a voxel model, which took 10 seconds to display. The cleft on the left hand side can clearly be seen. The loss of bony definition in the right and left infra-orbital regions are due to the threshold selected for bone. The artefacts seen around the teeth are due to the presence of orthodontic brackets.
(From Moss et al., 1987, figure 4)

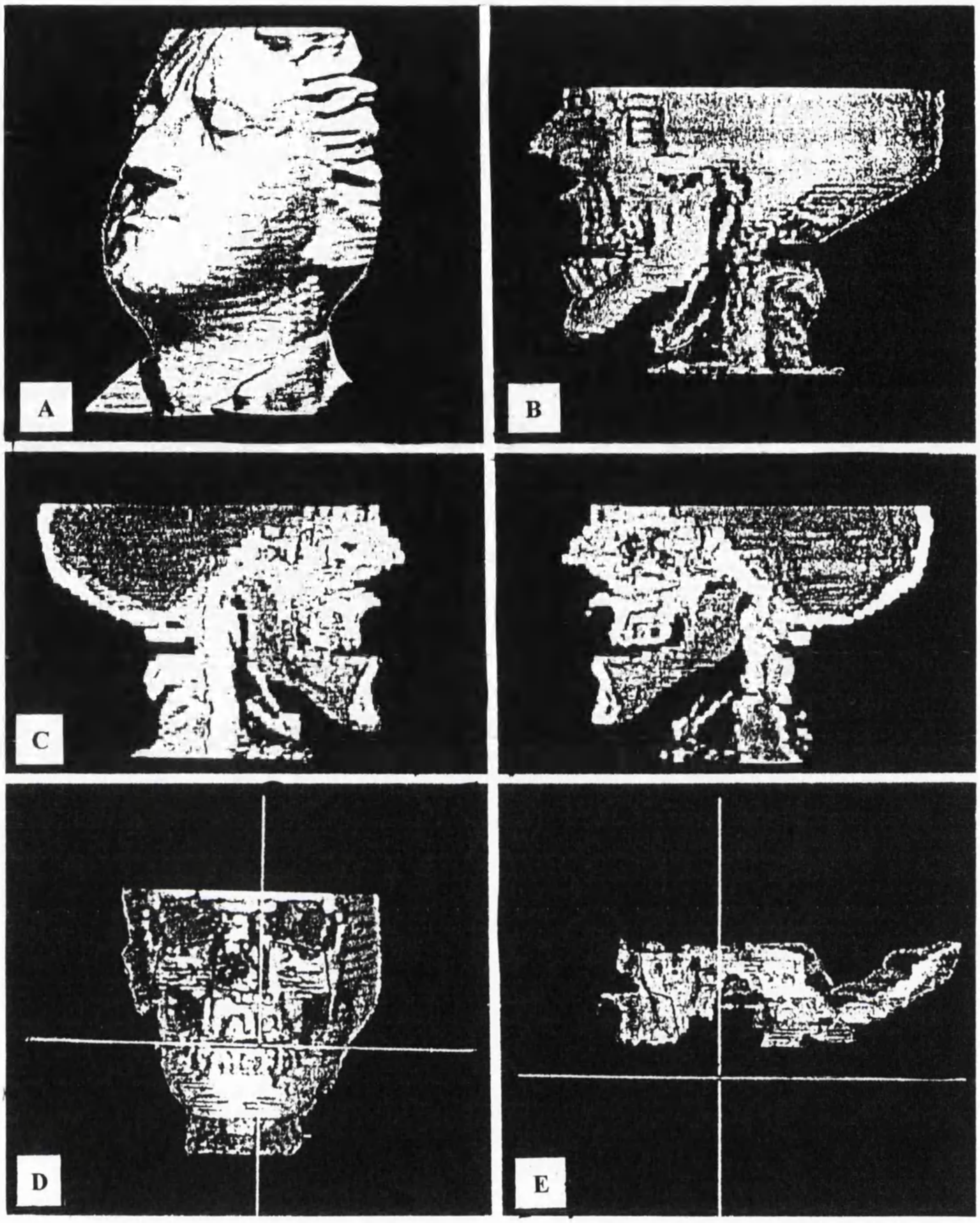


FIGURE 78

A. Shaded polygon image from laser scan data of the face of a patient with a cleft lip and palate. The mottled appearance is caused by digitization noise at alevel of less than 0.5 mm. **B.** A lateral view of a voxel-based image of the patient shown in figure (A). **C.** The skull has been split in the midline and the two halves separated and viewed from within. **D.** Frontal view of the skull showing the cursor line, operated by a trackerball, marking out the area of the maxilla and zygomatic arches to be removed at the time of surgical treatment. **E.** Lateral view showing the final modification to be made to the section to be repositioned.
(From Moss et al., 1988, p: 471, figure 2, 3, 4, 5, and 6)

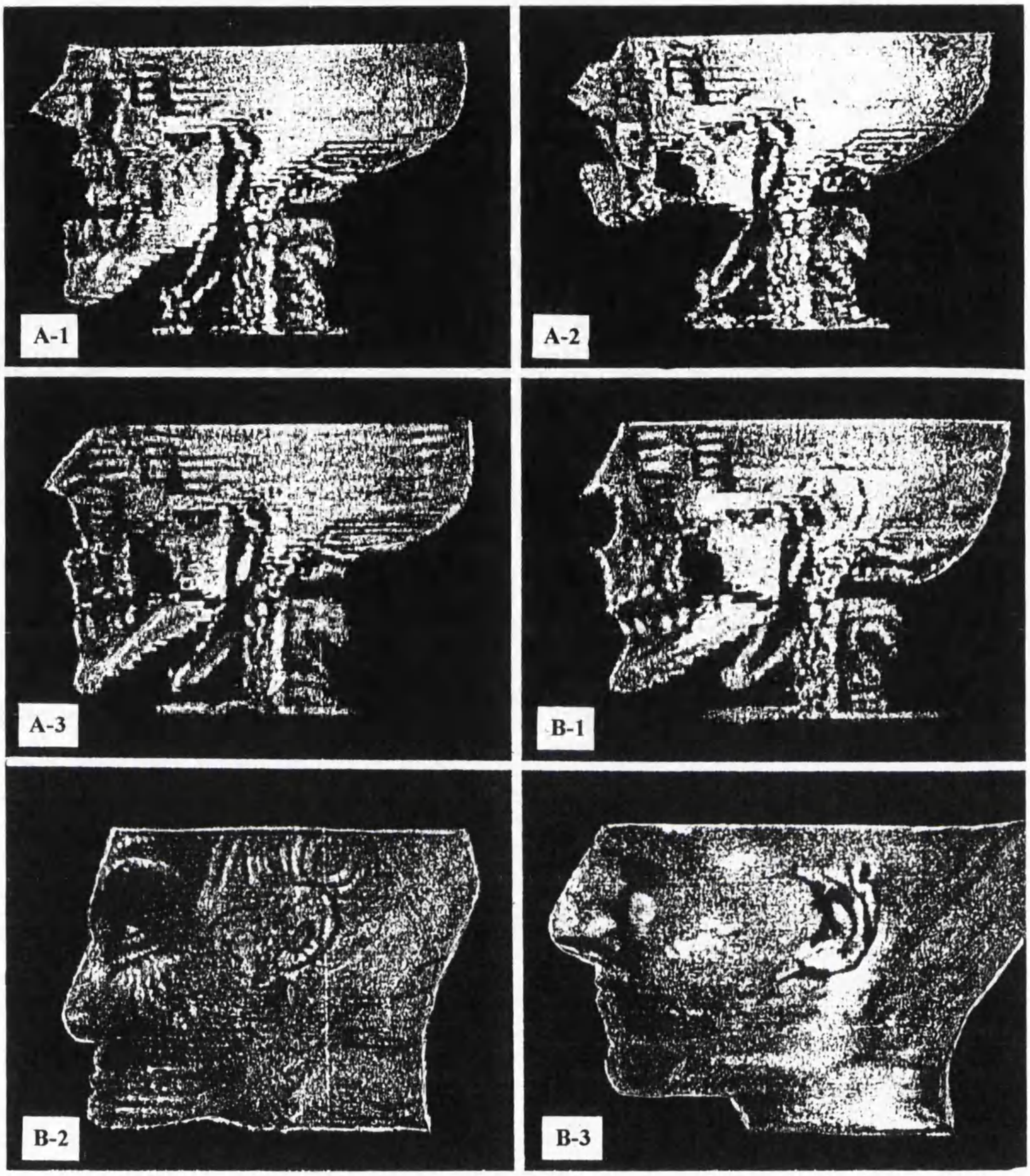


FIGURE 79

A-1. The displacement of the bone to be repositioned with surgery is marked by an arrow. **A-2.** The mandible has been removed and the maxillary fragment repositioned. **A-3.** The mandible has been moved into its corrected relationship with the maxilla.

B-1. A voxel image of the skull with the repositioned hard tissues shown in white and the superimposed soft tissues shown in red. **B-2.** A voxel image of the soft tissues in the modified position, following the exact movements of the bone. **B-3.** A polygon image of the modified soft tissue in which displacement over the midline is a definite fraction of the bone movement; away from the midline the movement is decreased in a linear fashion to the point at which no underlying bone displacement has occurred.

(From Moss et al., 1988, p. 472, figures 7A, B, C and 8A, B, C.)

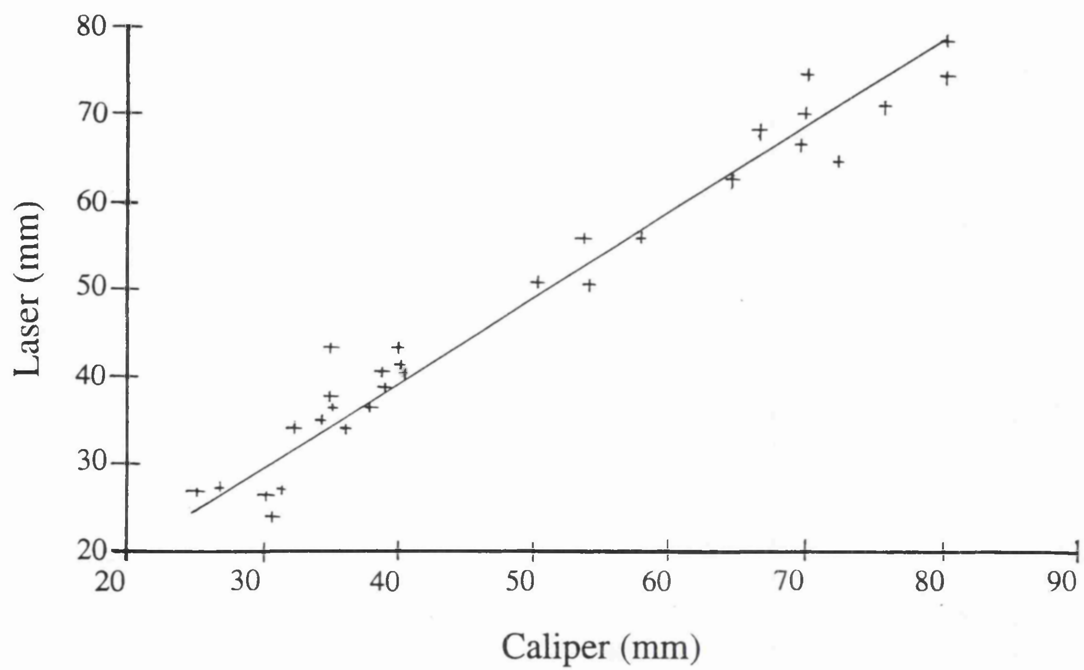


FIGURE 80
Distances measured between pairs of points on the laser based image of plaster cast plotted against direct caliper measurements.
(From Moss et al., 1989, p: 187, figure 6)

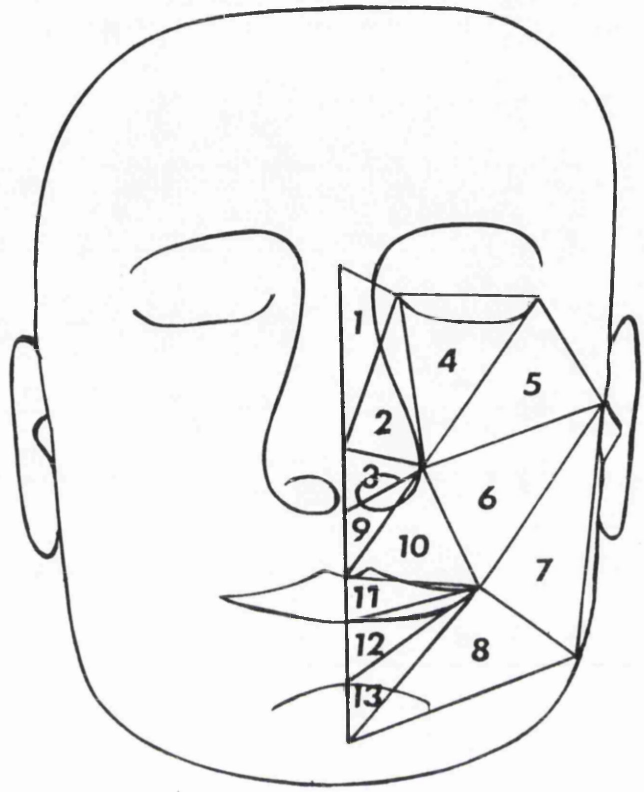


FIGURE 81
Diagram illustrating the triangles formed by joining the 13 points on the surface of the face. Triangles 1, 2,3 represent the area of the nose; 4, 5: the area of the eye; 6, 7: the cheek area; 8: the area of the mandible; 9, 10: the area of the upper lip; 11 the mouth; 12, 13: the lower lip.
(From Moss et al., 1991, p: 141, figure 2)

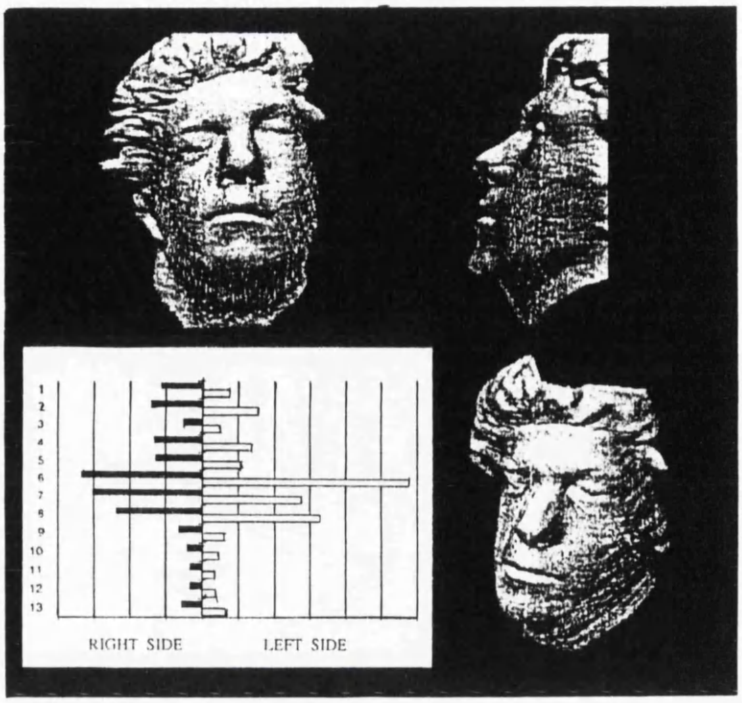
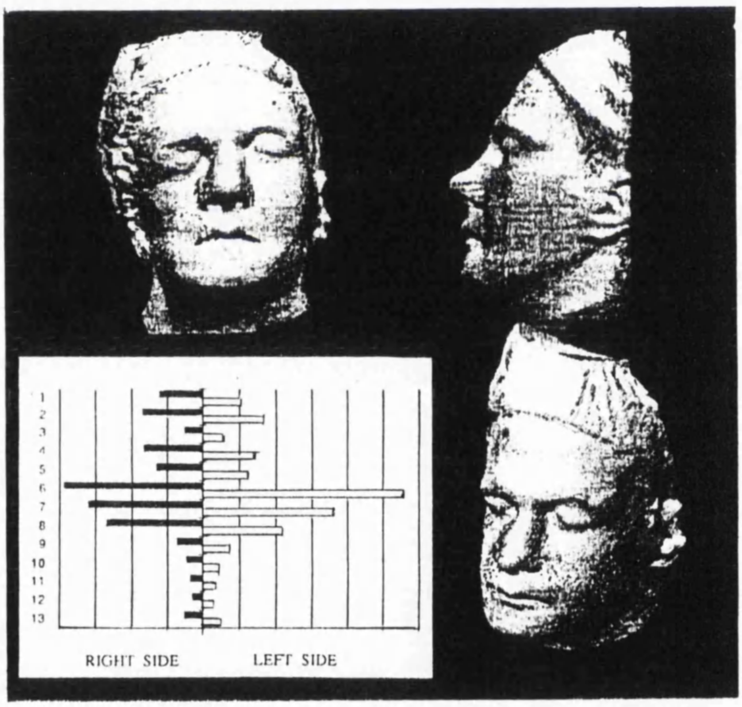


FIGURE 82
A. The areas of the triangles in a *patient with a right* sided Microsomia. The three views of the patient are taken from the laser scan. The patient was wearing a hat to keep the hair from off the forehead. Notice the imbalance and the decrease in size of the areas of the triangles on the right side.



B. The laser scan views of the same patient following surgery and a chart of the triangles. Notice that there is still an imbalance of the triangles especially on the right side which was affected by the abnormality. The area of the triangle representing the upper lip is larger on the affected side due to the position of the corner of the mouth.
(From Moss et al., 1991, p: 143, figures 4a and 4b)

APPENDIX 8
HISTORICAL TABLES

TABLE N° 1

Comparison of antemortem and postmortem records of Mrs. Isabella Ruxton (Glaister and Brash, 1937, p:111, Table XII)

	Isabella Ruxton	**Body N° 2-Female**
Age	34 years 7 months (3rd October, 1935).	Certainly between 30 and 55. Probably between 35 and 45.
Stature	5 ft. 5 in. to 5 ft. 6 in.	5 ft. 3½ in. (without shoes).
Hair	Soft texture, mid-brown with patch of grey slightly to right of top of head	Scalp completely removed; a few adherent hairs light to medium brown. Eyelashes dark brown. Available body hair mid-brown.
Eyes	Deep-set; grey-blue	Removed
Complexion	Fair	Ears, nose, lips, and skin of face removed
Teeth	Denture replacing three named teeth in gap which would show during life; old extraction of one other named tooth.	Old extraction or loss of fifteen teeth, including the four named
Fingers and Nails	Long fingers. Recognisable nails-bevelled, brittle, growing tight at corners, rounded at ends, regularly manicured.	Terminal segments of all fingers removed.
Legs and Ankles	Thick ankles. Legs of same thickness from knees to ankles.	Soft tissues removed from legs.
Left Foot	Inflamed bunion of left big toe.	Hallux Valgus of left foot; tissues removed over metatarso-phalangeal joint down to bone and joint opened. X-rays showed exostosis of head of metatarsal.
Size and shape of Feet	Left shoe as evidence	Cast of left foot fitted shoe.
Nose	Bridge uneven	Removed, but bone and cartilage arched.
Form of Head and Face	High forehead, high cheek-bones, rather long jaw. Two photographs in different positions.	Corresponding features. Outlines of photographs of skull in same positions fitted
Breasts	Pendulous breasts: three children	Appearance and structure of pair of breasts consistent.
Uterus	Three children	Separate uterus. Could not be assigned but structure consistent

TABLE N° 2

Comparison of antemortem and postmortem records of Miss. Mary Rogerson (Glaister and Brash, 1937, p:108, Table XI)

	Mary Jane Rogerson	**Body N° 1-Female**
Age	Twenty years (8th October 1935	Certainly between 18 and 25 Probably between 20 and 21
Stature	About 5 ft.	4 ft. 10 in. to 4 ft. 11½ in. (without shoes)
Hair	Light brown	Hair from scalp and body light brown
Eyes	Blue. "Glide" in one.	Removed
Complexion	Light. Freckles on nose and cheeks	Ears, nose, lips, and most of skin o face removed; complexion of remainder of skin consistent.
Teeth	Old extraction of six teeth, four of them named.	Old extraction or loss of eight teeth including the four named.
Neck	Short neck	Very small larynx very highly situated
Tonsils	Subject to tonsillitis	Microscopic evidence consistent with recurrent tonsillitis.
Vaccination Marks	Four on left upper arm.	Four on left upper arm.
Finger-nails	Maidservant	Trimmed but not regularly manicured; scratches indicating some form of manual work.
Scars	1. Abdominal scar-appendix operation. 2. Operation for septic thumb which had left a mark.	1. Trunk missing. 2.First segment of right thumb denudes of tissue; no scar on left thumb.
Identifying Peculiarity	Birth marks (red patches) on right forearm near elbow.	Skin and soft tissues removed from upper third of forearm, and lower two-thirds of front only.
Size and Shape of Feet	Left shoe as evidence	Cast of left foot fitted shoe.
Form of Head and Face	Two photographs in different positions.	Outlines of photographs of skull in same positions fitted
Finger-prints	Numerous imprints from house at 2 Dalton Square	Positively identified as the finger-prints of both hands and palmar impressions of left hand.
Breasts	Age 20, unmarried.	Single breast, appearance and structure consistent.

TABLE N° 3

Comparison of casts and shoes.

Feet and shoes	Maximum length	Maximum Breadth	Remarks
Foot N° 1 Mary Rogerson's shoe	215.3 mm 220.1 mm	77.4 mm 78.6 mm	After preservation. Inside measurements.
Foot N° 2 Allowance for mutilation Probable original measurement Mrs Ruxton's Shoe	213.8 mm 28.5 mm 242.3 mm 245.3 mm	83.9 mm 2.0 mm 85.9 mm 86.0 mm	As found, after preservation Removal of toes and bunion Inside Measurements.

This table shows the general correspondence between the measurements of the feet and the inside measurements of the shoes.
(Glaister an d Brash, 1937, p: 140, Table XIV)

TABLE N° 4

(McKenna case study "Jar Murders")

Features of correspondence of the facial skeletons of Skulls Z_7, Z_6, and Z_{20} with the superimposed photographic images of the victim's faces, after the features of the dentition had been matched by measurements and superimposition.

Features	Skull Z_7 Victim 1	Skull Z_6 Victim 2	Skull Z_{20} Victim 3	
Anterior nasal spine	X	X	X	
Zygomatic arches (and surrounding soft tissues)	X	X	X	
Orbits (and eyes)	X	X	X	
Supra orbital ridges (and eyebrows)	X	X	X	
Midline of maxilla (between sockets of 11 and 21)			X	
Mandibular angles	X	X		
Mandibular body (and surrounding soft tissues)	X	X		
Midline of mandible (between 31 and 41)	X			
Lip line	X	X		
Hair line (estimated)	X	X	X	
Overall outline and thicknesses of soft tissues	X	X	X	

(McKenna et al., 1984, p: 791, Table 1)

TABLE N° 5

Examining lines on the Face and Skull Images

Face Image		Skull Image
Glabella line		Upper orbit tangent
Central line		Central line
Gnathion line		Gnathion tangent
Ectocanthion line		Line between junctures of external orbit
Subnasale line		Piriform aperture lower tangent
Cheilion line		Mouth line
Vertical line through left endocanthion		Left canine
Vertical line through right endocanthion		Right canine

(From: Chai et al., 1993, p: 171-181)
(Iscan and Helmer, 1993, p: 176, table 2)

TABLE N° 6

Facial soft tissue thicknesses (mm) at 15 points over face as determined on cadavera

		Suicides (Sound)					
		Males				Females	
Point of measurement	**Death after Wasting Illness (9 males)**	**All (28)**	**17-40 years (16)**	**50-72 years (8)**		**18-52 years (4)**	**Range**
A. Midline							
1.Hairline (St_1)	**3.4**	**4.08**	4.03	4.1		4.16	2.5-5.0
2. Glabella (St_2)	**3.9**	**5.17**	4.91	5.3		4.75	3.0-6.0
3.Nasion (Nw)	**4.8**	**5.45**	5.50	5.6		5.0	3.0-7.0
4. Nasal bridge (Nr)	**3.0**	**3.29**	3.25	3.5		3.0	2.0-3.5
5. Root of the upper lip (Oi_1)	**10.8**	**11.25**	11.38	11.6		9.75	8.0-14.0
6.Philtrum of the upper lip (Oi_2)	**8.16**	**9.37**	9.53	9.5		8.26	6.5-12.0
7.Mentolabial furrow (K_1)	**8.5**	**10.00**	9.62	10.9		9.75	7.0-14.0
8.Chin eminence (K_2)	**8.5**	**11.05**	10.66	12.2		10.75	8.0-15.0
9.Under chin where mandible has min. depth (K_3)	**4.1**	**6.16**	5.97	6.4		6.5	2.5-8.0
B. Side Face							
10.Center of eyebrow (abr)	**4.6**	**5.80**	5.69	6.1		5.5	4.0-8.0
11.Middle of lower border of orbit (uA)	**3.75**	**4.90**	4.56	5.6		5.25	4.0-6.5
12.Mandibular border, in front of masseter (Uk)	**4.75**	**8.37**	7.90	9.4		8.1	3.5-12.0
13.Over zygomatic arch (Jb)	**3.8**	**6.05**	5.75	6.4		6.75	2.5-9.0
14.Ascending ramus, at center of masseter (Ms)	**13.0**	**17.55**	18.0	18.1		17.0	10.0-22.0
15.Gonial angle (Kw)	**8.0°**	**12.08°**	12.12°	12.3°		11.5°	5.5-16.0°

(From: His, 1895a, p: 407)

(Reprinted in Iscan and Helmer, 1993, p: 434, table 11.2. From Stewart, 1954, Table XXV)

TABLE N° 7

Facial Soft Tissue Thicknesses Data (mm) in White Males and Females. Incorporating Body Build Type and Nutritional State

		MEAN (mm)					RANGE (mm)			
		Male		Female			Male		Female	
Landmarks		**Very Thin**	**Well Nour.**	**Thin**	**Well Nour.**		**Max**	**Min**	**Max**	**Min**
Upper forehead	St_1	------	3.07	1.86	3.02		4.0	2.0	4.2	2.0
Lower forehead	St_2	3.0	4.29	2.93	3.90		5.8	3.0	5.4	3.2
Nasal root	Nw	3.1	4.31	3.53	4.10		6.0	3.0	4.7	2.5
Mid nasal bone	Nr	2.5	3.13	2.1	2.57		5.0	2.1	4.0	2.0
Tip of nasal bone	Ns	2.1	2.12	1.46	2.07		3.0	1.3	3.0	1.6
Root of upper lip	Ow	14.7	11.65	7.1	10.1		14.7	8.3	11.0	8.0
Philtrum	Lg	11.0	9.46	6.2	8.1		13.0	6.1	10.0	7.0
Mental sulcus	Lf	8.8	9.84	7.2	10.95		13.5	8.0	14.1	7.8
Chin prominence	Kw	5.7	9.02	4.96	9.37		13.0	5.0	12.1	7.7
Under the chin	K_3	5.1	5.98	3.66	5.86		9.0	3.0	9.4	3.8
Mid eyebrow	ABr	3.8	5.41	4.1	5.15		6.8	2.0	5.5	4.6
Mid infraorbital	Ua	2.1	3.51	3.76	3.65		6.1	2.1	4.4	3.0
Front of masseter	Uk	5.0	7.76	3.6	6.16		12.0	2.3	8.5	4.7
Root of zygom. arch	Jb_2	5.8	7.42	6.6	7.1		11.0	3.9	9.8	4.8
Hi. pt. zygom. arch	Jb_1	3.0	4.33	2.76	5.32		7.8	1.8	8.0	3.1
Hi. pt. on malar	Wb	3.2	6.62	4.2	7.73		10.9	3.2	9.5	6.7
Mid of masseter	Ms	-------	17.01	11.5	14.83		24.5	6.3	19.0	12.0
Jaw angle	Kw	4.5	8.72	3.75	7.56		15.1	3.0	10.2	4.7
Nose root-alar margin	Nl	57.0	52.05	50.66	46.75		63.0	41.0	50.0	44.0
Nose breadth at alae	Nb	33.0	35.65	31.33	34.75		43.0	29.0	38.0	32.0
Nose depth, tip-lip root	Nt	28.0	24.75	27.0	22.50		29.0	20.0	24.0	19.0
Height of upper lip	Ho	19.0	21.55	19.0	20.50		27.0	18.0	23.0	19.0
Oral cleft-chin prom.	Rk	35.0	33.45	29.0	25.50		42.0	28.0	30.0	25.0

(From Kollmann and Büchly, 1898, p: 357, table 2)

(Reprinted in Krogman and Iscan, 1986, p: 435, Table 11.3)

TABLE N° 8-A

Relationship to the Sex and Body build parameters in the Mean Bizygomatic dimension and Mean Facial soft tissue thickness

Body-build of specimen				
MALE		**THIN**	**MEDIUM**	**FAT**
Number		20	30	19
A. Mean bizygomatic dimension (mm)		138	142	154
B. Mean thickness of soft tissues (mm)		8	12	21
C. A-B		130	130	133
FEMALE		**THIN**	**MEDIUM**	**FAT**
NUMBER		11	16	8
A. Mean bizygomatic dimension (mm)		134	138	145
B. Mean thickness of soft tissu (mm)		10	15	21
C. A-B		124	123	124

There is a marked difference between the readings from each sex, little difference between the readings in the three body-build classes.
(From Sutton, 1969, p: 305, figure 1)

TABLE N° 8-B

The percentage distribution in each body-build class of the total thickness of the soft tissues over both zygions.
(From Sutton, 1969, p: 305, figure 1)

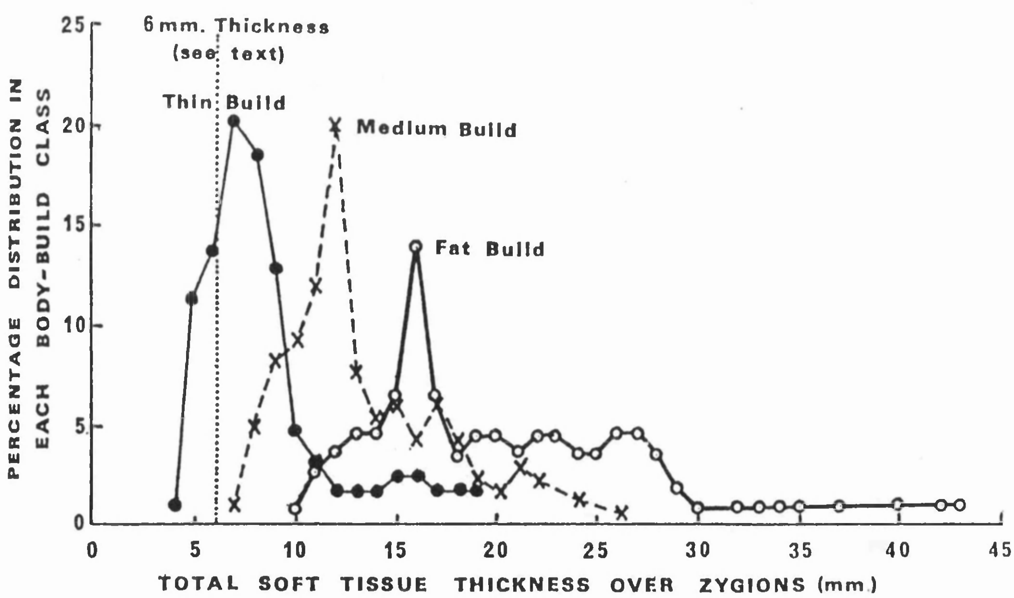


TABLE N° 9

Soft tissue thickness data in American Blacks according to Sex

LOCATION	MALE	FEMALE
MIDLINE		
1. Supraglabella	4.75	4.50
2. Glabella	6.25	6.25
3. Nasion	6.00	5.75
4. End of nasal	3.75	3.75
5. Mid-Philtrum	12.25	11.25
6. Upper lip margin	14.00	13.00
7. Lower lip margin	15.00	15.50
8. Chin-lip fold	12.00	12.00
9. Mental eminence	12.25	12.25
10. Beneath chin	8.00	7.75
LATERAL		
11. Frontal eminence left	8.25	8.00
Frontal eminence right	8.75	8.00
12. Supraorbital left	4.75	4.50
Supraorbital right	4.75	4.50
13. Suborbital left	7.50	8.50_b
Suborbital right	7.75	8.25
14. Inferior malar left	16.25	17.25
Inferior malar right	17.00	17.75
15. Lateral orbits left	13.00	14.25_b
Lateral orbits right	13.25	12.75
16. Zygomatic arch left	8.75_b	9.25_b
Zygomatic arch right	8.50	9.00
17. Supraglenoid left	11.75	12.00
Supraglenoid right	11.75	12.25
18. Occlusal line left	19.50_b	18.25
Occlusal line right	19.00	19.25
19. Gonion left	14.25	14.25
Gonion right	14.75	14.25
20. Sub M_2 left	15.75	16.75
Sub M_2 right	16.50	17.25
21. Supra M^2 left	22.25_b	20.75
Supra M^2 right	22.00	21.25
Sample size	44	15
Average age	38.0	32.8
(b Left measurement greater than the right)		

(From Rhine and Campbell, 1980, p: 855, Table 4)

TABLE N° 9 A

Comparison of Facial Tissue Thickness

	BLACK		EUROPEAN			JAPANESE		
LOCATION	MALE	FEMALE	POINT	MALE	FEMALE	POINT	MALE	FEMALE
MIDLINE								
1. Supraglabella	4.75	4.50	st_1	3.50	3.50	m	3.00	2.00
2. Glabella	6.25	6.25	st_2	4.75	4.25	gl	3.80	3.20
3. Nasion	6.00	5.75	nw	5.00	4.50	n	4.10	3.40
4. End of nasal	3.75	3.75	ns	2.00	2.00	rhi	2.20	1.60
5. Mid-Philtrum	12.25	11.25	ow	11.50	10.00	---	---	---
6. Upper lip margin	14.00	13.00	lg	9.50	8.25	---	---	---
7. Lower lip margin	15.00	15.50	---	---	---	---	---	---
8. Chin-lip fold	12.00	12.00	k_1	10.00	10.00	ml	10.50	8.50
9. Mental eminence	12.25	12.25	k_2	10.25	10.00	pg	6.20	5.30
10. Beneath chin	8.00	7.75	k_3	6.00	6.25	gn	4.80	2.80
LATERAL								
11. Frontal eminence left	8.25	8.00	---	---	---	---	---	---
Frontal eminence right	8.75	8.00	---	---	---	---	---	---
12. Supraorbital left	4.75	4.50	oa	5.75[a]	5.25[a]	---	---	---
Supraorbital right	4.75	4.50	---	---	---	sc	4.50	3.60
13. Suborbital left	7.50	8.50[b]	ua	4.25	4.50	---	---	---
Suborbital right	7.75	8.25	---	---	---	or	3.70	3.00
14. Inferior malar left	16.25	17.25	---	---	---	---	---	---
Inferior malar right	17.00	17.75	---	---	---	---	---	---
15. Lateral orbits left	13.00	14.25[b]	wb	6.75	7.75	---	---	---
Lateral orbits right	13.25	12.75	---	---	---	ma	5.40	4.70
16. Zygomatic arch left	8.75[b]	9.25[b]	jb_1	4.25	5.25	---	---	---
Zygomatic arch right	8.50	9.00	---	---	---	zy	4.40	2.90
17. Supraglenoid left	11.75	12.00	jb_2	6.75	7.00	---	---	---
Supraglenoid right	11.75	12.25	---	---	---	---	---	---
18. Occlusal line left	19.50[b]	18.25	---	---	---	---	---	---
Occlusal line right	19.00	19.25	---	---	---	---	---	---
19. Gonion left	14.25	14.25	go	10.50	9.50	---	---	---
Gonion right	14.75	14.25	---	---	---	go	6.80	4.00
20. Sub M_2 left	15.75	16.75	---	---	---	--	---	---
Sub M_2 right	16.50	17.25	---	---	---	m_1	10.20	9.70
21. Supra M^2 left	22.25[b]	20.75	---	---	---	---	---	---
Supra M^2 right	22.00	21.25	---	---	---	m^1	14.50	12.30
Sample size	44	15		45	8		9[c]	7
Average age	38.0	32.8		over 40			over 40	
a Kollmann and Büchly's measurements are larger b Left measurement greater than the right c Only well-nourished individuals included								

(From Rhine and Campbell, 1980, p: 855, Table 4)

TABLE N° 10

Results of the test used by Snow et al. (1970)
Number of correct identifications made by policemen, civilian males, and civilian females for the two facial reconstructions. (Probabilities are based on 2 x 2 Chi square analyses using N/7 for the number of chance-expected correct identifications.)

				Civilian			Civilian			All	
Policemen				Males			Females			Subjects	
	N	Correct		N	Correct		N	Correct		N	Correct
Reconstruction											
Case 3	36	10		34	7		34	10		104	27[1]
Case 4	91	73[2]		76	39[2]		33	23[2]		200	135[2]
[1] $p < 0.05$ [2] $p < 0.005$											

(From Snow et al., 1970, p: 225, Table 1)-(Reprinted in Stewart, 1979, p: 270, Table XXXVII)

TABLE N° 11

Facial Features which are significant in the Recognition of a Face.

GOOD IDENTIFIERS	POOR IDENTIFIERS
Facial marks	Race
Ears	Lips
Eye colour	Body weight
Teeth	General appearance
Facial expression	Facial features
Hair style	Brows
Mouth	Hair colour
Space between mouth and nose	Intuition
Facial deformities	Eyes
Expression of mouth: Set into face	Whole face
Ear shape	Eye shape
Skin colouring	Mental picture
Cheeks	Width of nose
Face shape	Nose
Expression eyes	Chin
Eye size	Space between eyes
Slant of eyes	Fullness of face
Watery eyes	Nose shape
Bone structure	Shoulder
Turned up nose	Hairline
Nostrils	Size
Drooping mouth	Hair texture
Dimples on cheeks	Relationship of features
Posture	Face size
Attitude	Facial texture
Hair	Size of features
Forehead	Eyelashes
Neck	Area around eyes
Shape of mouth	Spacing
Age	Dimple on chin
Lobes	Glasses
Prominent features	Nose size
Skin	Beard
	Position of chin

(From Zabala and Paley, 1972, Table VI-3, **"Responses used most often by good identifiers vs poor identifiers in order of importance"** p: 52)

TABLE N° 12

General Identification of Human Remains (1991)

CASE N°	Race	Sex	Age	Height (cm)	Height determined in Glasgow using Trotter and Glesse Regresion equation (1995)
1	Caucasoid	Male	a) Anthropological ±30-40 (40-44) b) Odontological: 35-40	173 cm (171±3)	Average: 170.15 cm Range: 167.16to 173.14 cm
2	Caucasoid	Male	a) ±35-40 (25-30) b) 30-35	155.7 cm	Average: 159.62 cm Range: 156.63 to 162.61 cm
3	Caucasoid	Male	a) x 35 (30-35) b) ≈30	161.7 cm	Average:165.21 cm Range: 162.22 to 168.2 cm
4	Caucasoid	Male	a) 16-18 b) 20-22	167.1 cm	Average: 170.54 cm Range: 167.55 to 173.53 cm
5	Caucasoid	Male	a) x 25 b)37	162.6 cm	Average: 166.38 cm Range: 163.39 to 169.37 cm
6	Caucasoid	Male	a) 25-26 b)37±5	151.1 cm (158±3)	Average: 158.58 cm Range: 155.59 to 161.57 cm
7	Caucasoid	Male	a) x 27 b)22±5	167.5 cm	Average: 169.11 cm Range: 166.12 to 172.1 cm
8	Caucasoid	Male	a) 39-40 b) 35-40	165.5 cm	Average: 167.68 cm Range: 164.69 to 170.67 cm
9	Caucasoid	Male	a) ±25-28 b) 19-21	155 cm	Average: 160.79 cm Range: 157.8 to 163.78 cm
10	Caucasoid	Male	a) ±25-30 b) 30	157.1	Average: 158.51 cm Range: 155.24 to 161.78 cm
11	Caucasoid	Male	a)x 42 (41-45) b) 45-50	150.2 cm (156±3)	Average: 156.63 cm Range: 153.64 to 159.62 cm >30 years: Average: 155.97 cm Range: 152.98 to 158.96 cm
12	Caucasoid	Male	a) 50 b) 55	163 cm (167±3)	Average: 164.22 cm Range: 160.95 to 167.49 cm >30 years Average: 163.08 cm Range: 159.81 to 166.35 cm
13	Caucasoid	Male	a) 35-40 b) ≈40	166.3 cm (164)	Average: 163.51 cm Range: 160.24 to 166.78 cm >30 years Average: 161.72 cm Range: 158.73 to 164.71 cm
14	Caucasoid	Male	a) ±30-37 b) 45-50	171.57 cm (172±3)	Average: 172.36 cm Range: 169.37 to 175.35 cm >30 years Average: 171.94 cm Range: 168.95 to 174.94 cm
			( )Second determinati a) Anthropological determination b) Odontological determination	( )Second determination	

TABLE N° 13

***Anthropological records of missing persons**

Missing person N°	SEX	AGE	HEIGHT (cm)
1	Male	25	170-175
2	Male	30	± 168
3	Male	30	172
4	Male	20	165
5	Male	27	±170
6	Male	23	160
7	Male	27	165
8	Male	24	170
9	Male	22	±160
10	Male	23	± 158-159
11	Male	41	160
12	Male	49	±175 ±170
13	Male	36	170
14	Male	36	± 165
*These parameters correspond to anthropological records based on missing relatives' information. Records showed in some cases discordant information in the same evaluated parameter. No one of the cases had medical or odontological records			

TABLE N° 14

Comparison between General Identification of Human Remains (1991) with anthropological records of missing persons

Human Remains				Missing persons		
CASE N°	Age	Height (cm)	Height determined in Glasgow using Trotter and Glesse Regresion equation (1995)		AGE	HEIGHT
1	a) Anthropologica ±30-40 (40-44) b) Odontological: 35-40	173 cm (171±3)	Average: 170.15 cm Range: 167.16 to 173.14 cm		25	170-175
2	a) ±35-40 (25-30) b) 30-35	155.7 cm	Average: 159.62 cm Range: 156.63 to 162.61 cm		30	±168
3	a) x 35 (30-35) b) ≈30	161.7 cm	Average:165.21 cm Range: 162.22 to 168.2 cm		30	172
4	a) 16-18 b) 20-22	167.1 cm	Average: 170.54 cm Range: 167.55 to 173.53 cm		20	165
5	a) x 25 b)37	162.6 cm	Average: 166.38 cm Range: 163.39 to 169.37 cm		27	±170
6	a) 25-26 b)37±5	151.1 cm (158±3)	Average: 158.58 cm Range: 155.59 to 161.57 cm		23	160
7	a) x 27 b)22±5	167.5 cm	Average: 169.11 cm Range: 166.12 to 172.1 cm		27	165
8	a) 39-40 b) 35-40	165.5 cm	Average: 167.68 cm Range: 164.69 to 170.67 cm		24	170
9	a) ±25-28 b) 19-21	155 cm	Average: 160.79 cm Range: 157.8 to 163.78 cm		22	±160
10	a) ±25-30 b) 30	157.1	Average: 158.51 cm Range: 155.24 to 161.78 cm		23	±158-159
11	a)x 42 (41-45) b) 45-50	150.2 cm (156±3)	Average: 156.63 cm Range: 153.64 to 159.62 cm >30 years: Average: 155.97 cm Range: 152.98 to 158.96 cm		41	160
12	a) 50 b) 55	163 cm (167±3)	Average: 164.22 cm Range: 160.95 to 167.49 cm >30 years Average: 163.08 cm Range: 159.81 to 166.35 cm		49	±175 ±170
13	a) 35-40 b) ≈40	166.3 cm (164)	Average: 163.51 cm Range: 160.24 to 166.78 cm >30 years Average: 161.72 cm Range: 158.73 to 164.71 cm		36	170
14	a) ±30-37 b) 45-50	171.57 cm (172±3)	Average: 172.36 cm Range: 169.37 to 175.35 cm >30 years Average: 171.94 cm Range: 168.95 to 174.94 cm		36	±165
	( )Second determination a) Anthropological determination b) Odontological determination	( )Second determination				

TABLE N° 15

Facial Tissue thickness of American Whites (mm)

Measurement	Emaciated			Normal			Obese		
MIDLINE	**MALE (3)**	**FEMALE (3)**		**MALE (37)**	**FEMALE (19)**		**MALE (8)**	**FEMALE (3)**	
Supraglabella	2.25	2.50		4.25	3.50		5.50	4.25	
Glabella	2.50	4.00		5.25	4.75		7.50	7.50	
Nasion	4.25	5.25		6.50	5.50		7.50	7.00	
End of Nasals	2.50	2.25		3.00	2.75		3.50	4.25	
Midphiltrum	6.25	5.00		10.00	8.50		11.00	9.00	
Upper Lip Margin	9.75[b]	6.25		9.75	9.00		11.00	11.00	
Lower Lip Margin	9.50[b]	8.50		11.00	10.00		12.75	12.25	
Chin-Lip-Fold	8.75	9.25		10.75	9.50		12.25	13.75	
Mental Eminence	7.00	8.50		11.25	10.00		14.00	14.25	
Beneath Chin	4.50	3.75		7.25	5.75		10.75	9.00	
BILATERAL									
Frontal Eminence	3.00	2.75		4.25	3.50		5.50	5.00	
Supraorbital	6.25	5.25		8.25	7.00		10.25	10.00	
Suborbital	2.75	4.00		5.75	6.00		8.25	8.50	
Inferior Malar	8.50	7.00		13.25	12.75		15.25	14.00	
Lateral Orbit	5.00	6.00		10.00	10.75		13.75	14.75[b]	
Zygomatic arch, midway	3.00	3.50		7.25	7.50		11.75	13.00[b]	
Supraglenoid	4.25	4.25		8.50	8.00		11.25	10.50[b]	
Gonion	4.50	5.00		11.50	12.00[b]		17.50	17.50	
Supra M^2	12.00	12.00		19.50	19.25		25.00	23.75	
Occlusal line	12.00	11.00		18.25	17.00		23.50	20.25	
Sub M_2	10.00	9.50[b]		16.00	15.50		19.75	18.75	
b Given the small samples, these values have been slightly adjusted from observed to values more in accord with trends in the rest of yhe data									

(Adapted from; Rhine and Moore, 1982; revised 1984. Prepared by J. Stanley Rhine and C. Elliot Moore, through the co-operation of J. T. Weston)

TABLE N° 16 A

Comparative analysis of direct measurements with indirect measurements

Measurements taken directly

REGION	N	Measurements taken from the prints	N	
HEAD	12	ft-ft, t-t,, tri-g, tr-n, forehead inclination	5	
FACE	23	zy-zy, go-go, tr-gn, n-gn, n-sto, sn-gn, sto-gn, left n-t,, sn-t, gn-t, go-gn, inclinations of the upper face (g-sn) and lower face (sn-pg)	13	
ORBITS	16	en-en, ex-ex, ex-en rt & lt, ps-pi rt & lt, or-sci rt % lt, eye fissure inclination rt & lt	10	
NOSE	23	n-sn, n-prn, al-al, sn-prn, sbal-sn rt & lt, left ac-prn and sn-c', nasal bridge	12	
LIPS AND MOUTH	14	cph-cph, ch-ch, ch-sto rt & lt, sn-sto, sn-ls, ls-sto, sto-li, sbal-ls' rt & lt, left ch-t, upper lip and labial fissure inclinations	13	
EARS	12	sa-sba rt & lt, left pra-pa, gn-obi, gn-obs, obs-obi, ear inclination	7	
TOTAL	100		60	

Measurements taken directly

REGION	N	Measurements which cannot be taken from the prints	N	
HEAD	12	eu-eu, v-n, v-gn, g-op, v-po rt & lt, head circumference	7	
FACE	23	t-sn-t, t-gn-t, t-sn surf rt & lt, t-gn rt & lt, right t-n, t-sn, t-gn, gn-go	10	
ORBITS	16	or-os rt & lt, ex-t rt & lt, ex-go rt & lt	6	
NOSE	23	mf-mf, en-se rt & lt, al'-al' rt & lt, sn'-sn', right ac-prn and sn-c', ac-prn surf rt & lt, columella deviation	11	
LIPS AND MOUTH	14	right ch-t	1	
EARS	12	right pra-pa, gn-obi, gn-obs, obs-obi, ear inclination	5	
TOTAL	100		40	

(From Farkas, 1994, p: 80, Table 5-1)

TABLE N° 16 B

Photogrammetry: Usable results

Measurements			
REGION	**LINEAR**	**ANGULAR**	**Subtotal N**
HEAD	None	Forehead inclination from the vertical	1
FACE	Upper face height (n-sto)	Upper face inclination from the vertical (g-sn); lower face inclination from the vertical (sn-pg)	3
ORBITS	Intercanthal width (en-en); eye fissure height (ps-pi) (lateral view); orbit and brow height (or-sci)	Eye fissure inclination from the horizontal rt & lt	5
NOSE	Nose height (n-sn); columella length (sn-c')	Nasal bridge inclination from the vertical; nasal bridge deviation from the facial midline	4
LIPS AND MOUTH	Upper lip height (sn-sto); lower vermilion height (sto-li); philtrum width (cph-cph); lateral upper lip height (sbal-ls') rt & lt	Upper lip inclination from the vertical; labial fissure inclination from the horizontal	7
EARS	None	None	
			TOTAL: 20

(From Farkas, 1994, p: 81, Table 5-2_

TABLE N° 16 C
Photogrammetry; consistently shorter measurements

Print and type of measurement	Measurement	Average Difference (mm)	
Left Lateral (N-11)			
HORIZONTAL	lt t-n lt t-sn lt t-gn lt go-gn lt ac-prn lt ch-t lt obs-gn lt obi-gn	17.6 15.3 11.6 13.2 3.5 5.6 14.6 9.6	
VERTICAL	tr-n sn-gn sto-gn	2.0 4.0 3.9	
Frontal (N=11)			
HORIZONTAL	ex-ex rt ex-en lt ex-en rt sbal-sn lt sbal-sn rt ch-sto lt ch-sto	2.0 2.3 2.4 1.7 2.5 5.5 5.1	
VERTICAL	tr-g rt or-sci	3.5 1.9	
SEMISAGITTAL	rt en-se lt en-se	7.2 7.4	

(From Farkas, 1994, p: 83, Table 5-3)

TABLE N° 16 D
Photogrammetry: Indirect measurements that are larger or shorter

Average Differences					
		Longer		Shorter	
Print and type of measurement	Measurement	Millimeters	Degrees	Millimeters	Degrees
Left Lateral (N=11)					
HORIZONTAL	pra-pa	1.3	-	2.5	-
VERTICAL	tr-gn n-gn sa-sba obs-obi sn-prn n-prn ls-sto	2.5 2.8 1.6 1.5 1.5 1.1 1.3	- - - - - - -	4.3 2.8 1.5 2.6 1.4 1.4 1.3	- - - - - - -
ANGLE	Nasolabial Nasofrontal	- -	4.5 5.8	- -	6.0 4.5
INCLINATION FRONTAL (N=4)					
HORIZONTAL	ft-ft t-t ch-ch	4.0 3.4 2.8	- - -	3.4 2.9 2.3	- - -
VERTICAL	ps-pi	1.2	-	1.4	-

(From Farkas, 1994, p: 83, Table 5-4)

TABLE N° 17

Comparison of photogrammetric data between Farkas study and the literature

		Tanner and Weiner 1949 (N=70)	Gavan et al. 1952 (N=2)	Fraser and Pashayan, 1970 (N=50)	Farkas study 1994 (N=36)
AREA	MEASUREMENT				
Head	v-po		Longer by 2 mm		
	g-op		Longer by 5 mm		Could not be taken from prints
	eu-eu		Longer by 18 mm		
	ft-ft	Longer	Longer by 12 mm		Longer by 4 mm or shorter by 5.9 mm
Face	zy-zy	same		Correlated well	Longer by 3.6 mm
	go-go	same		Correlated well	Longer by 21.6 mm
	n-gn		Longer by 18 mm	Correlated well	Longer or shorter by 2.8 mm
	gn-go			Correlated well	Shorter by 13.2 mm
Orbits	en-en			Correlated well	Same (± 1 mm)
	ex-ex			Correlated well	Shorter by 2 mm
Nose	n-sn	Longer		Correlated well	Same (± 1mm)
	al-al	Longer	Longer by 4 mm	Correlated well	Longer by 2.4 mm
	n-prn			Correlated well	Longer by 1.1 mm or shorter by 1.4 mm
	sn-prn			Correlated well	Longer by 1.5 mm or shorter by 1.4 mm
Lips and mouth	ch-ch	Approximately		Correlated well	Longer by 2.8 mm or shorter by 2.3 mm
	cph-cph	Approximately same		Correlated well	Same (± 1 mm)

(From Farkas, 1994, p: 87, Table 5-5)

APPENDIX 9
PRESENT STUDY
FIGURES AND TABLES

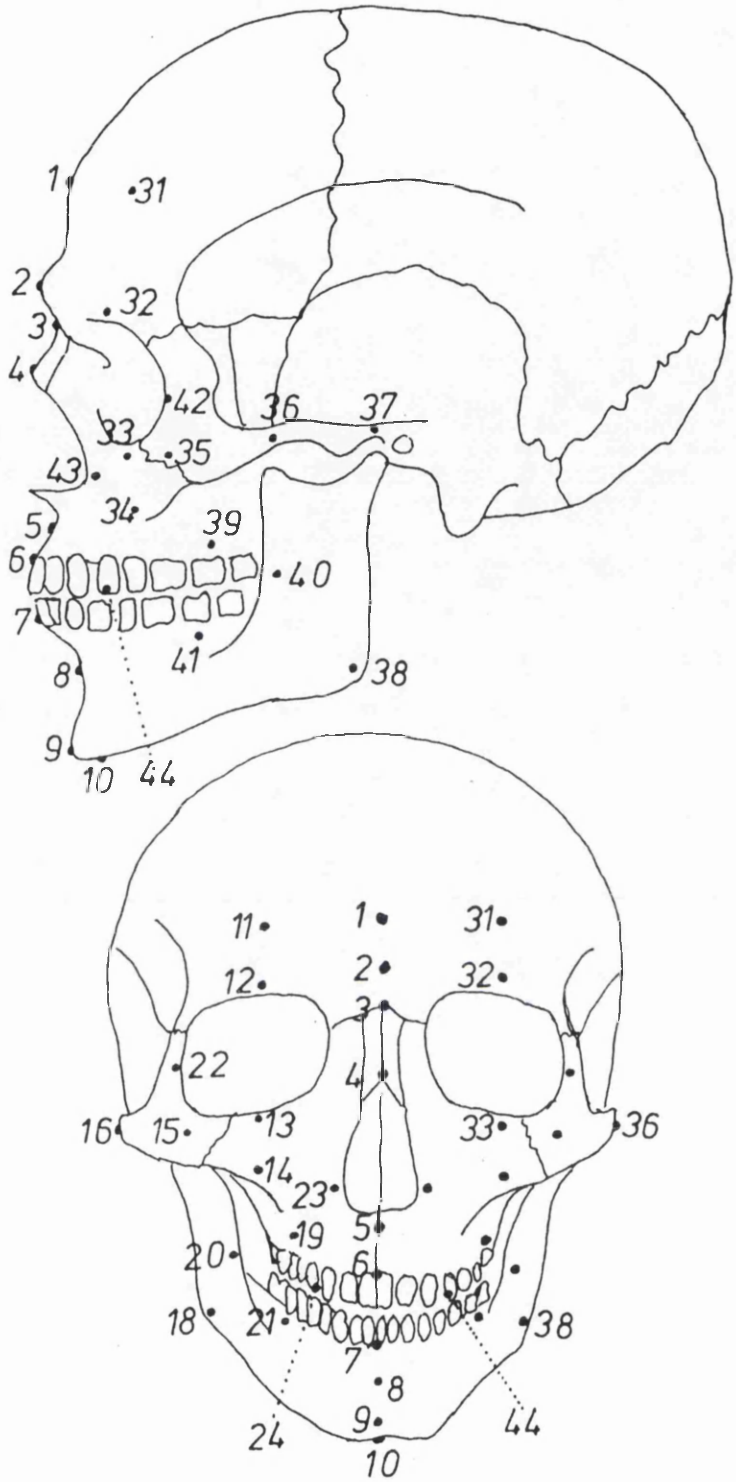


FIGURE 83
Lateral and frontal diagrams showing craniometric landmarks selected and used by the facial reconstruction sofware according to Rhine et al., studies of soft tissue thickness (1980, 1982, 1984)

SCHEMATIC PLAN OF THE OPTICAL FACE SCANNER

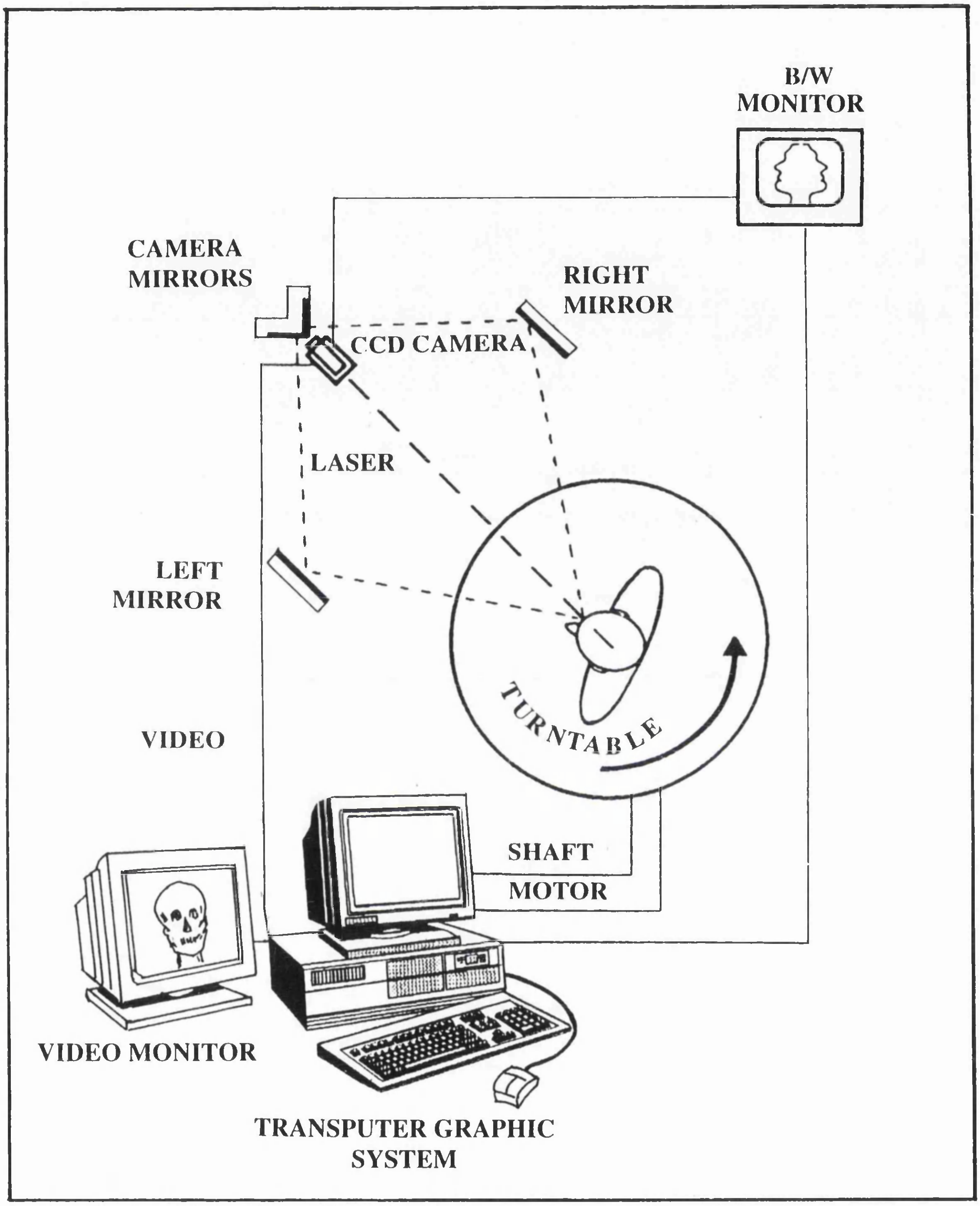
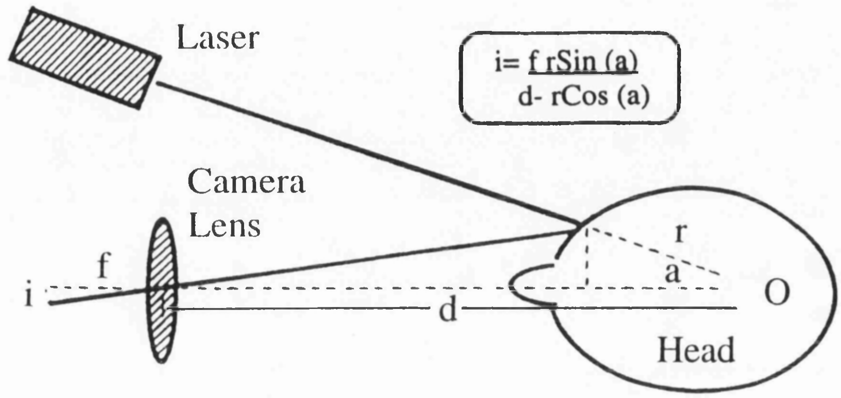


FIGURE 84
Schematic diagram of the Optical Surface Laser scanner system.
(From Linney et al., 1993, p: 5, figure 1)



O	Origin; the axis of rotation
a	Angle between laser and camera
r	Distance from origin of point being recorded
d	Distance from camera lens to Origin
i	Horizontal displacement of image

FIGURE 85
Geometric Diagram of the Laser Scanner system.
(From Moss et al., 1989, p: 181, figure 2)

FIGURES 86 A-B-C
Photographs illustrating the Optical Surface Laser Scanner System

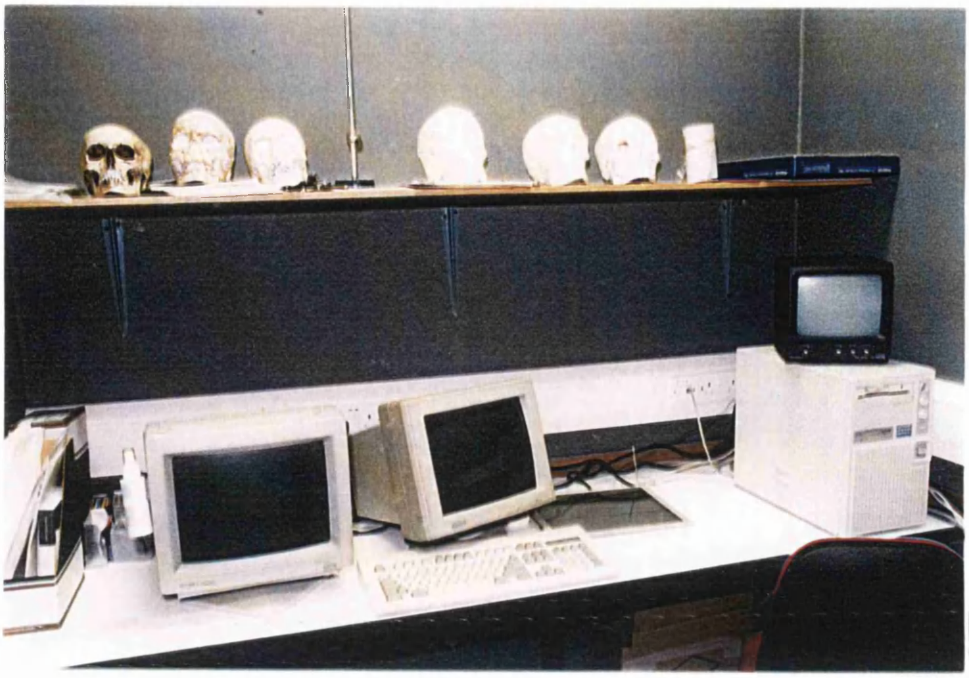


FIGURE 86-A
Photograph showing the Workstation consisted of a graphic display, a personal computer, a transputer and a Black-White monitor.

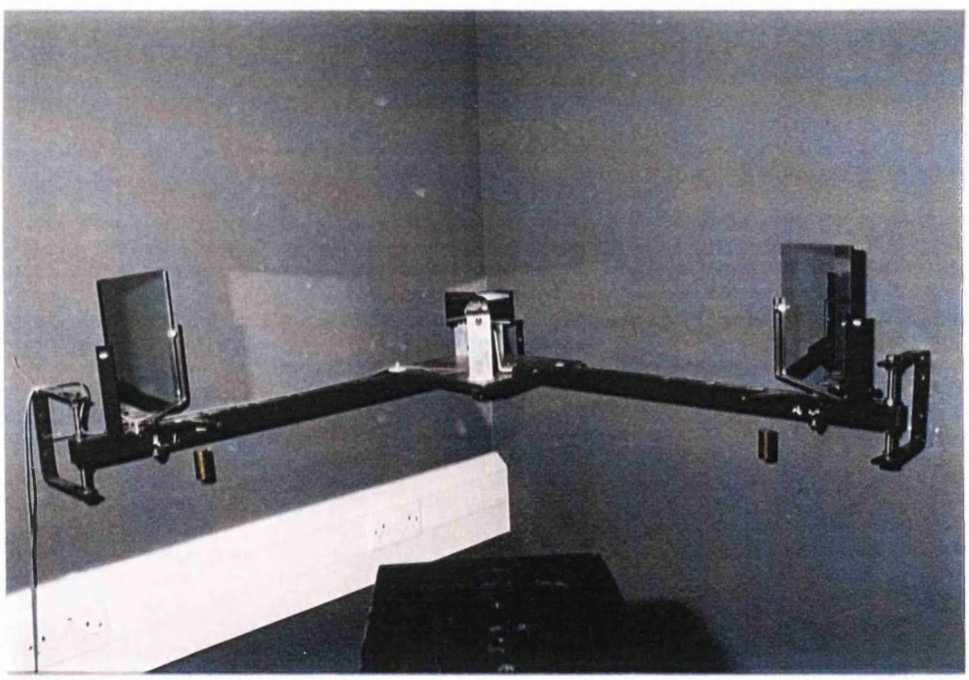


FIGURE 86-B
Photograph showing the mirrors system, CCD camera, and Laser system.

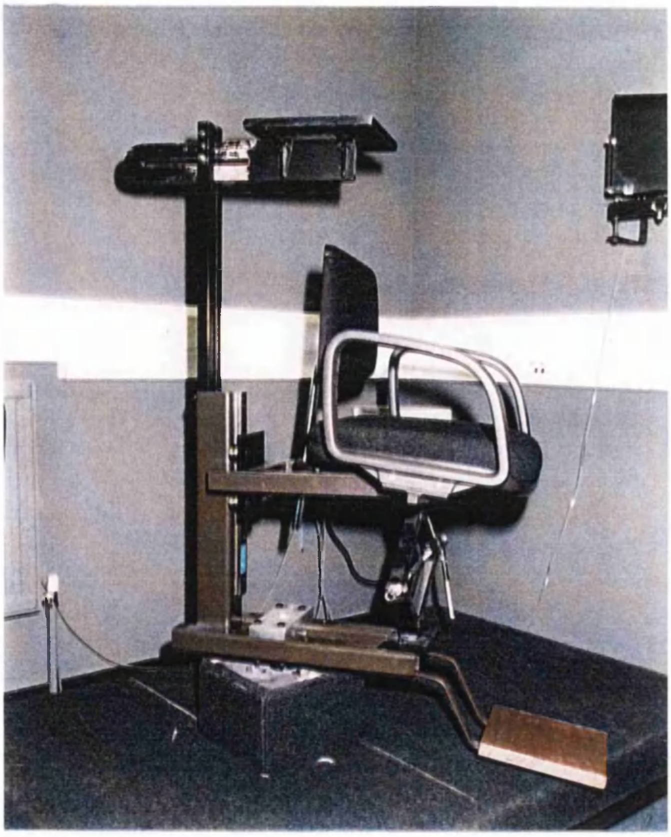


FIGURE 86-C
Photograph showing the computer controlled rotating platform.

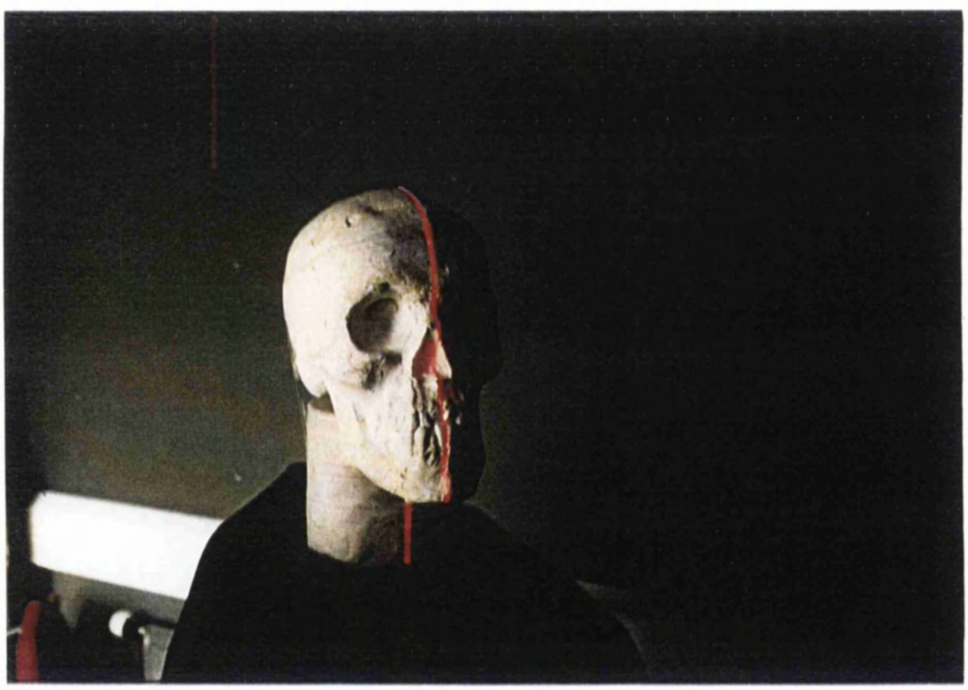
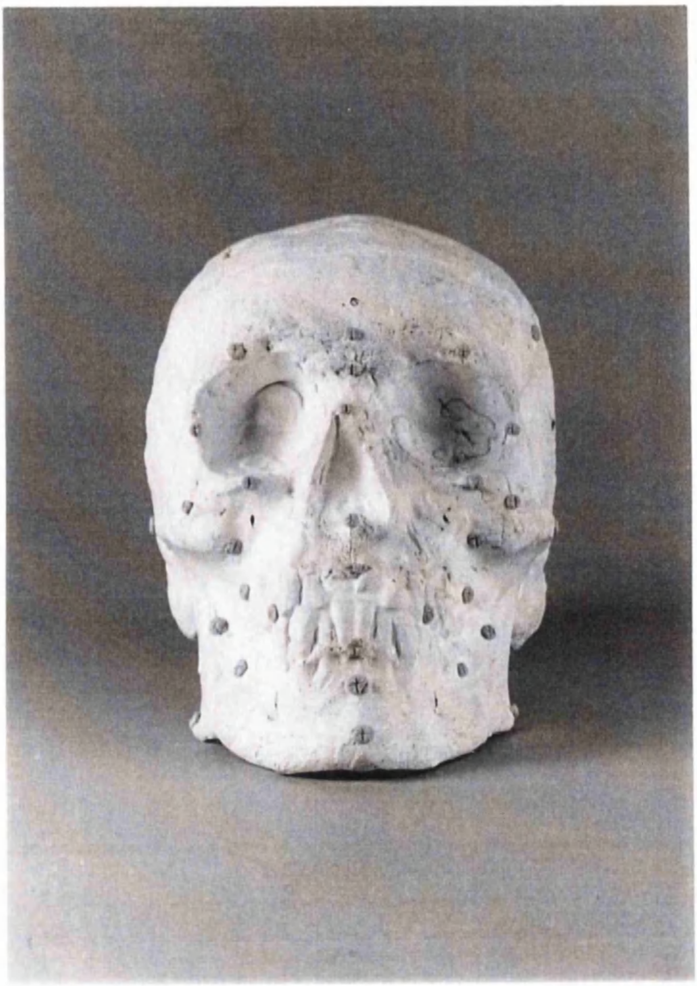


FIGURE 87
Photograph showing the plaster cast of skull selected from 16 cases to illustrate the whole process of facial reconstruction by computing using an optical surface laser scanner system.
Photograph of the laser showing the red laser line running vertically down on a plaster cast of skull



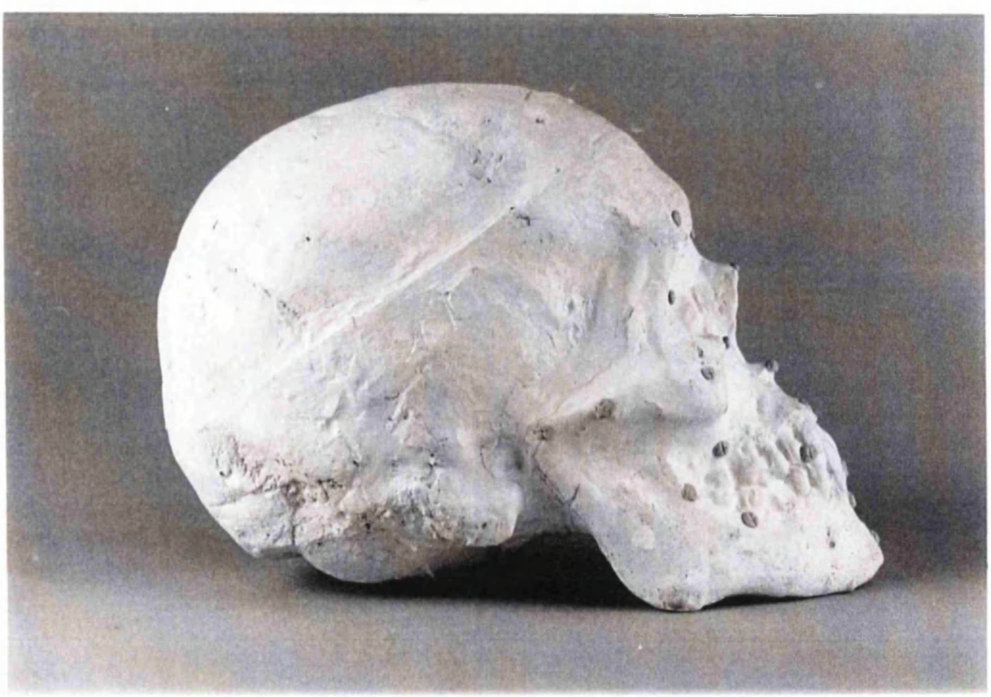


FIGURE 88
Frontal and lateral views of the plaster cast of skull selected illustrating the locations of the craniometric landmarks selected and used by Facial Reconstruction software.

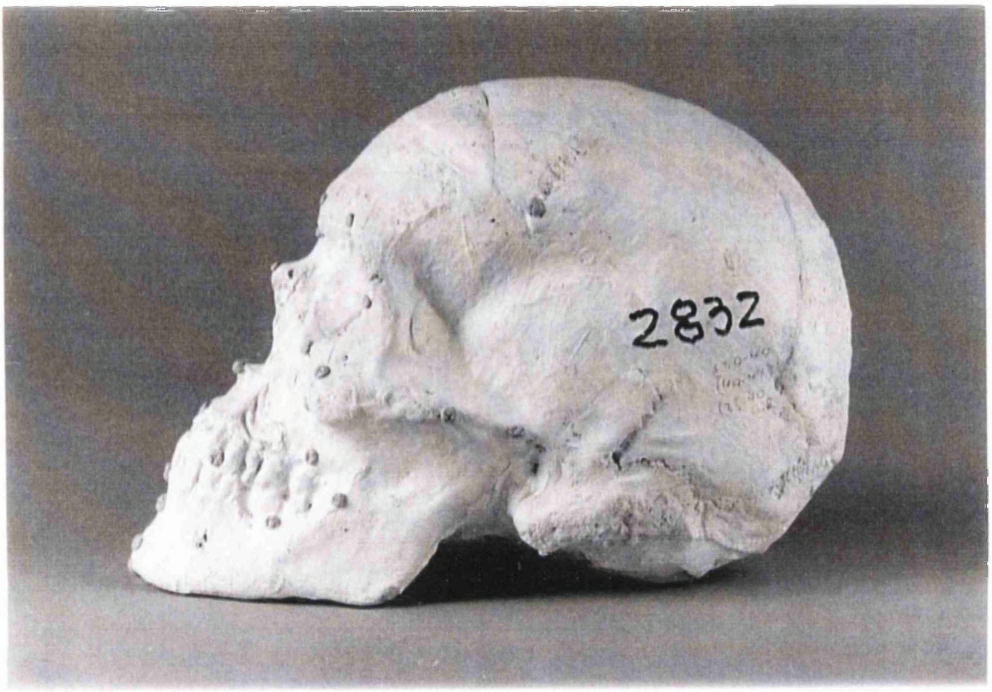


FIGURE 88

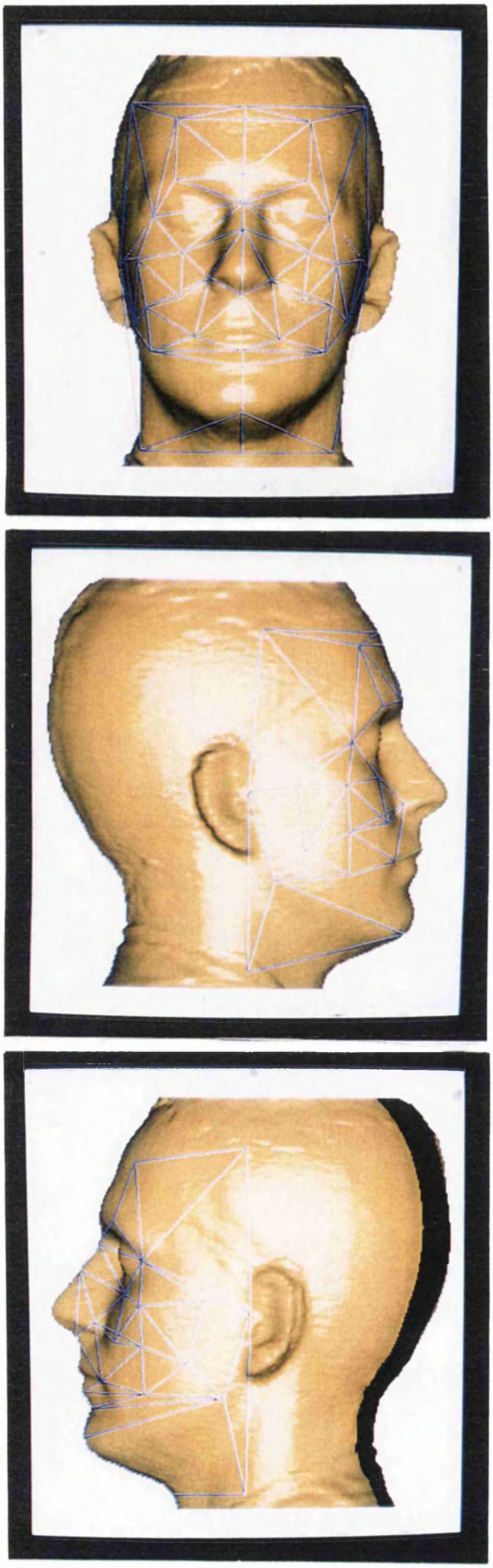


FIGURE 89
Frontal and lateral photographs of the average face used in the Facial Reconstruction program taken from the screen showing the locations of cephalometric landmarks, used by Facial Reconstruction software. The corresponding facial landmarks, assumed homologues to those showed in figure 88

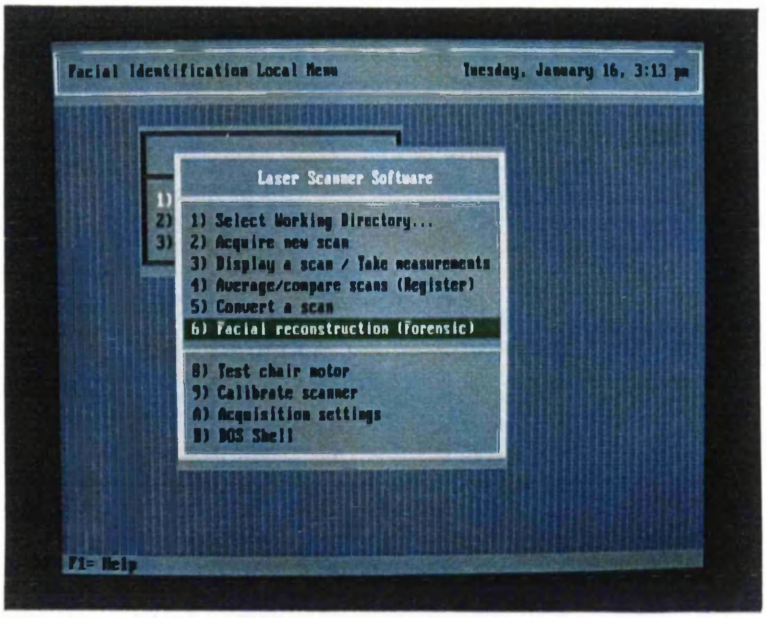


FIGURE 90
Facial Reconstruction program from Laser scanner software.

FIGURE 91
Photograph showing the MAIN MENU of the Facial Reconstruction program. Corresponds to step A.

FIGURE 92
Photograph from the screen showing the contents of File Menu. The operator must select the first item of this menu when the program gives the first instruction. Corresponds to step B

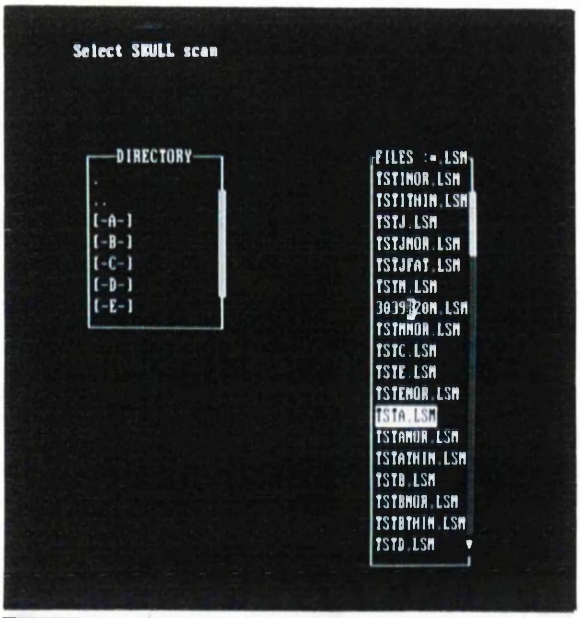


FIGURE 93
Photograph taken from the screen showing the special data file created to contain all the plaster cast scans and reconstruction performed on them. Photograph also illustrates the operator selecting the specific skull scan (TSTA.LSM). Corresponds to step B

FIGURE 94
Photograph of plaster cast of skull selected from 16 cases taken from the screen. The data set on the skull is displayed as a fully shaded three dimensional surface.
Corresponds to step B.

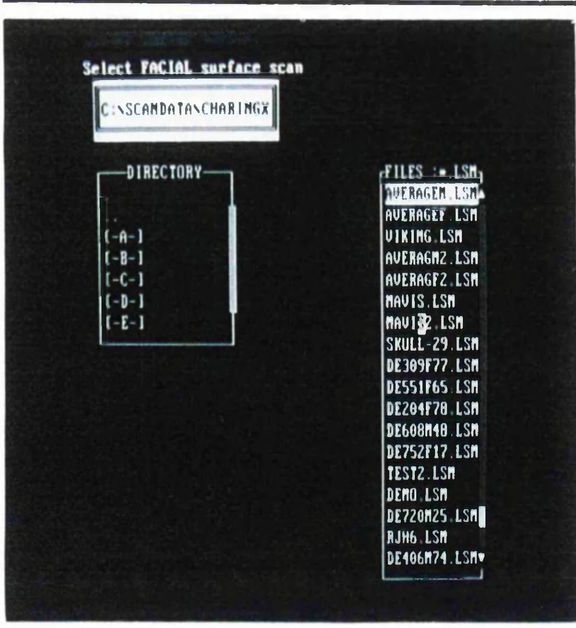


FIGURE 95
Photograph taken from the screen showing the special data file containing facial surface scans. The operator then selected the facial surface scan. In this case an average face male of similar characteristic of the skull in question was selected This is the second tutored step of the Facial Reconstruction program. Corresponds to step C.

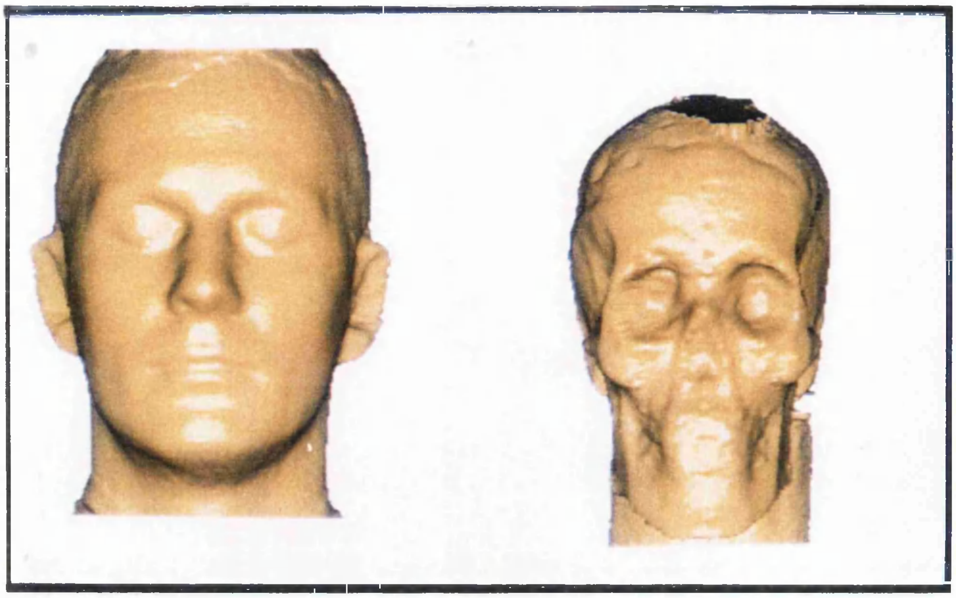


FIGURE 96
Photograph taken from the screen illustrating realistically the image on the screen of facial surface scan, in this case an average face male (on the left), together with the skull scan selected (on the right). Corresponds to step C.

FIGURE 97
Photograph showing the option select tissue type from the Main Menu corresponding to step D of Facial Reconstruction procedure.

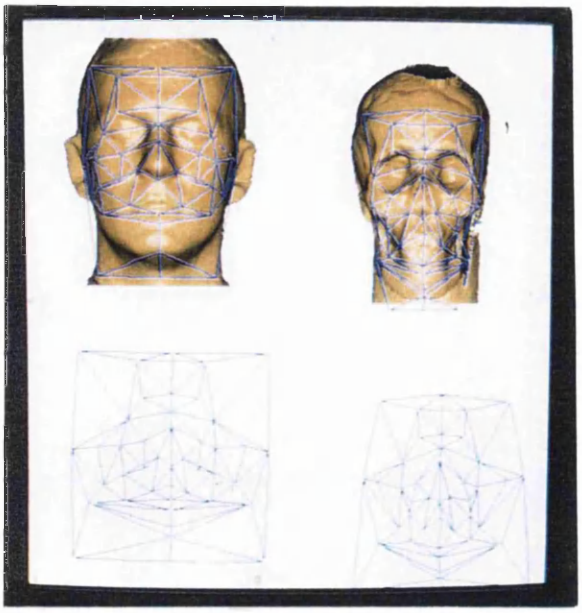


FIGURE 98
Photograph taken from the screen showing the stage of Facial Reconstruction program where the operator must place the landmarks in both images in their correct position according to the scheme of the program shown in figure 83. There are two main types of peg displays; the superior image shows the peg grid over the surface of the scans, allowing the locations of the pegs to be seen. An unwrapped display of the peg map is shown below of the two scans on the screen that allow the operator to judge symmetry or modify the positions of the landmarks when these are not clear in the images. This step corresponds to stage E.

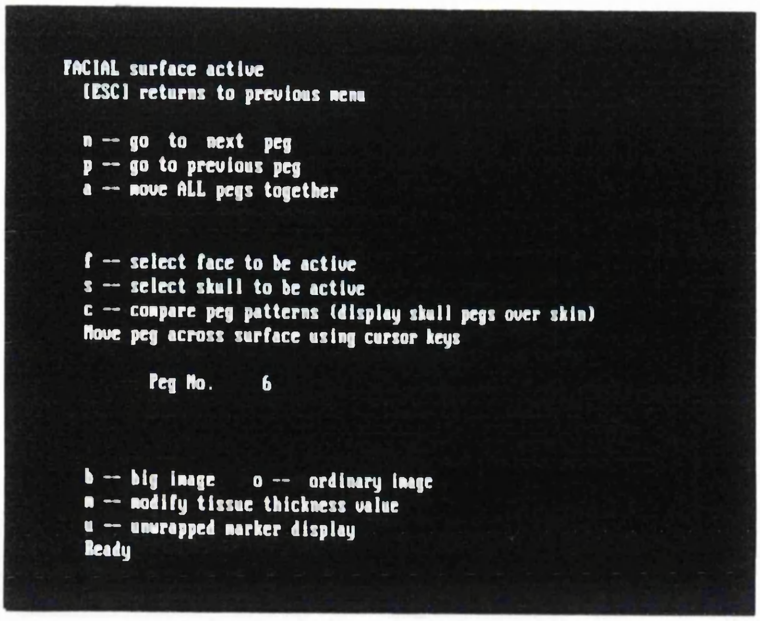


FIGURE 99
Photograph taken from the screen showing the keystrokes contained in the Adjust peg markers item selected from the Main Menu. This item is auto explanatory and allows the operator to locate and placing the landmarks in both scans. Corresponds to step E.

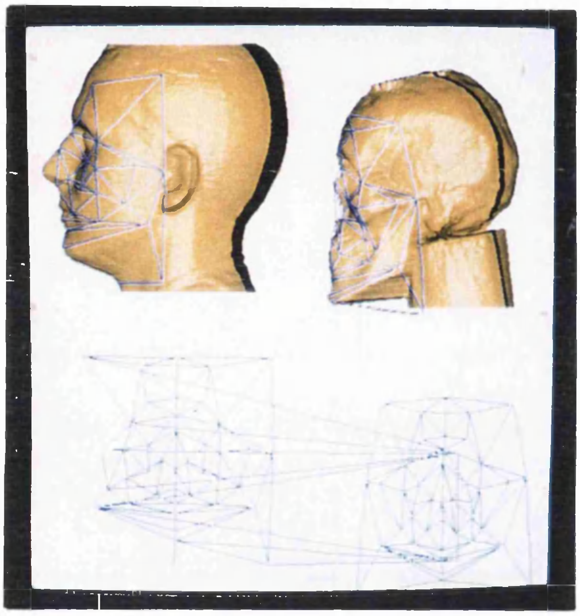
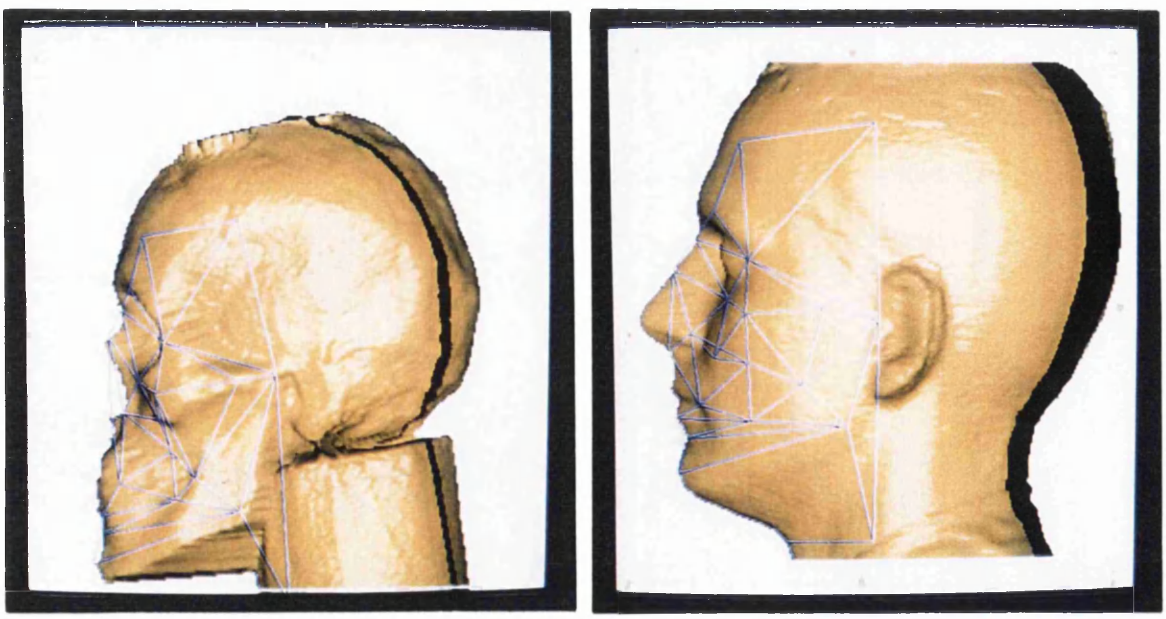


FIGURE 100
All photographs show frontal and lateral views on both images (skull and average face) with the right position of craniometric and cephalometric landmarks according to the numbering scheme shown in figure 83.
Corresponds to step F.



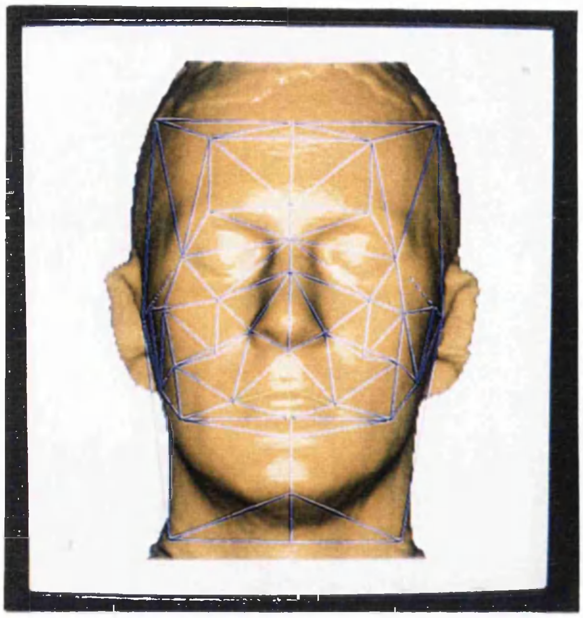
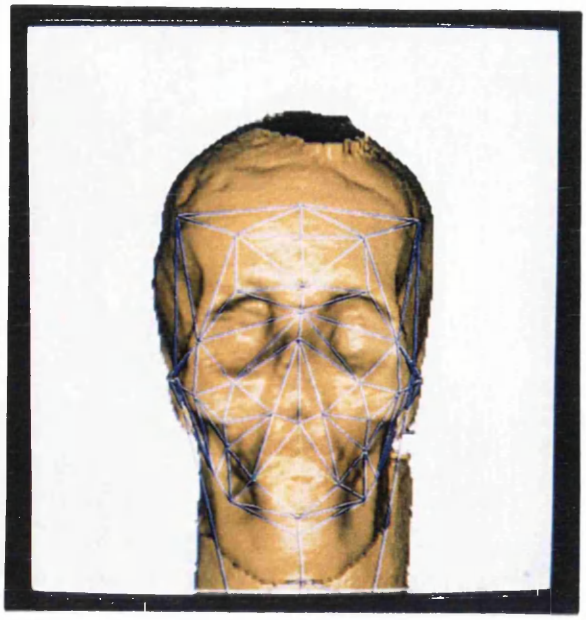



FIGURE 100
(continuation)

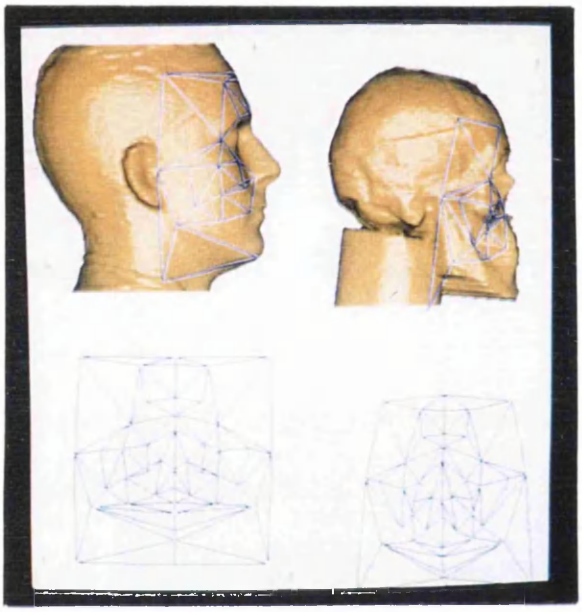
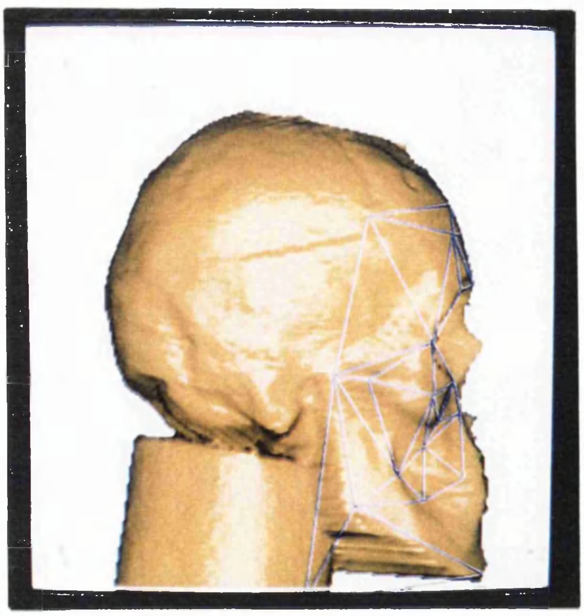
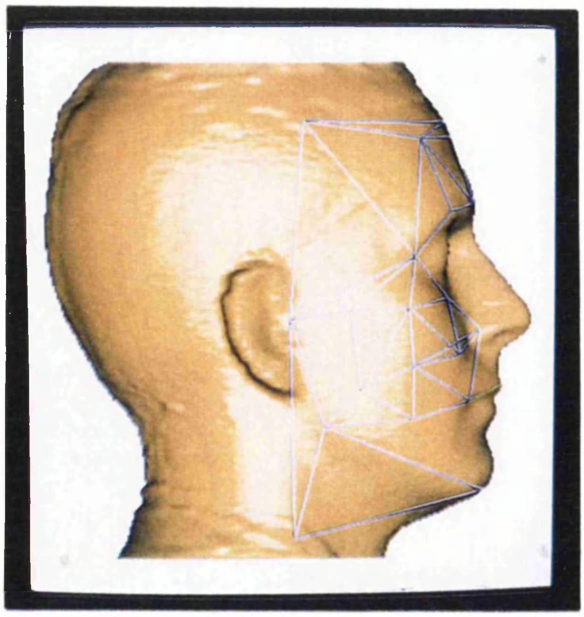




FIGURE 101
Photographs illustrating the application of Align and distort menu from the Main Menu in both scans images. This process allows adjusting a face scan to match the shape of a skull scan.

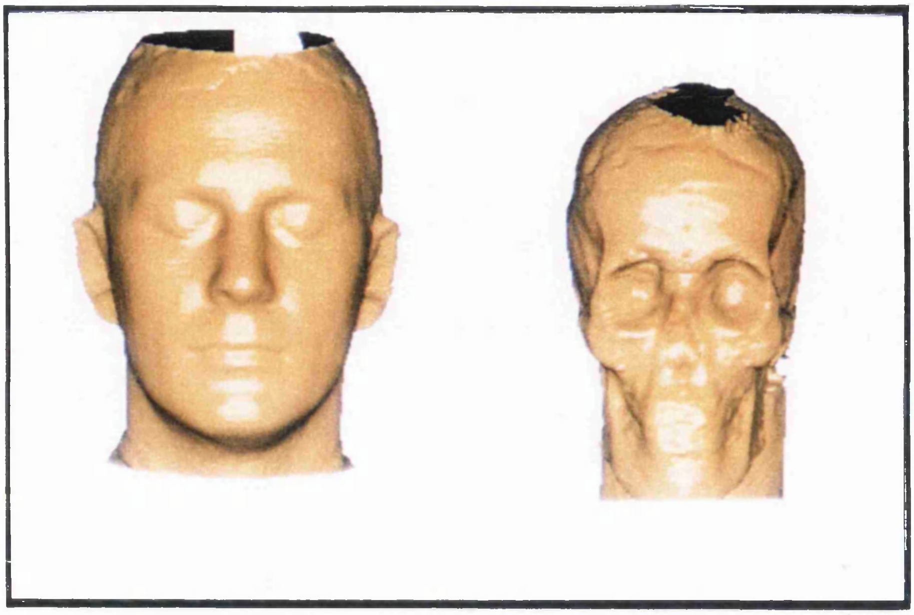


FIGURE 101A. Shows the scan images after applying the option Normalise orientations. This option rotates the face data to match the orientation of the skull data.

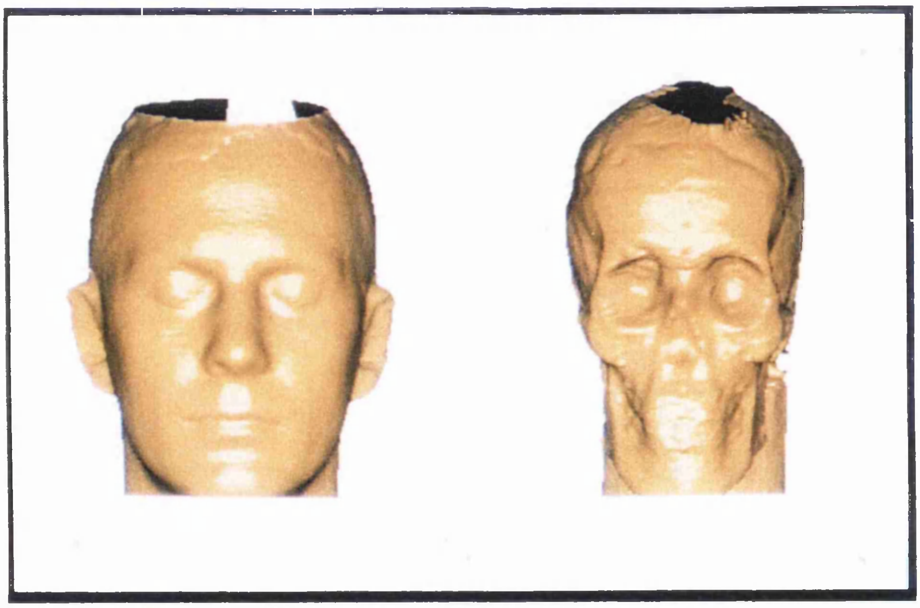


FIGURE 101B. Shows both scan images after applied the option Normalise position. This option shifts the face data to match the location of the skull data.

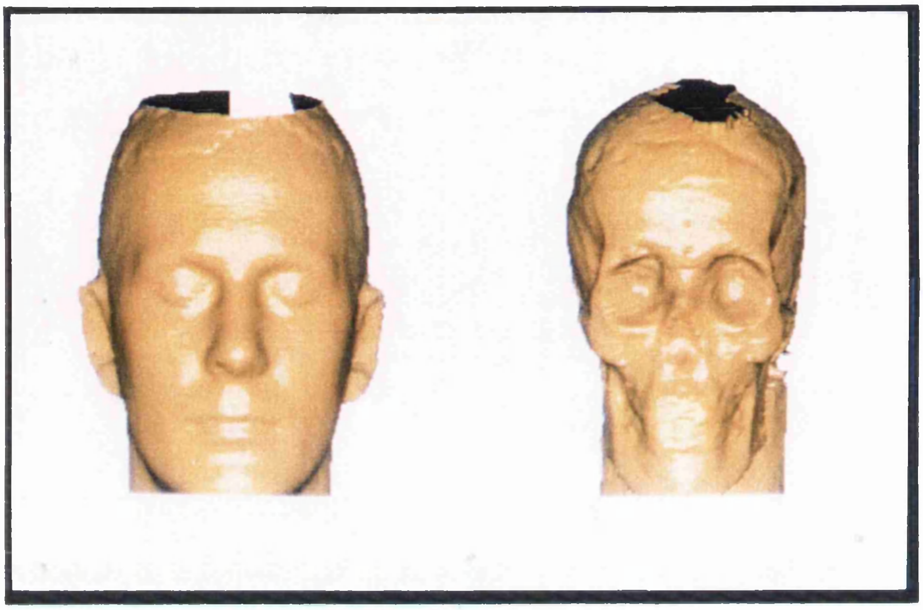


FIGURE 101C. Shows both scan images after applying the option Normalise scale. This option re-sizes the face data to match the size of the skull data.

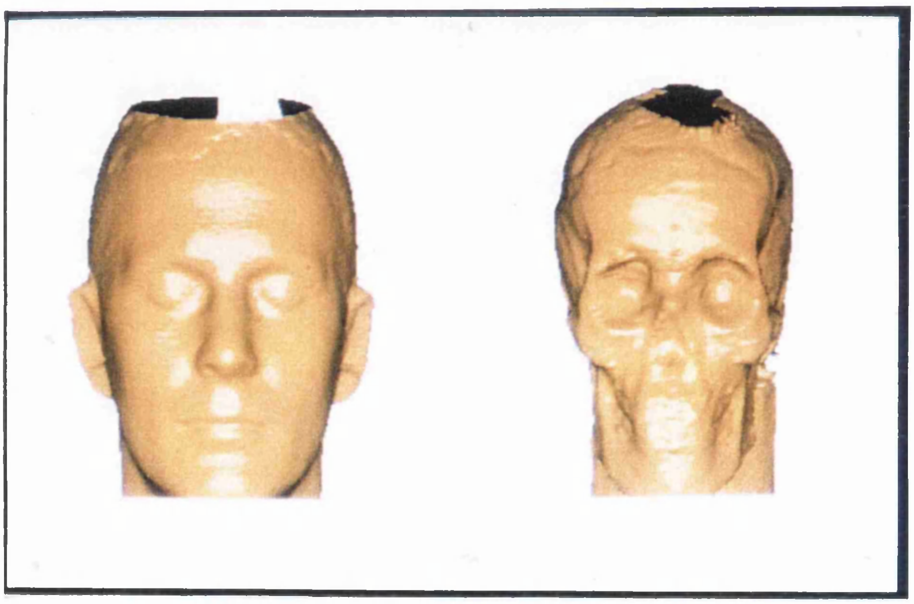


FIGURE 101 D

Shows both scans images after applying the option "Complete alignment". This operation sequentially applies all of the first three operations at the top of this menu (Align and distort menu).

All these photographs correspond to step F.

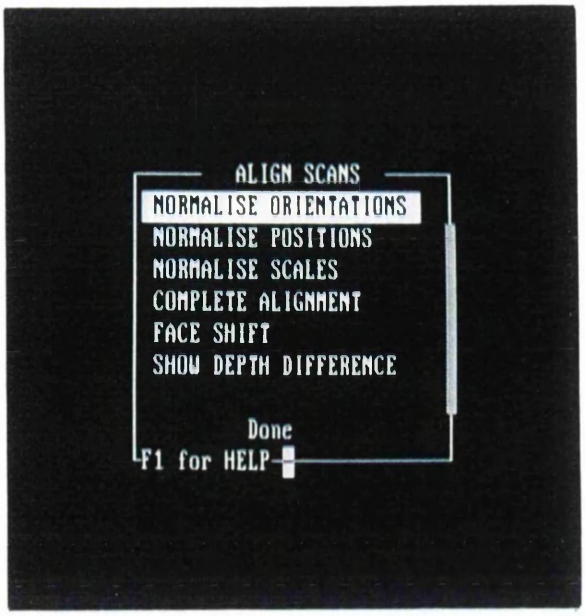


FIGURE 102
Photograph showing Align and Distort menu and its option. This option is applied in step F.

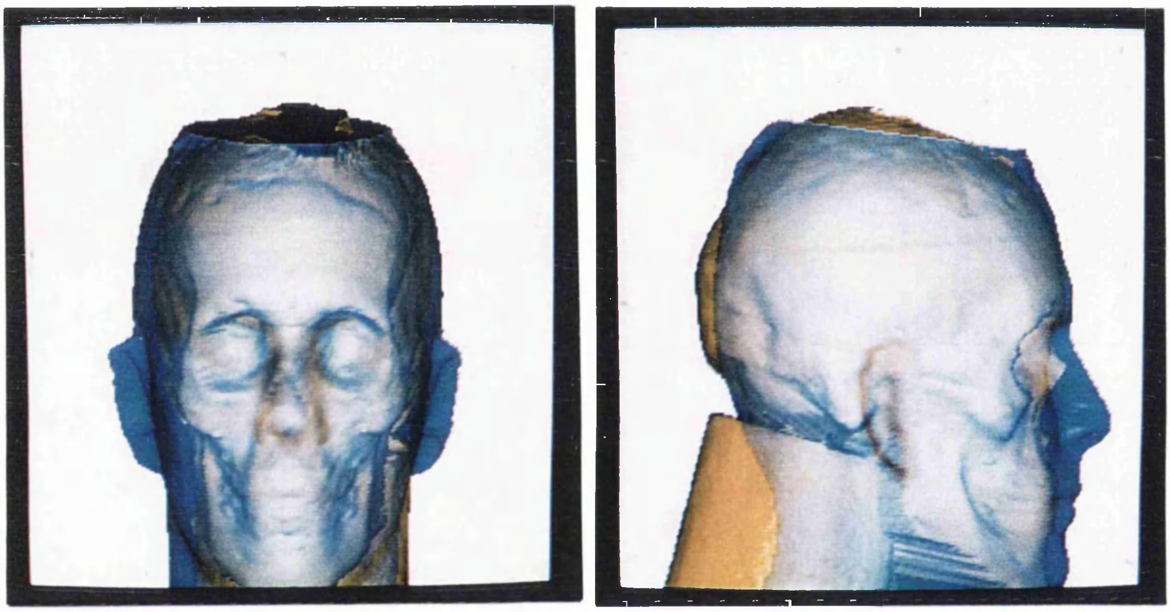


FIGURE 103
Frontal and Lateral photographs taken from the screen illustrating the application of the option "Show mixed image" that allow to the operator to superimpose the facial image (average face male) translucently over the plaster cast of skull selected allowing a visual comparison. This option allows to be checked the complete alignment of both scans images. Corresponds to step G.

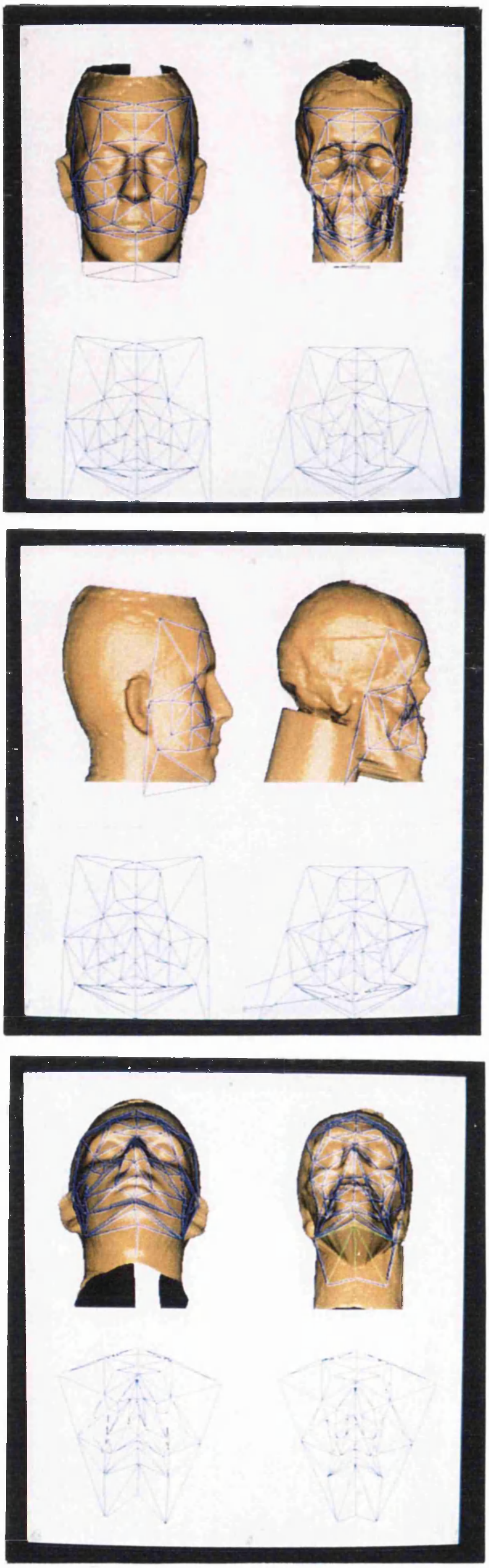


FIGURE 104

These photographs show a very important step of the facial reconstruction procedure; the checking of the position of craniometric and cephalometric landmarks before applying Face shift option. Once the landmarks have been checked, the peg location information can be saved for future use, for either the skull scan or face scan.

The option view control to interactively orientate the three dimensional surface data in various ways as shown in the last photograph where the images were rotated upwards in 45 degree. This rotation allows the operator a better visualization and location of some landmarks such as gnathion. In this case the skull shows the right position of this landmark while in the surface facial data must be adjusted.

Corresponds to step H

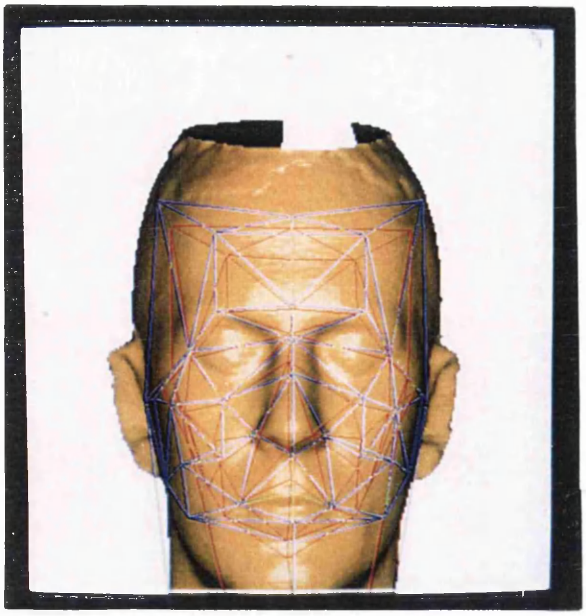
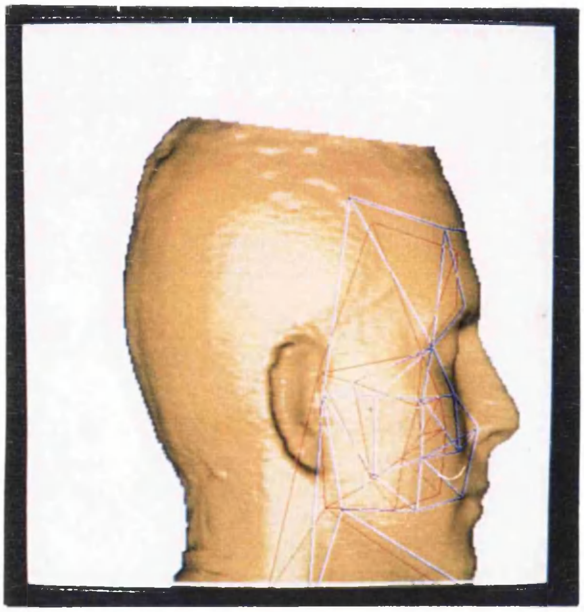
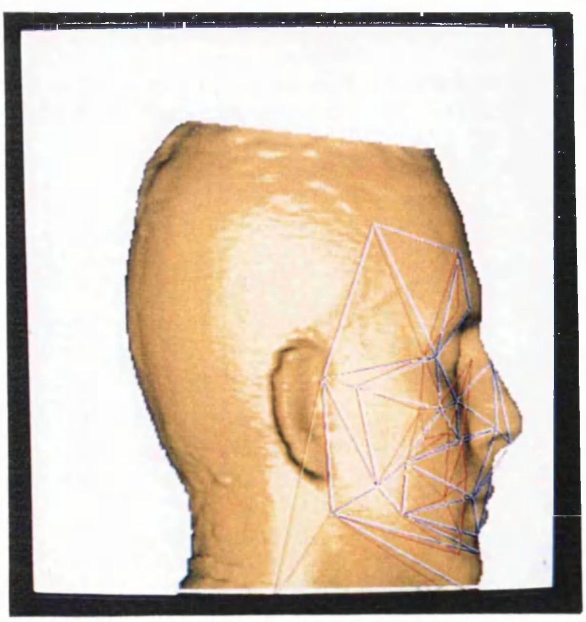
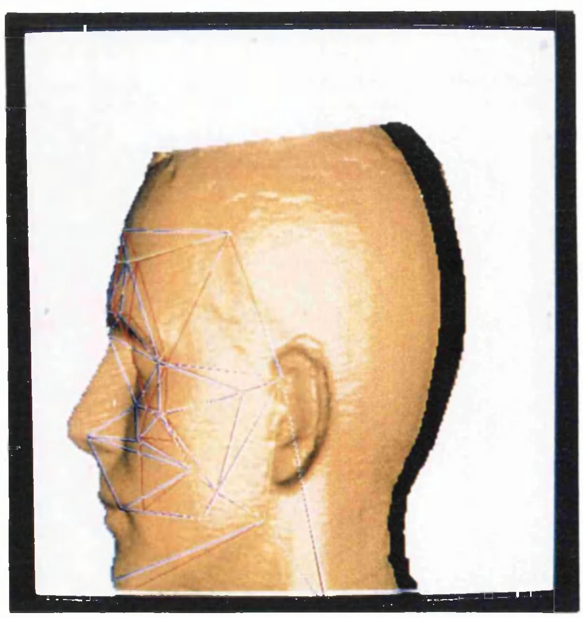


FIGURE 105
These set of frontal and lateral photographs of the facial surface scan show the operator working in "Adjust peg markers" from the main menu. Specifically shows the item c of this menu that allows comparison of skull and face pegs position. Here the operator can see the peg grid of both images superimposed. The blue grid corresponds to facial surface scan pegs' locations and the red one grid represents skull peg's locations allowing the operator "to build" the face according to the specific skull's landmarks. This step is applied before the option Face shift.
Corresponds to step I.







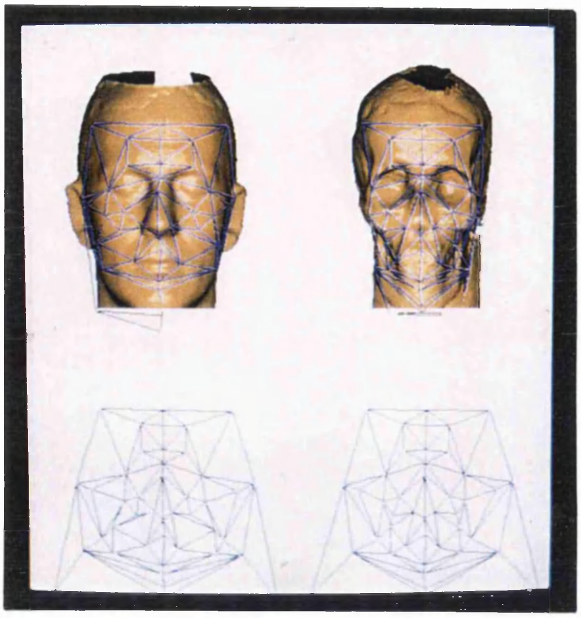


FIGURE 106
Frontal photograph of both scan images showing the peg grids over the surface of the scans and the unwrapped peg map below both images. The right locations of craniometric and cephalometric landmarks have been re-checked. The operator is preparing the last step of this procedure that means apply Face shift.
Corresponds to step I.

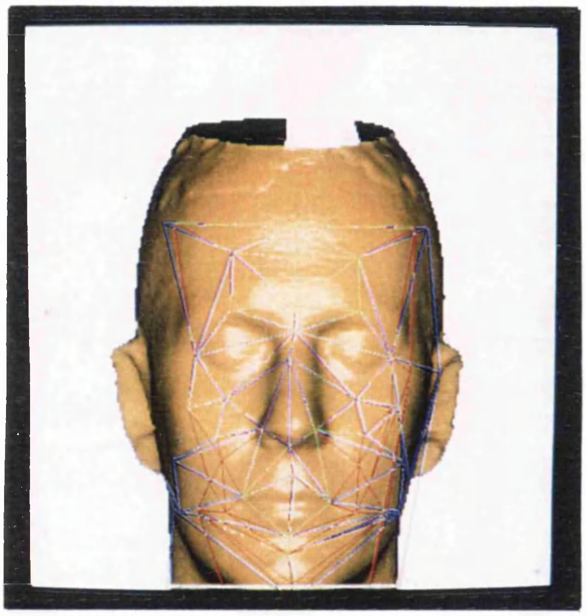
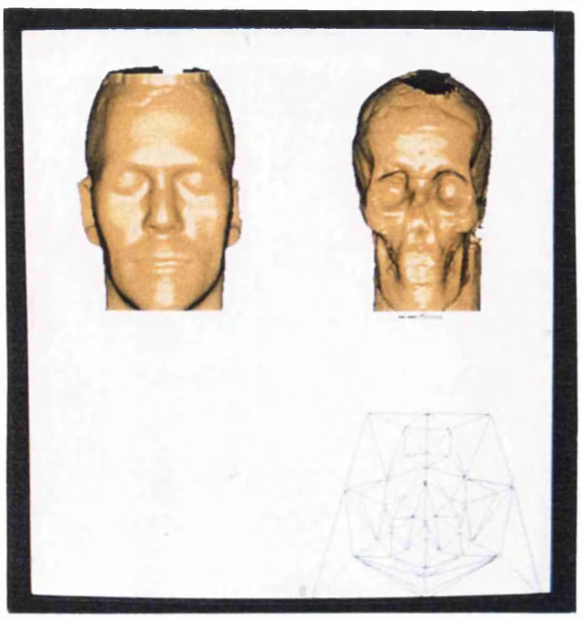
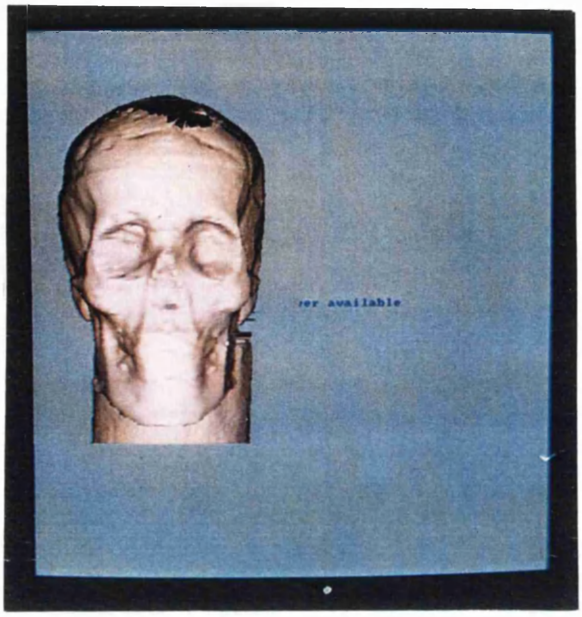


FIGURE 107
A. Photograph of the facial surface scan showing the peg grids superimposed after applying option c of the Adjust peg markers menu. The operator has built the face according to plaster cast of skull's landmark. Once this step has been applied the operator can apply the final step Face shift. This option performs the facial surface adjustment and must be preceded by complete alignment. All adjustment should be finalised before applying this option for a successful facial reconstruction. This procedure takes several minutes; in routine practice takes 15-20 minutes. Corresponds to the last step of facial reconstruction procedure. Step I

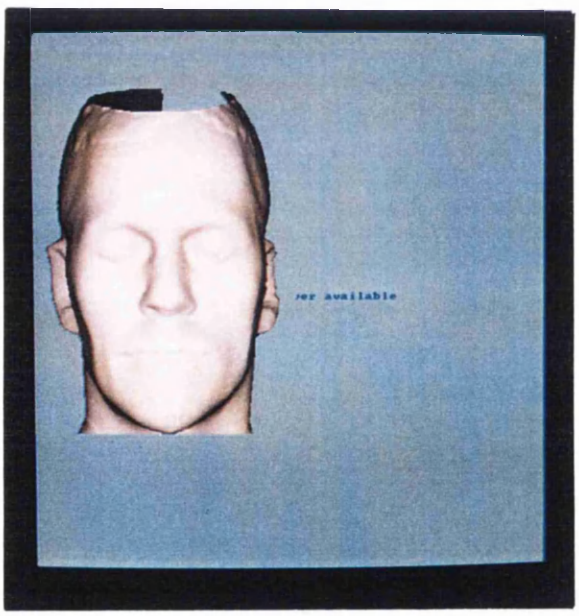


B. Photograph showing the frontal view of the finished three dimensional facial reconstruction by computing using an Optical Surface Laser Scanner. The average face used as facial surface scan has been modified giving a modified face data, which has been built according to the landmark's of plaster cast of skull. The software adjusted the facial surface over the skull producing a mask according to skull's landmarks.

FIGURE 108



A. Photograph showing the plaster cast of skull's scan. The operator has changed to another program of the system modifying the colour in order to show the image more "human".



B. Frontal photograph of the finished reconstructed face in the same program of figure A showing a more "humanised" image.

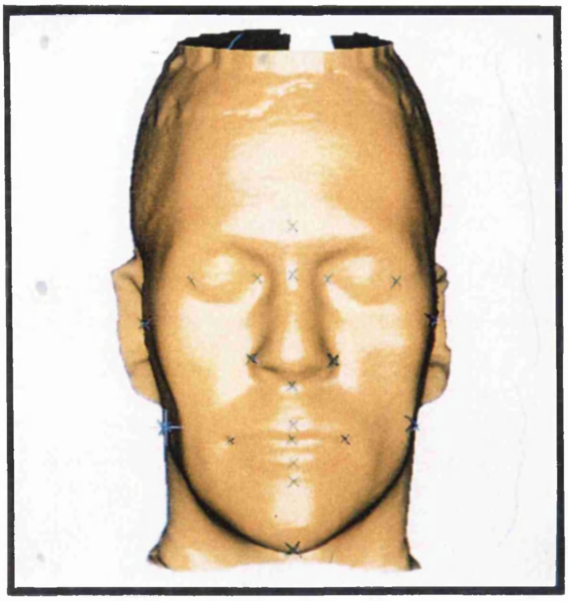
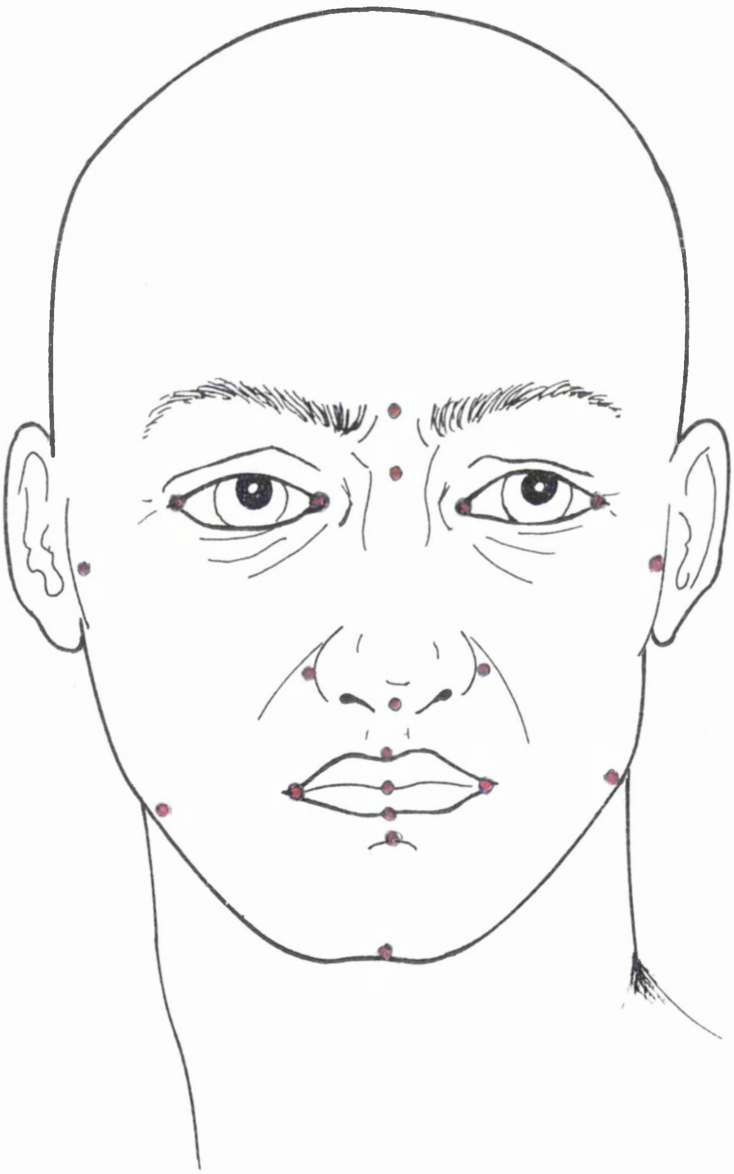
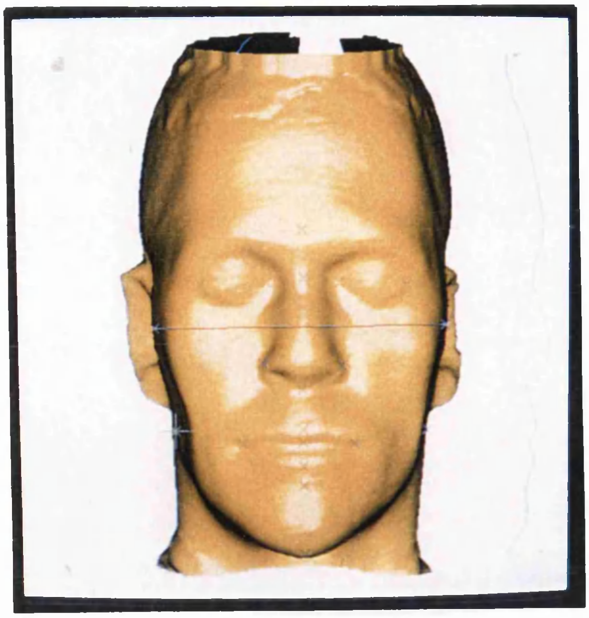
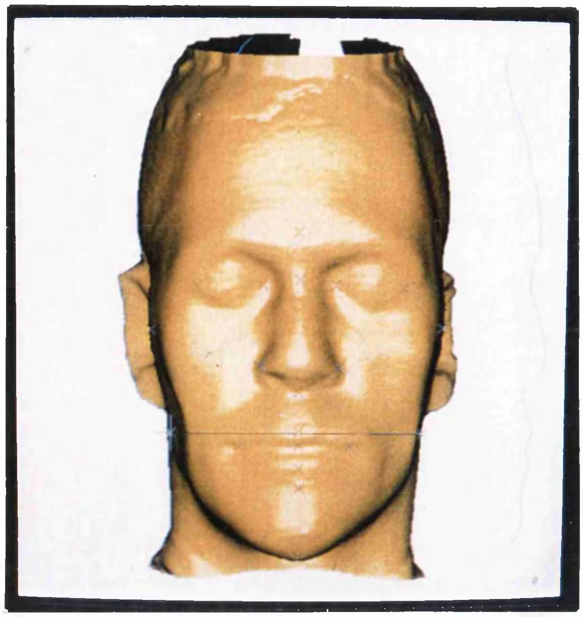


FIGURE 109
Frontal photograph taken from the screen and diagram illustrating the eight midline and six paired classical anatomical landmarks selected for the present study. The landmarks were placed over the surface of the three dimensional facial recontruction using the same system used for performing the facial reconstruction. The surface facial scan corresponds to the reconstructed face for the plaster cast of skull selected for illustrating the facial reconstruction procedure.

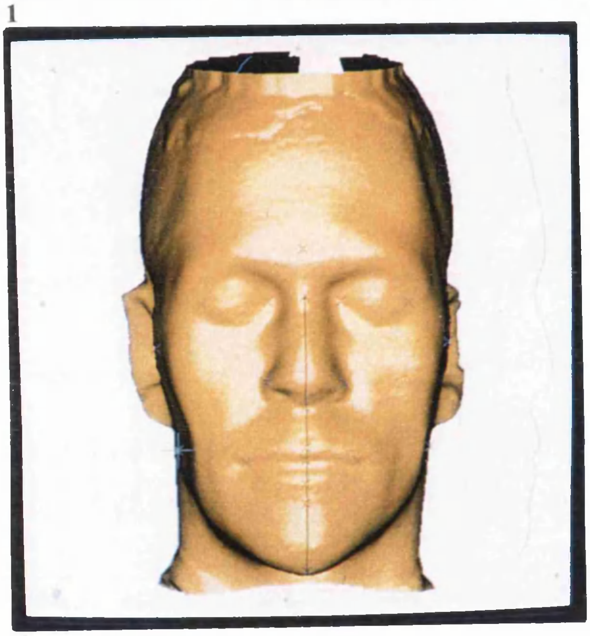




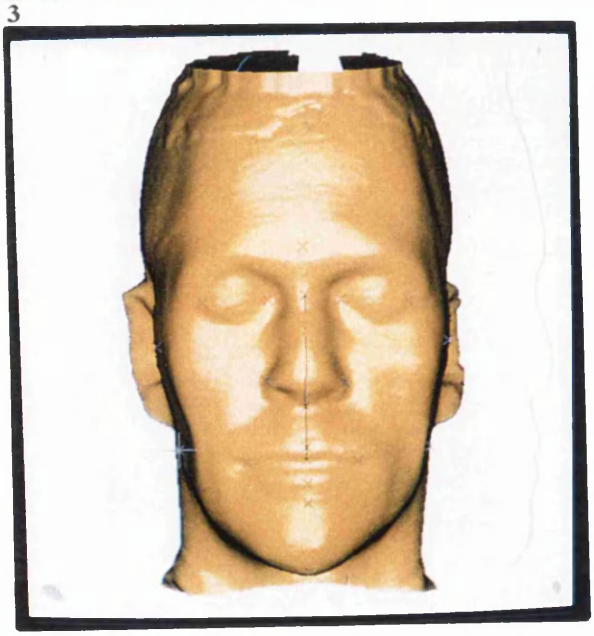
1



2



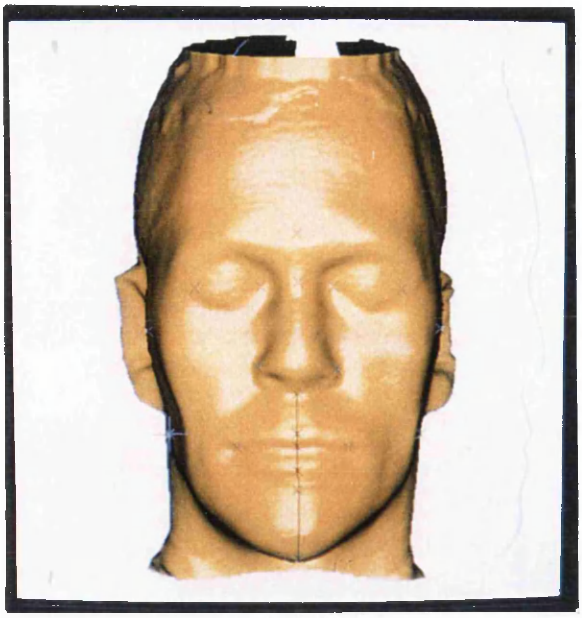
3



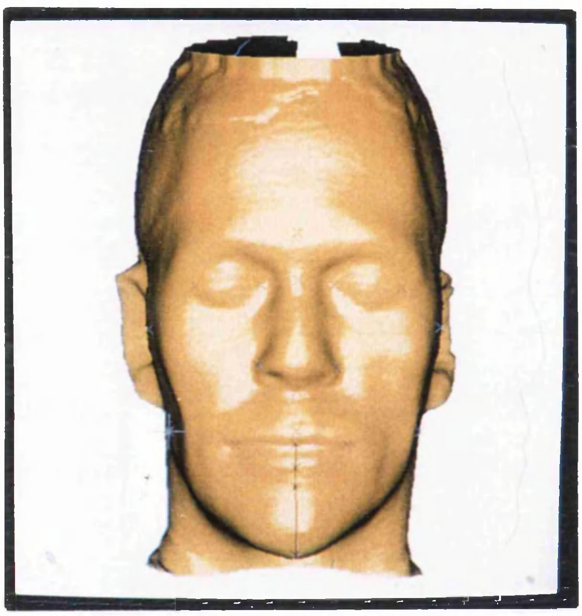
4

FIGURE 110
Frontal photographs of the three dimensional reconstructed face of the plaster cast of skull selected for illustrating the facial reconstruction procedure showing the nineteen projective facial measurements selected for the present study. The photographs were taken from the screen. The measurement thus obtained selecting the landmarks involved is computerised. The image shows the distance to be calculated between two marked points on the surface. On the right anatomical gonion the figure shows the cursor in position for marking an anatomical landmark.

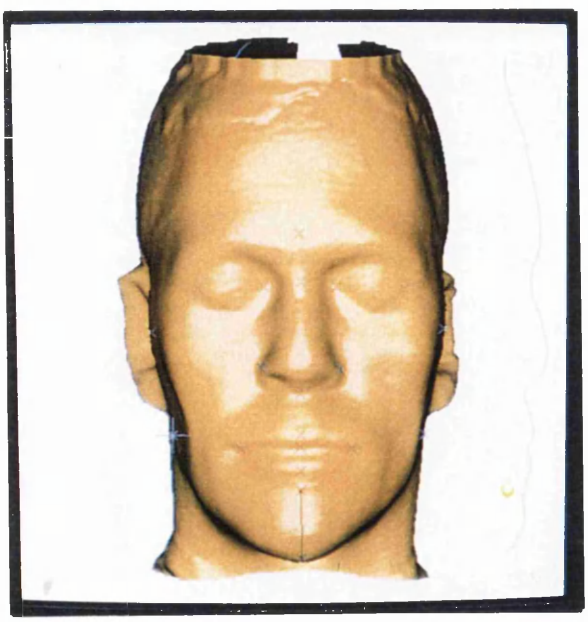
1. **Width of the face (zygion -zygion) (zy-zy)**
2. **Width of the lower face (gonion-gonion) (go-go)**
3. **Morphological height of the face (nasion-gnathion) (n-gn)**
4. **Physiognomical height of the upper face (nasion-stomion) (n-sto)**



5. Height of the lower face
(subnasale-gnathion) (sn-gn)

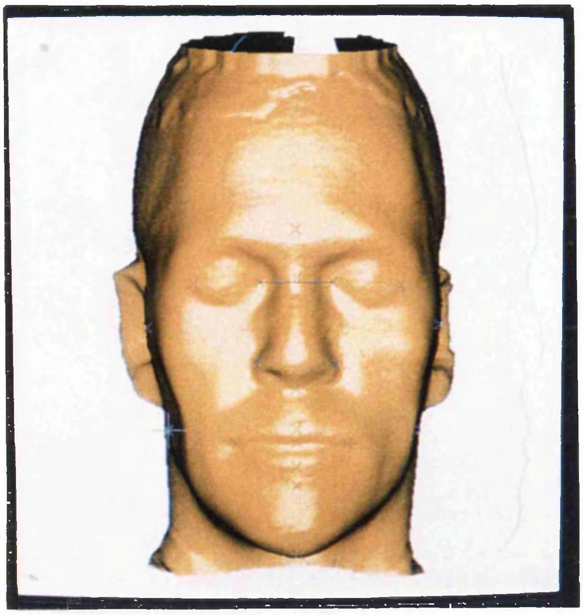


6. Height of the lower third of the face
or height of the mandible
(stomion-gnathion) (sto-gn).

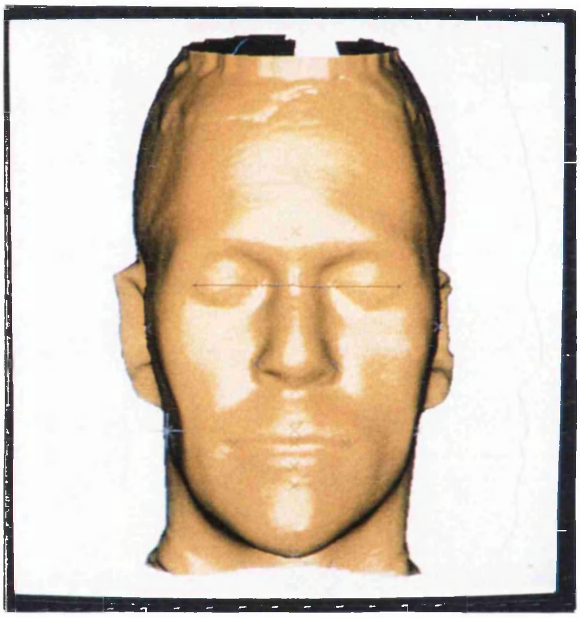


7. Chin height (sublabiale-gnathion)
(sl-gn)

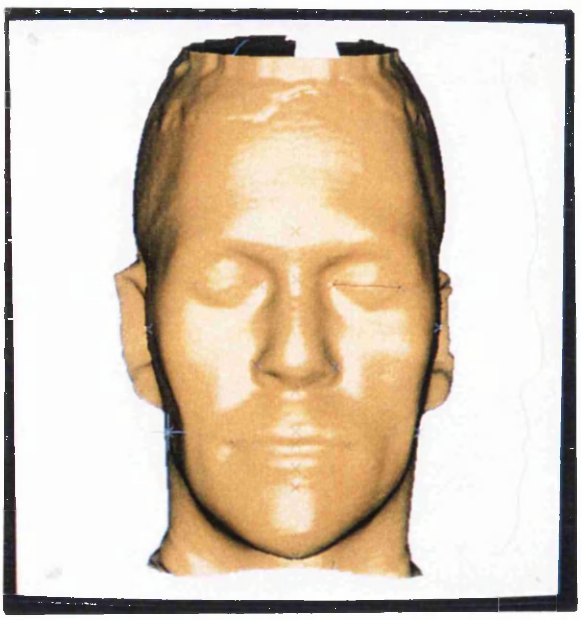
AREA ORBITS (3)



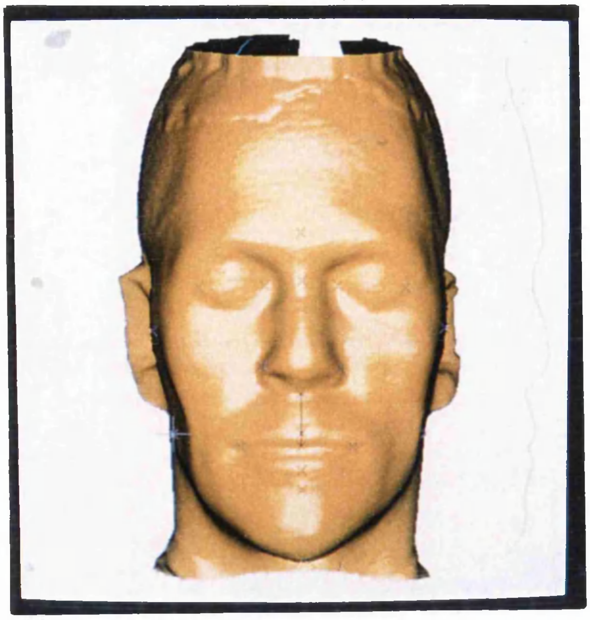
8. Intercanthal width
(endocanthion-endocanthion) (en-en)



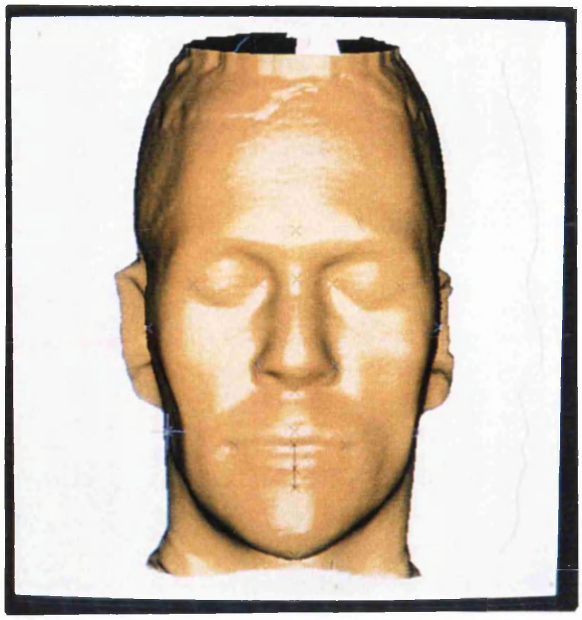
9. Biocular width
(exocanthion-exocanthion) (ex-ex)



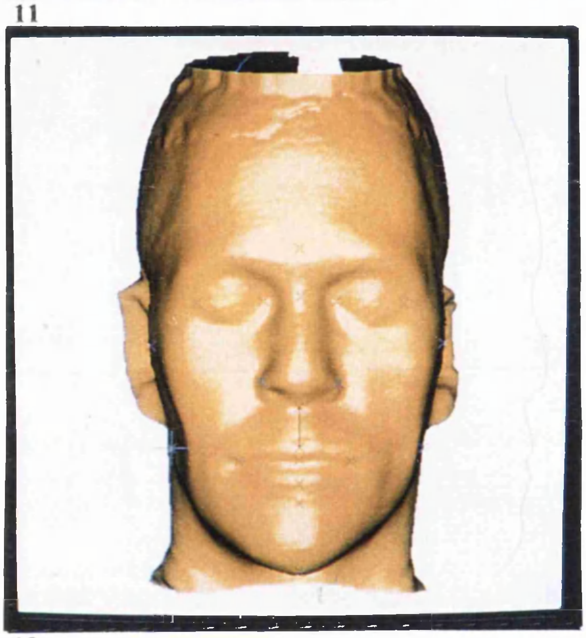
10. Eye fissure width
(endocanthion-exocanthion) (en-ex)



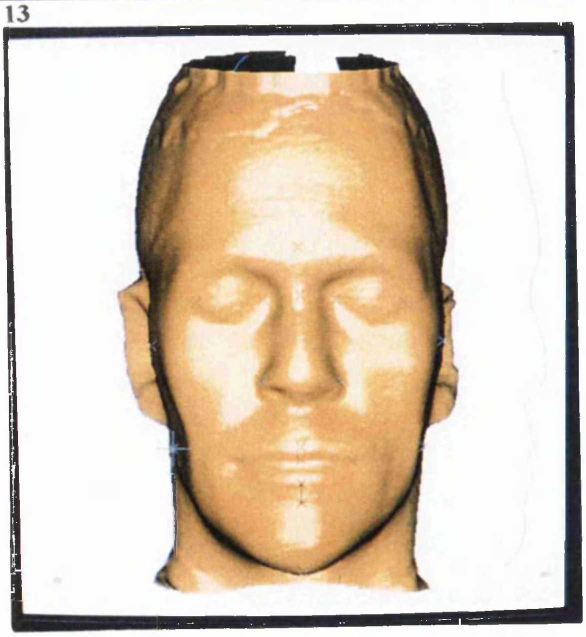
11



12



13



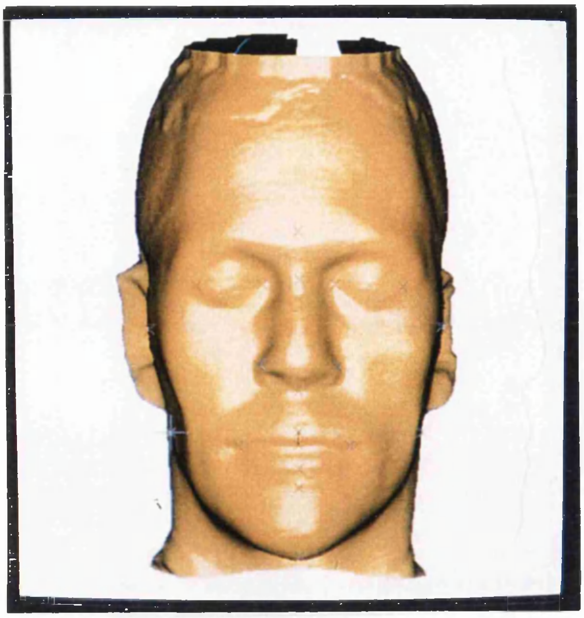
14

11. Upper lip height
(subnasale-stomion) (sn-sto)

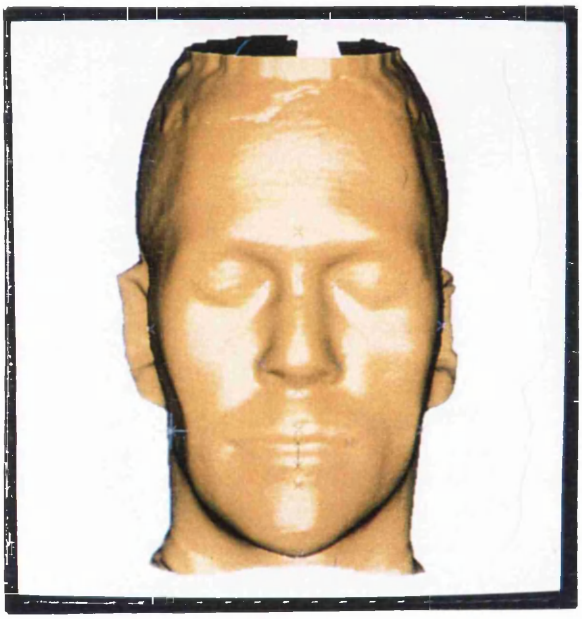
12. Lower lip height
(stomion-sublabiale) (sto-sl)

13. Cutaneus upper lip height
(subnasale-labiale superior) (sn-ls)

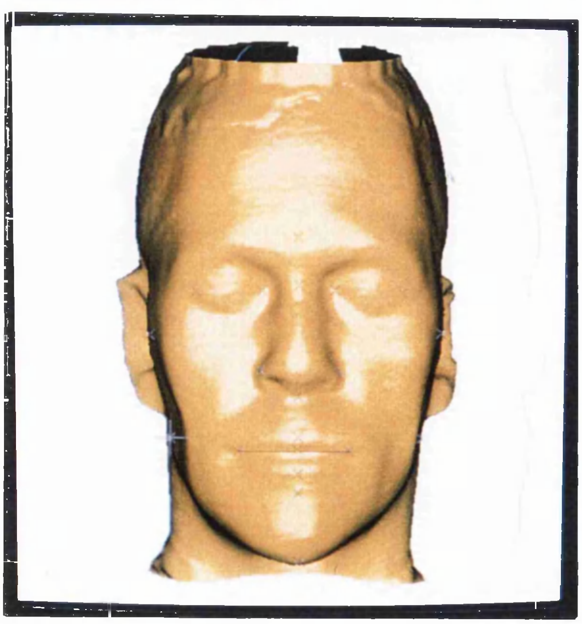
14. Cutaneus lower lip height
(labiale inferius-sublabiale) (li-sl)



15. Upper vermilion height
(labiale superius-stomion) (ls-sto)

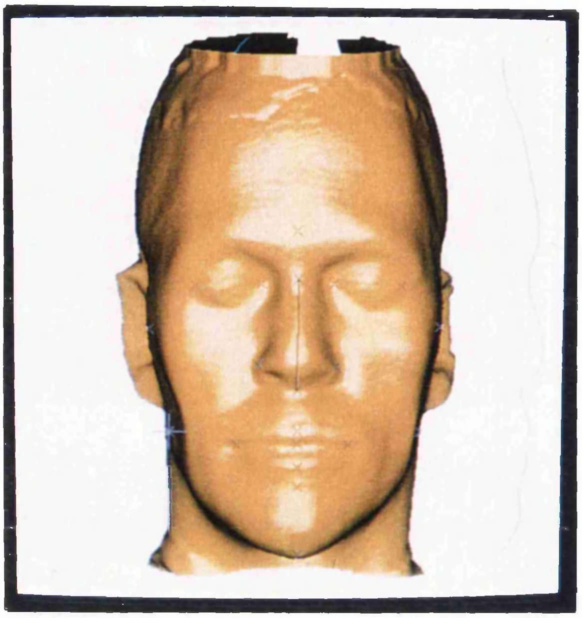


16. Lower vermilion height
(stomion-labiale inferius) (sto-li)

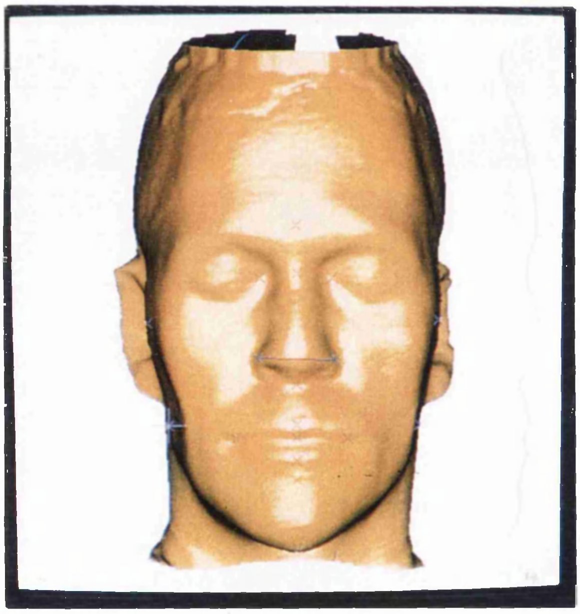


17. Mouth width
(cheilion-cheilion) (ch-ch)

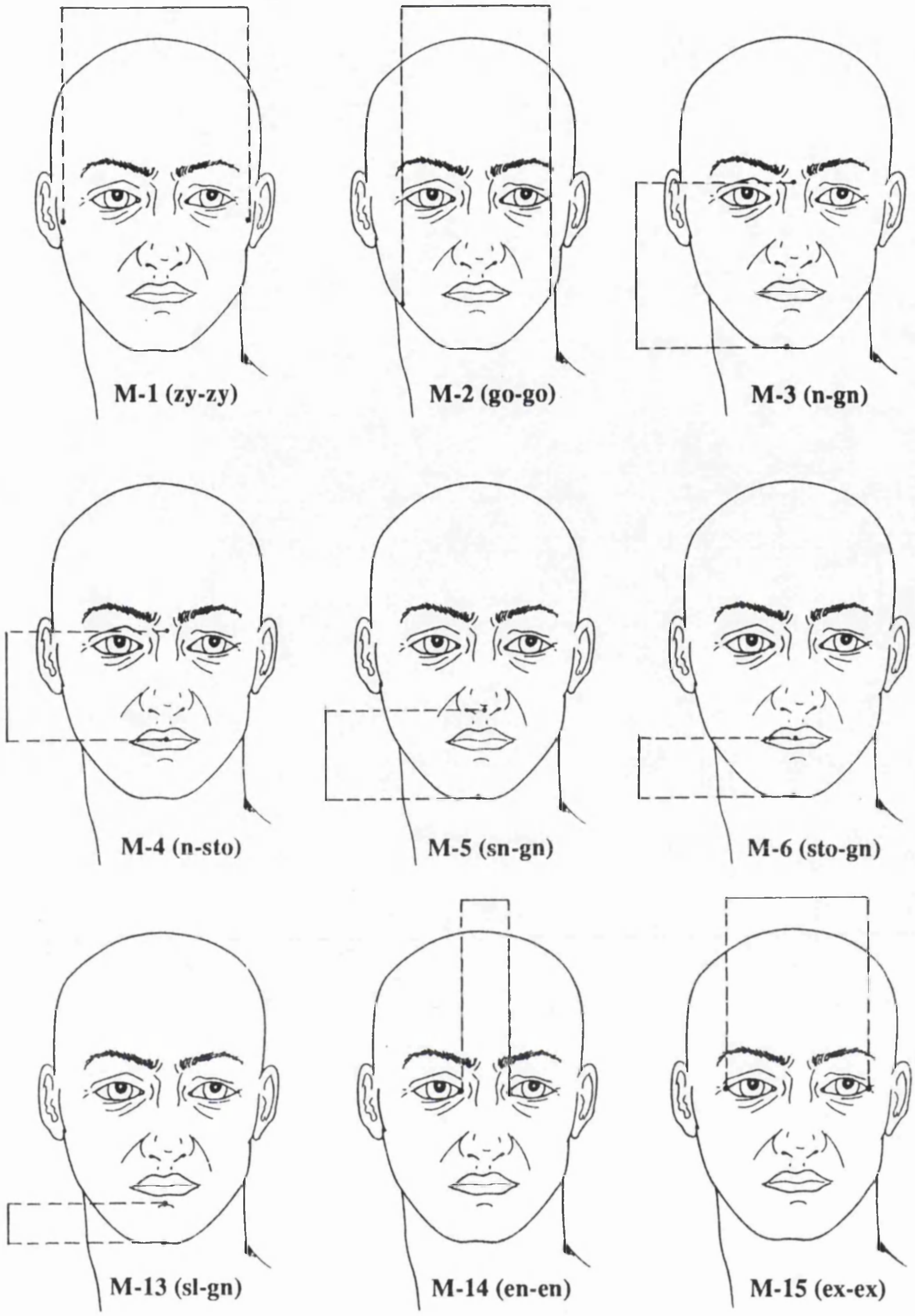
AREA NOSE (2)



18. Nose height
(nasion-subnasale)
(n-sn)



19. Nose width
(alare-alare) (al-al)



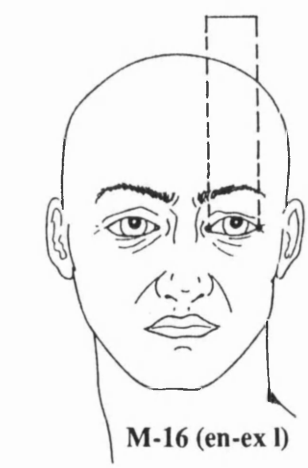
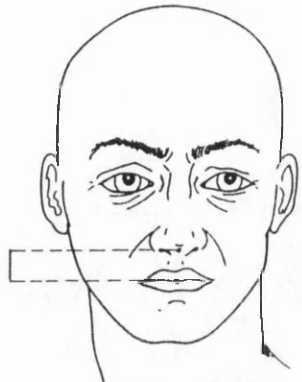
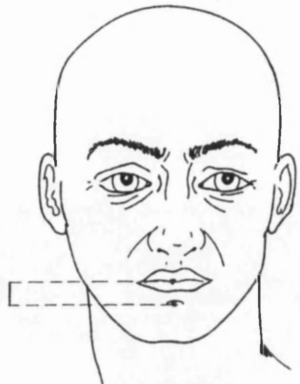


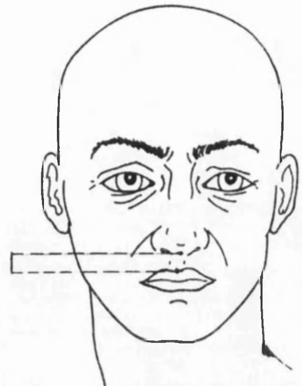
FIGURE 110
Frontal diagrams of the face showing the nineteen linear or projective facial measurements selected for the present study.



M-8 (sn-sto)

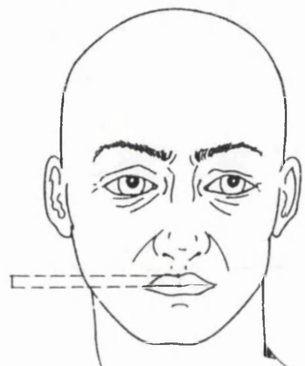


M-19 (sto-sl)

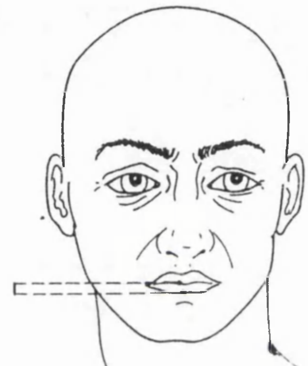


M-9 (sn-ls)

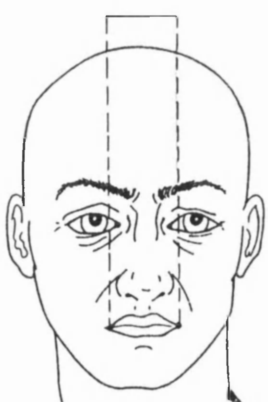
M-12 (li-sl)



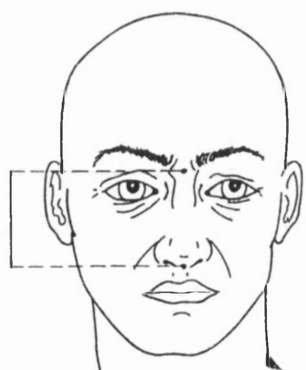
M-10 (ls-sto)



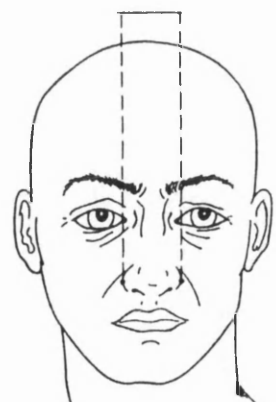
M-11 (sto-li)



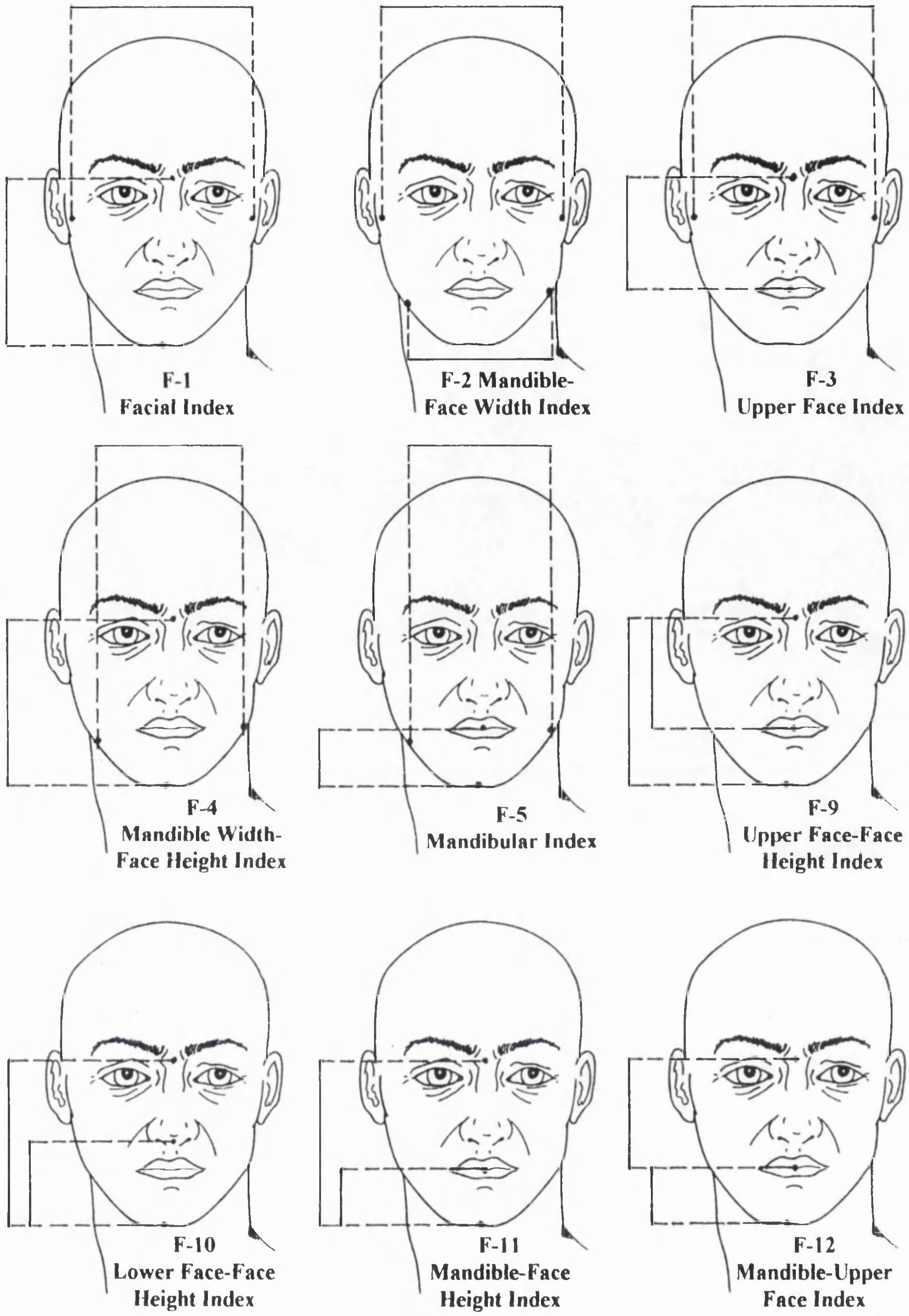
M-17 (ch-ch)



M-7 (n-sn)



M-18 (al-al)



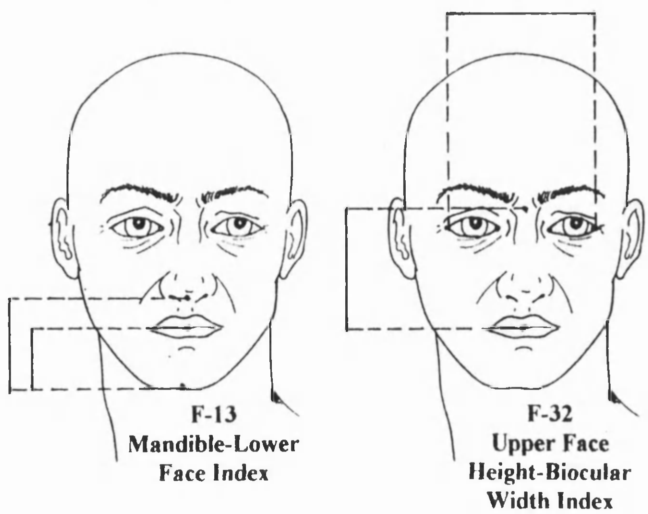
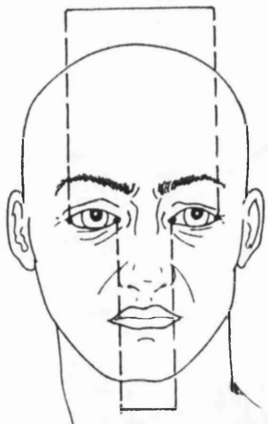
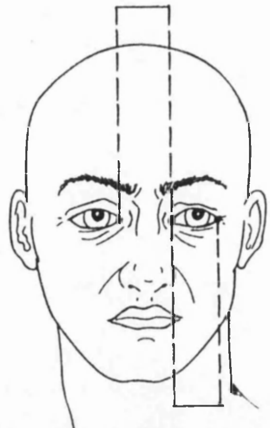


FIGURE 111
Frontal diagrams of the face showing the thirty-three proportion indices selected produced from the nineteen linear facial measurements selected for the present study.

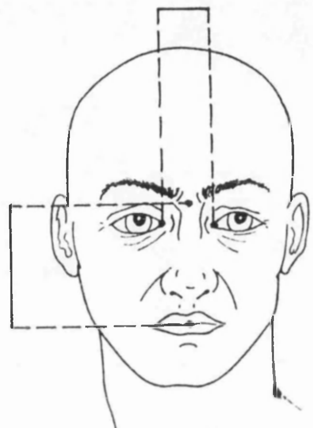


O-1
Intercanthal
Index

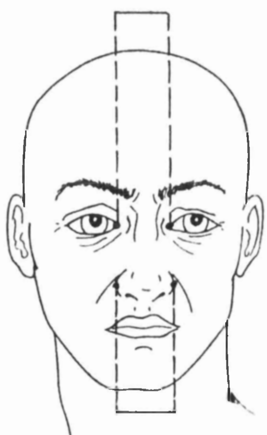


O-3
Orbital Width
Index

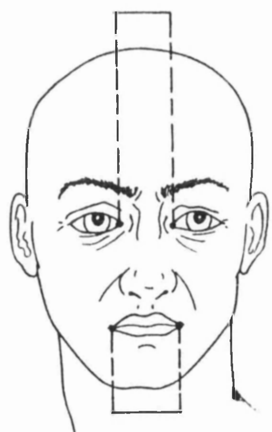
O-8
Biocular-Face
Width Index



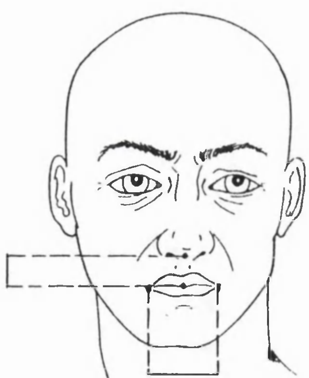
O-9
Intercanthal
Width-Upper
Face Height Index



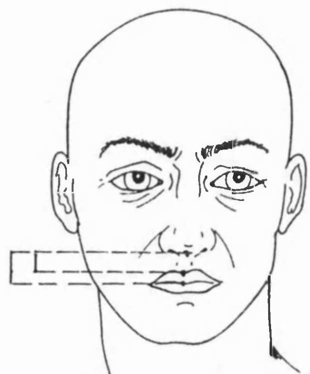
O-10
Intercanthal-
Nasal Width
Index



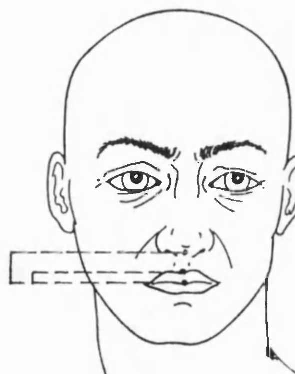
O-12
Intercanthal-
Mouth Width
Index



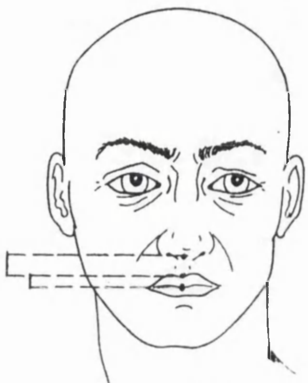
L-1
Upper Lip Height-Mouth Width Index



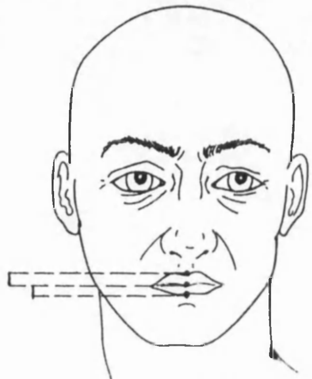
L-5
Cutaneous- Total Lip Height Index



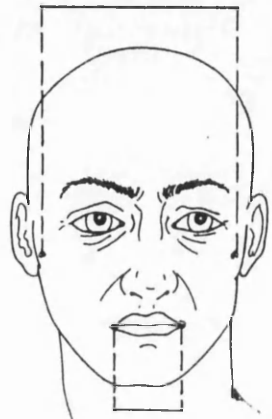
L-6
Vermilion-Total Upper Lip Height Index



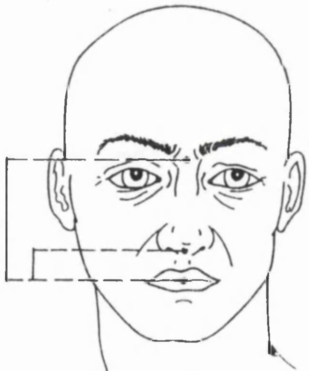
L-7
Vermilion-Upper Lip Height Index



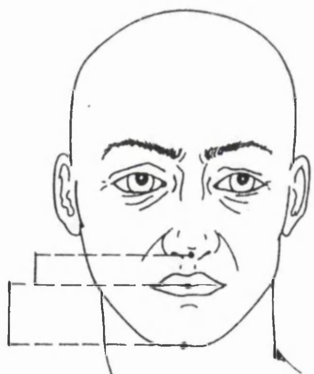
L-9
Vermilion Height Index



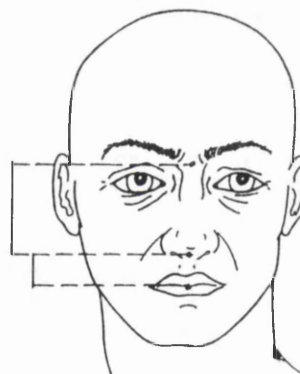
L-10
Mouth-Face Width Index



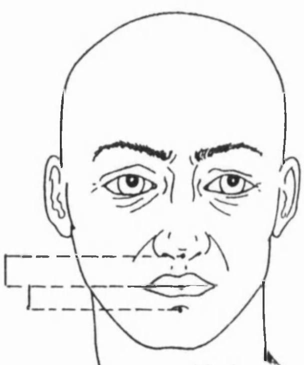
L-11
Upper Lip- Upper Face Height Index



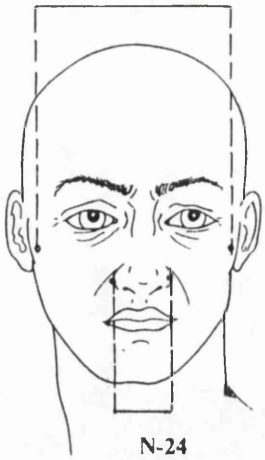
L-12
Upper Lip-Mandible Height Index



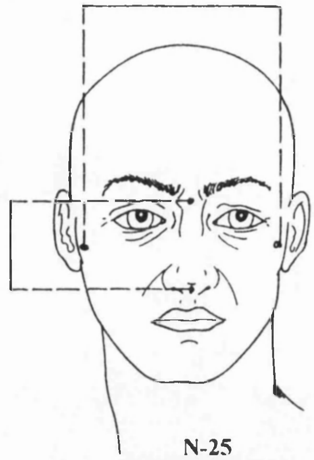
L-14
Upper Lip-Nose Height Index



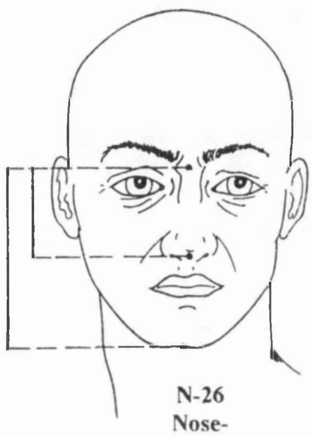
AL-3
Lower-Upper Lip Height Index



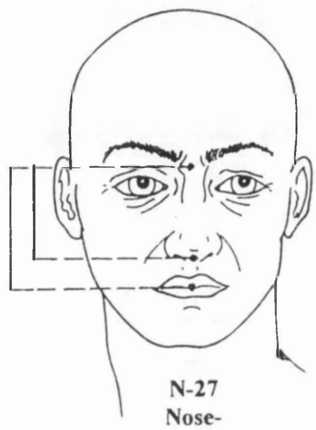
N-24
Nose-
Face Width Index



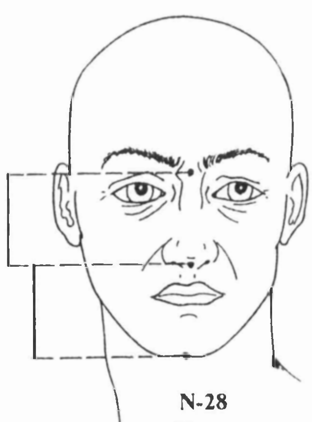
N-25
Nose Height-Face
Width Index



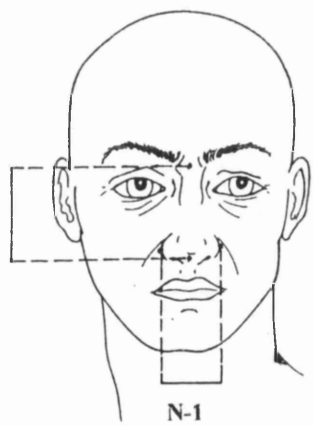
N-26
Nose-
Face Height Index



N-27
Nose-
Upper Face
Height Index



N-28
Nose-
Face Height Index



N-1
Nasal Index

TABLE N° 18

NINETEEN FACIAL MEASUREMENTS SELECTED IN A SAMPLE OF FOURTEEN FACIAL RECONSTRUCTION (mm)

CASE N°	FACIAL RECONSTRUCTION Name	M-1 zy-zy	M-2 go-go	M-3 n-gn	M-4 n-sto	M-5 sn-gn	M-6 sto-gn	M-7 n-sn	M-8 sn-sto
2832	SANOR	133.68	114.36	124.04	76.09	72.1	52.44	50	24.21
2915	SBNOR	137.63	117.54	112.03	72.01	63.21	40.15	50.14	22.17
2950	SC1NOR	124.94	109.46	112.09	68.4	67.49	45.58	46.99	22.11
2973	SDNOR	125.58	107.83	116.12	71.86	68.13	47.59	51.53	21.05
3018	SENOR	128.66	110.23	122.78	72.12	73.49	52.56	50.11	22.05
3019	SFNOR	138.15	118.93	114.23	72.16	65.99	43.42	49.27	23.00
3039	SGNOR	128.82	116.78	119.06	74.42	68.72	46.14	51.57	23.00
3052	SHNOR	105.68	93.16	104.00	63.15	62.02	41.34	42.00	21.34
3055	SINOR	131.6	112.91	116.08	74.57	66.52	43.74	50.31	24.31
2831	SJNOR	127.63	115.27	120.08	73.42	71.56	48.25	49.37	24.08
2996	SKNOR	133.45	112.67	109.08	65.09	66.55	44.38	43.38	22.17
2850	SMNOR	128.62	114.08	120.07	74.13	70.04	46.8	51.59	23.25
2938	SNNOR	127.36	114.69	118.26	74.17	67.05	45.38	52.31	22.01
3009	SPNOR	130.62	114.64	118.14	74.19	68.17	45.38	51.45	23.05

TABLE N° 18

(continuation)

NINETEEN FACIAL MEASUREMENTS SELECTED IN A SAMPLE OF FOURTEEN FACIAL RECONSTRUCTIONS (mm)

CASE N°	FACIAL RECONSTRUCTION Name	M-9 sn-ls	M-10 ls-sto	M-11 sto-li	M-12 li-sl	M-13 sl-gn	M-14 en-en	M-15 ex-ex	M-16 en-ex l	M-17 ch-ch
2832	SANOR	16.92	8.32	8.41	8.3	32.84	36.25	97.04	31.6	51.39
2915	SBNOR	18.03	7.58	9.13	8.58	24.48	36.25	100.07	32.6	53.51
2950	SC1NOR	15.03	7.7	8.05	8.86	29.41	33.35	92.21	29.78	48.26
2973	SDNOR	14.00	7.2	8.00	10.99	29.44	34.92	93.57	30.98	49.30
3018	SENOR	16.32	6.24	8.77	10.47	36.1	36.41	87.98	25.2	44.66
3019	SFNOR	14.08	9.2	6.18	9.85	28.31	35.99	96.69	31.97	52.33
3039	SGNOR	15.36	8.54	6.32	12.71	28.16	38.27	97.62	29.25	49.96
3052	SHNOR	16.79	5.17	8.2	7.34	26.46	30.4	80.85	26.06	41.38
3055	SINOR	17.2	8.35	9.2	7.43	28.47	34.6	96.11	31.04	48.29
2831	SJNOR	16.49	8.25	8.41	11.32	30.14	35.37	90.48	27.58	47.90
2996	SKNOR	16.03	6.26	7.28	8.32	29.52	34.19	92.04	29.31	46.98
2850	SMNOR	16.01	7.62	8.69	8.18	31.72	34.77	93.66	27.93	48.09
2938	SNNOR	17.02	5.25	8.44	9.08	29.57	34.03	97.67	32.70	49.19
3009	SPNOR	16.03	7.4	8.32	8.51	29.9	36.95	97.26	29.10	52.53

TABLE N° 18
(continuation)

NINETEEN FACIAL MEASUREMENTS SELECTED IN A SAMPLE OF FOURTEEN FACIAL RECONSTRUCTIONS (mm)

CASE N°	FACIAL RECONSTRUCTION Name	M-18 al-al	M-19 sto-sl							
2832	SANOR	36.83	16.71							
2915	SBNOR	38.23	17.71							
2950	SC1NOR	35.73	16.91							
2973	SDNOR	36.06	18.99							
3018	SENOR	35.36	19.24							
3019	SFNOR	39.75	16.03							
3039	SGNOR	38.68	19.03							
3052	SHNOR	32.63	15.54							
3055	SINOR	37.75	16.63							
2831	SJNOR	36.36	19.73							
2996	SKNOR	37.10	15.60							
2850	SMNOR	37.15	16.87							
2938	SNNOR	37.23	17.52							
3009	SPTHIN	36.99	16.83							

TABLE N° 19

NINETEEN FACIAL MEASUREMENTS SELECTED IN A SAMPLE OF FOURTEEN PHOTOGRAPHS (mm)

CASE N°	PERSONAL IDENTITY N°	M-1 zy-zy	M-2 go-go	M-3 n-gn	M-4 n-sto	M-5 sn-gn	M-6 sto-gn	M-7 n-sn	M-8 sn-sto	M-9 sn-ls
2832	1	102	92	110	64	68	45	42	22	15
2915	2	*	*	72	45	43	27	29	15	12
2950	3	92	83	85	*	54	*	31	*	*
2973	4	*	*	68	*	43	*	25	*	*
3018	5	85	77	73	*	48	*	26	*	*
3019	6	*	*	78	*	48	*	31	*	*
3039	7	86	81	79	46	50	32	29	17	12
3052	8	104	93	103	62	69	41	34	28	22
3055	9	19	15	18	11	12	7	6	4	3
2831	10	112	104	90	54	55	35	35	19	12
2996	11	117	101	101	65	57	36	44	21	18
2850	12	108	96	97	63	57	34	40	23	19
2938	13	86	75	65	44	34	20	31	14	9
3009	14	100	81	95	59	55	35	40	19	14
*Measurement not taken										

TABLE N° 19

(continuation)

NINETEEN FACIAL MEASUREMENTS SELECTED IN A SAMPLE OF FOURTEEN PHOTOGRAPHS (mm)

CASE N°	PERSONAL IDENTITY N°	M-10 ls-sto	M-11 sto-li	M-12 li-sl	M-13 sl-gn	M-14 en-en	M-15 ex-ex	M-16 en-ex left	M-17 ch-ch	M-18 al-al	M-19 sto-sl
2832	1	7	7	5	35	22	61	21	39	29	12
2915	2	3.5	4.5	3.5	19.5	*	*	*	*	*	8
2950	3	*	*	*	23	27	64	25	*	29	*
2973	4	*	*	3	21	20	53	17	*	21	*
3018	5	*	*	*	22	24	60	18	*	23	*
3019	6	*	*	*	24	*	*	*	*	*	*
3039	7	5	7	4	21	26	57	16	35	26	11
3052	8	6	8	4	29	29	73	22	41	30	12
3055	9	1	2	0.5	5	5	13	4	8	6	2.5
2831	10	7	10	4	21	30	70	20	38	32	14
2996	11	3	8	5	23	*	*	*	*	35	13
2850	12	4	5	4	24	28	78	24	46	32	9
2938	13	4	6	3	12	22	55	17	31	22	9
3009	14	5	6	6	23	27	70	21	41	29	12
*Measure ment not taken											

TABLE N° 20

MEAN AND STANDARD DEVIATION OF NINETEEN FACIAL MEASUREMENTS SELECTED IN A SAMPLE OF FOURTEEN FACIAL RECONSTRUCTIONS

MEASUREMENTS		-2SD	-1SD	MEAN	SD	+2SD	+2SD
1. Width of the face (zy-zy)	M-1	113.20	120.97	128.74	7.77	136.51	144.28
2. Width of the lower face (go-go)	M-2	99.77	106.01	112.32	6.31	118.63	124.94
3. Morphological height of the face (n-gn)	M-3	105.21	110.68	116.15	5.47	121.62	127.09
4. Physiognomical height of the upper face (n-sto)	M-4	64.32	68.08	71.84	3.76	75.60	79.36
5. Height of the lower face (sn-gn)	M-5	61.54	64.73	67.93	3.19	71.12	74.31
6. Height of the lower third of the face or Height of the mandible (sto-gn)	M-6	38.83	42.38	45.93	3.55	49.49	53.04
7. Nose height (n-sn)	M-7	43.07	46.17	49.28	3.10	52.39	55.50
8. Upper lip height (sn-sto)	M-8	20.64	21.67	22.70	1.02	23.72	24.75
9 Cutaneous upper lip height (sn-ls)	M-9	13.78	14.93	16.09	1.15	17.24	18.40

TABLE N° 20
(continuation)
MEAN AND STANDARD DEVIATION OF NINETEEN FACIAL MEASUREMENTS SELECTED IN A SAMPLE OF FOURTEEN FACIAL RECONSTRUCTIONS

MEASUREMENTS		-2SD	-1SD	MEAN	SD	+2SD	+2SD
10. Upper vermillion height (ls-sto)	M-10	4.91	6.14	7.36	1.22	8.58	9.80
11. Lower vermillion height (sto-li)	M-11	6.26	7.18	8.10	0.91	9.01	9.93
12. Cutaneous lower lip height (li-sl)	M-12	6.13	7.70	9.28	1.57	10.85	12.42
13. Chin height (sl-gn)	M-13	24.09	26.85	29.60	2.75	32.36	35.12
14 Intercanthal width (en-en)	M-14	31.35	33.24	35.12	1.88	37.01	38.89
15. Biocular width (ex-ex)	M-15	83.82	88.81	93.80	4.99	98.79	103.78
16. Eye fissure width (en-ex)l	M-16	24.96	27.30	29.65	2.34	31.99	34.33
17. Mouth width (ch-ch)	M-17	42.41	45.62	48.84	3.21	52.05	55.27
18. Nose width (al-al)	M-18	33.47	35.16	36.84	1.68	38.53	40.21
19. Lower lip height (sto-sl)	M-19	14.62	16.00	17.38	1.37	18.75	20.13
Facial Reconstruction							

TABLE N° 21

MEAN AND STANDARD DEVIATION OF NINETEEN FACIAL MEASUREMENTS SELECTED IN A SAMPLE OF FOURTEEN PHOTOGRAPHS

MEASUREMENTS		-2SD	-1SD	MEAN	SD	+2SD	+2SD		
1. Width of the face (zy-zy)	M-1	38.85	65.38	91.91	26.53	118.44	144.97		
2. Width of the lower face (go-go)	M-2	33.36	57.50	81.64	24.14	105.78	129.92		
3. Morphological height of the face (n-gn)	M-3	35.18	58.09	81.00	22.91	103.91	126.82		
4. Physiognomical height of the upper face (n-sto)	M-4	18.56	34.93	51.30	16.37	67.67	84.04		
5. Height of the lower face (sn-gn)	M-5	20.94	35.22	49.50	14.28	63.78	78.06		
6. Height of the lower third of the face or Height of the mandible (sto-gn)	M-6	9.34	20.27	31.20	10.93	42.13	53.06		
7. Nose height (n-sn)	M-7	12.70	22.17	31.64	9.47	41.11	50.58		
8 Upper lip height (sn-sto)	M-8	5.32	11.76	18.20	6.44	24.64	31.08		
9 Cutaneous upper lip height (sn-ls)	M-9	2.80	8.20	13.60	5.40	19.00	24.40		

TABLE N° 21
(continuation)
MEAN AND STANDARD DEVIATION OF NINETEEN FACIAL MEASUREMENTS SELECTED IN A SAMPLE OF FOURTEEN PHOTOGRAPHS

MEASUREMENTS		-2SD	-1SD	MEAN	SD	+2SD	+2SD		
10. Upper vermillion height (ls-sto)	M-10	0.82	2.68	4.55	1.86	6.41	8.27		
11. Lower vermillion height (sto-li)	M-11	1.92	4.13	6.35	2.12	8.56	10.77		
12. Cutaneous lower lip height (li-sl)	M-12	0.98	2.39	3.81	1.41	5.23	6.65		
13. Chin height (sl-gn)	M-13	7.75	14.68	21.61	6.93	28.54	35.47		
14. Intercanthal width (en-en)	M-14	9.74	16.69	23.64	6.95	30.59	37.54		
15. Biocular width (ex-ex)	M-15	24.81	42.13	59.45	17.32	76.77	94.09		
16. Eye fissure width (en-ex)l	M-16	7.32	12.98	18.64	5.66	24.30	29.96		
17. Mouth width (ch-ch)	M-17	11.41	23.14	34.87	11.73	46.60	58.33		
18. Nose width (al-al)	M-18	10.85	18.51	26.17	7.66	33.83	41.49		
19. Lower lip height (sto-sl)	M-19	3.59	6.92	10.25	3.33	13.58	16.91		
Photographs									

TABLE N° 22

MEANS AND STANDARD DEVIATION OF THIRTY-THREE PROPORTION INDICES IN A SAMPLE OF FOURTEEN FACIAL RECONSTRUCTIONS.

N°	Proportion Index	n	-2SD	-1SD	MEAN	SD	+1SD	+2SD
1	F-1 n-gn/zy-zy	14	80.01	85.22	90.43	5.21	95.64	100.85
2	F-2 go-go/zy-zy	14	83.20	85.24	87.28	2.04	89.33	91.37
3	F-3 n-sto/zy-zy	14	50.03	52.96	55.90	2.93	58.54	61.77
4	F-4 go-go/n-gn	14	87.07	91.92	96.77	4.85	101.62	106.47
5	F-5 sto-gn/go-go	14	33.73	37.36	41.00	3.63	44.63	48.26
6	F-9 n-sto/n-gn	14	58.68	60.27	61.85	1.58	63.43	65.02
7	F-10 sn-gn/n-gn	14	55.75	57.13	58.50	1.37	59.87	61.25
8	F-11 sto-gn/n-gn	14	35.75	37.64	39.52	1.88	41.41	43.30
9	F-12 sto-gn/n-sto	14	54.91	59.46	64.01	4.55	68.56	73.11
10	F-13 sto-gn/sn-gn	14	62.78	65.16	67.54	2.38	69.93	72.31
11	F-32 n-sto/ex-ex	14	70.34	73.50	76.65	3.15	79.80	82.95
12	O-1 en-en/ex-ex	14	34.24	35.86	37.47	1.61	39.01	40.70
13	O-3 en-exl/en-en	14	70.40	77.48	84.56	7.08	91.64	98.72
14	O-8 ex-ex/zy-zy	14	67.67	70.30	72.93	2.63	75.56	78.20
15	O-9 en-en/n-sto	14	45.08	47.00	48.92	1.92	50.84	52.76
16	O-10 en-en/al-al	14	87.88	91.62	95.35	3.73	99.09	102.83
17	O-12 en-en/ch-ch	14	64.83	68.44	72.04	3.60	75.65	79.26
18	L-1 sn-sto/ch-ch	14	40.44	43.53	46.62	3.09	49.71	52.81
19	L-5 sn-ls/sn-sto	14	60.26	65.62	70.98	5.36	76.34	81.70
20	L-6 ls-sto/sn-sto	14	23.10	27.72	32.34	4.62	36.96	41.58
21	L-7 ls-sto/sn-ls	14	27.39	36.77	46.15	9.38	55.53	64.91
22	L-9 ls-sto/sto-li	14	44.80	68.81	92.82	24.01	116.83	140.84
23	L-10 ch-ch/zy-zy	14	34.86	36.41	37.95	1.54	39.50	41.05
24	L-11 sn-sto/n-sto	14	28.83	30.23	31.63	1.40	33.03	34.43
25	L-12 sn-sto/sto-gn	14	42.08	45.86	49.64	3.78	53.42	57.20

TABLE N° 22
(continuation)
MEANS AND STANDARD DEVIATION OF THIRTY-THREE PROPORTION INDICES IN A SAMPLE OF FOURTEEN FACIAL RECONSTRUCTIONS.

N°	Proportion Index	n	-2SD	-1SD	MEAN	SD	+1SD	+2SD
26	L-14 sn-sto/n-sn	14	40.05	43.12	46.19	3.07	49.26	52.33
27	N-1 al-al/n-sn	14	66.44	70.69	74.94	4.25	79.19	83.44
28	N-24 al-al/zy-zy	14	26.78	27.71	28.65	0.93	29.59	30.53
29	N-25 n-sn/zy-zy	14	33.68	36.01	38.34	2.32	40.67	43.00
30	N-26 n-sn/n-gn	14	39.07	40.75	42.42	1.67	44.10	45.77
31	N-27 n-sn/n-sto	14	65.20	66.89	68.58	1.68	70.26	71.95
32	N-28 n-sn/sn-gn	14	63.95	68.28	72.61	4.33	76.94	81.27
33	AL-3 sto-sl/sn-sto	14	62.69	69.70	76.71	7.01	83.72	90.73

TABLE N° 23

MEANS AND STANDARD DEVIATION OF THIRTY-THREE PROPORTION INDICES IN A SAMPLE OF FOURTEEN PHOTOGRAPHS.

N°	Proportion Index	n	-2SD	-1SD	MEAN	SD	+1SD	+2SD
1	F-1 n-gn/zy-zy	11	73.12	81.96	90.80	8.84	99.64	108.48
2	F-2 go-go/zy-zy	11	78.89	83.53	88.17	4.64	92.81	97.45
3	F-3 n-sto/zy-zy	9	47.10	51.66	56.22	4.56	60.78	65.34
4	F-4 go-go/n-gn	11	74.91	86.46	98.01	11.55	109.56	121.11
5	F-5 sto-gn/go-go	9	25.09	32.20	39.31	7.11	46.42	53.53
6	F-9 n-sto/n-gn	10	55.83	58.88	61.93	3.05	64.98	68.03
7	F-10 sn-gn/n-gn	14	53.16	57.26	61.36	4.10	65.46	69.56
8	F-11 sto-gn/n-gn	10	31.33	34.40	37.48	3.07	40.55	43.62
9	F-12 sto-gn/n-sto	10	45.46	53.16	60.86	7.70	68.56	76.26
10	F-13 sto-gn/sn-gn	10	56.61	59.28	61.96	2.67	64.63	67.31
11	F-32 n-sto/ex-ex	8	67.43	76.05	84.67	8.62	93.29	101.91
12	O-1 en-en/ex-ex	11	33.88	36.81	39.73	2.92	42.66	45.59
13	O-3 en-exl/en-en	11	59.11	69.23	79.35	10.12	89.47	99.59
14	O-8 ex-ex/zy-zy	10	59.23	63.29	67.35	4.06	71.41	75.47
15	O-9 en-en/n-sto	8	33.38	40.37	47.36	6.99	54.35	61.34
16	O-10 en-en/al-al	11	76.71	84.85	92.99	8.14	101.13	109.27
17	O-12 en-en/ch-ch	8	52.57	60.07	67.57	7.50	75.07	82.57
18	L-1 sn-sto/ch-ch	8	36.97	44.41	51.85	7.44	59.29	66.73
19	L-5 sn-ls/sn-sto	10	58.88	66.53	74.18	7.65	81.83	89.48
20	L-6 ls-sto/sn-sto	10	12.00	18.72	25.44	6.72	32.16	38.88
21	L-7 ls-sto/sn-ls	10	10.13	22.78	35.43	12.65	48.08	60.73
22	L-9 ls-sto/sto-li	10	36.41	53.79	71.17	17.38	88.55	105.93
23	L-10 ch-ch/zy-zy	8	33.19	36.22	39.25	3.03	42.28	45.31
24	L-11 sn-sto/n-sto	10	27.60	31.51	35.42	3.91	39.33	43.24
25	L-12 sn-sto/sto-gn	10	44.18	51.47	58.76	7.29	66.05	73.34

TABLE N° 23
(continuation)

MEANS AND STANDARD DEVIATION OF THIRTY-THREE PROPORTION INDICES IN A SAMPLE OF FOURTEEN PHOTOGRAPHS.

N°	Proportion Index	n	-2SD	-1SD	MEAN	SD	+1SD	+2SD
26	L-14 sn-sto/n-sn	10	34.19	45.29	56.39	11.10	67.49	78.59
27	N-1 al-al/n-sn	12	64.57	74.26	83.95	9.69	93.64	103.33
28	N-24 al-al/zy-zy	11	25.57	27.34	29.12	1.77	30.90	32.67
29	N-25 n-sn/zy-zy	11	27.86	31.45	35.04	3.59	38.63	42.22
30	N-26 n-sn/n-gn	14	30.79	34.81	38.83	4.02	42.85	46.87
31	N-27 n-sn/n-sto	10	53.21	58.44	63.67	5.23	68.90	74.13
32	N-28 n-sn/sn-gn	14	41.32	52.65	63.98	11.33	75.31	86.44
33	AL-3 sto-sl/sn-sto	10	36.81	47.41	58.01	10.60	68.61	79.21

TABLE N° 24

MEAN, STANDARD DEVIATION, STANDARD ERROR MEAN AND 95% CONFIDENCE INTERVALS OF THIRTY-THREE PROPORTION INDICES

FACIAL RECONSTRUCTION

PROPORTION INDEX	N	MEAN		SD	SE MEAN	95% Confidence Interval	
F-1 n-gn/zy-zy	14	90.43		5.21	1.39	87.42 to 93.44	
F-2 go-go/zy-zy	14	87.28		2.04	0.54	86.11 to 88.46	
F-3 n-sto/zy-zy	14	55.90		2.93	0.78	54.20 to 57.59	
F-4 go-go/n-gn	14	96.77		4.85	1.30	93.97 to 99.57	
F-5 sto-gn/go-go	14	41.00		3.63	0.97	38.90 to 43.09	
F-9 n-sto/n-gn	14	61.85		1.58	0.42	60.94 to 62.76	
F-10 sn-gn/n-gn	14	58.50		1.37	0.36	57.71 to 59.29	
F-11 sto-gn/n-gn	14	39.52		1.88	0.50	38.43 to 40.61	
F-12 sto-gn/n-sto	14	64.01		4.55	1.22	61.38 to 66.63	
F-13 sto-gn/sn-gn	14	67.54		2.38	0.63	66.17 to 68.92	
F-32 n-sto/ex-ex	14	76.65		3.15	0.84	74.83 to 78.47	
O-1 en-en/ex-ex	14	37.47		1.61	0.43	36.54 to 38.40	
O-3 en-ex l/en-en	14	84.56		7.08	1.89	80.47 to 88.65	
O-8 ex-ex/zy-zy	14	72.93		2.63	0.70	71.41 to 74.45	
O-9 en-en/n-sto	14	48.92		1.92	0.51	47.81 to 50.03	
O-10 en-en/al-al	14	95.35		3.73	0.99	93.20 to 97.51	
O-12 en-en/ch-ch	14	72.04		3.60	0.96	69.96 to 74.13	
L-1 sn-sto/ch-ch	14	46.62		3.09	0.82	44.84 to 48.41	
L-5 sn-ls/sn-sto	14	70.98		5.36	1.43	67.88 to 74.07	
L-6 ls-sto/sn-sto	14	32.34		4.62	1.24	29.68 to 35.01	
L-7 ls-sto/sn-ls	14	46.15		9.38	2.51	40.73 to 51.56	
L-9 ls-sto/sto-li	14	92.82		24.01	6.42	78.96 to 106.68	
L-10 ch-ch/zy-zy	14	37.95		1.54	0.41	37.06 to 38.85	
L-11 sn-sto/n-sto	14	31.63		1.40	0.37	30.83 to 32.44	
L-12 sn-sto/sto-gn	14	49.64		3.78	1.01	47.45 to 51.82	
L-14 sn-sto/n-sn	14	46.19		3.07	0.82	44.42 to 47.97	

TABLE N° 24

(continuation)

MEAN, STANDARD DEVIATION, STANDARD ERROR MEAN AND 95% CONFIDENCE INTERVALS OF THIRTY-THREE PROPORTION INDICES

FACIAL RECONSTRUCTION

PROPORTION INDEX	N	MEAN		SD	SE MEAN	95% Confidence Interval	
N-1 al-al/n-sn	14	74.94		4.25	1.14	72.49 to 77.39	
N-24 al-al/zy-zy	14	28.65		0.93	0.25	28.11 to 29.20	
N-25 n-sn/zy-zy	14	38.34		2.32	0.62	37.00 to 39.69	
N-26 n-sn/n-gn	14	42.42		1.67	0.44	41.46 to 43.39	
N-27 n-sn/n-sto	14	68.58		1.68	0.45	67.60 to 69.55	
N-28 n-sn/sn-gn	14	72.61		4.33	1.16	70.11 to 75.10	
AL-3 sto-sl/sn-sto	14	76.71		7.01	1.87	72.67 to 80.76	

TABLE N° 25

MEAN, STANDARD DEVIATION, STANDARD ERROR MEAN AND 95% CONFIDENCE INTERVALS OF THIRTY-THREE PROPORTION INDICES

PHOTOGRAPHS

PROPORTION INDEX	N	MEAN		SD	SE MEAN	95% Confidence Interval	
F-1 n-gn/zy-zy	11	90.80		8.84	2.66	84.87 to 96.74	
F-2 go-go/zy-zy	11	88.17		4.64	1.40	85.05 to 91.28	
F-3 n-sto/zy-zy	9	56.22		4.56	1.52	52.71 to 59.73	
F-4 go-go/n-gn	11	98.01		11.55	3.48	90.25 to 105.77	
F-5 sto-gn/go-go	9	39.31		7.11	2.37	33.84 to 44.78	
F-9 n-sto/n-gn	10	61.93		3.05	0.96	59.75 to 64.11	
F-10 sn-gn/n-gn	14	61.36		4.10	1.10	58.99 to 63.73	
F-11 sto-gn/n-gn	10	37.48		3.07	0.97	35.28 to 39.67	
F-12 sto-gn/n-sto	10	60.86		7.70	2.44	55.35 to 66.37	
F-13 sto-gn/sn-gn	10	61.96		2.67	0.84	60.04 to 63.87	
F-32 n-sto/ex-ex	8	84.67		8.62	3.05	77.46 to 91.88	
O-1 en-en/ex-ex	11	39.73		2.92	0.88	37.77 to 41.70	
O-3 en-ex l/en-en	11	79.35		10.12	3.05	72.56 to 86.15	
O-8 ex-ex/zy-zy	10	67.35		4.06	1.28	64.45 to 70.26	
O-9 en-en/n-sto	8	47.36		6.99	2.47	41.52 to 53.21	
O-10 en-en/al-al	11	92.99		8.14	2.46	87.52 to 98.46	
O-12 en-en/ch-ch	8	67.57		7.50	2.65	61.29 to 73.85	
L-1 sn-sto/ch-ch	8	51.85		7.44	2.63	45.62 to 58.07	
L-5 sn-ls/sn-sto	10	74.18		7.65	2.42	68.71 to 79.65	
L-6 ls-sto/sn-sto	10	25.44		6.72	2.13	20.63 to 30.25	
L-7 ls-sto/sn-ls	10	35.43		12.65	4.00	26.38 to 44.48	
L-9 ls-sto/sto-li	10	71.17		17.38	5.50	58.74 to 83.60	
L-10 ch-ch/zy-zy	8	39.25		3.03	1.07	36.72 to 41.79	
L-11 sn-sto/n-sto	10	35.42		3.91	1.24	32.62 to 38.22	
L-12 sn-sto/sto-gn	10	58.76		7.29	2.31	53.54 to 63.97	
L-14 sn-sto/n-sn	10	56.39		11.10	3.51	48.45 to 64.33	

TABLE N° 25
(continuation)

MEAN, STANDARD DEVIATION, STANDARD ERROR MEAN AND 95% CONFIDENCE INTERVALS OF THIRTY-THREE PROPORTION INDICES
PHOTOGRAPHS

PROPORTION INDEX	N	MEAN		SD	SE MEAN	95% Confidence Interval	
N-1 al-al/n-sn	12	83.95		9.69	2.80	77.79 to 90.11	
N-24 al-al/zy-zy	11	29.12		1.77	0.53	27.93 to 30.31	
N-25 n-sn/zy-zy	11	35.04		3.59	1.08	32.62 to 37.45	
N-26 n-sn/n-gn	14	38.83		4.02	1.07	36.51 to 41.15	
N-27 n-sn/n-sto	10	63.67		5.23	1.66	59.93 to 67.42	
N-28 n-sn/sn-gn	14	63.98		11.33	3.03	57.44 to 70.52	
AL-3 sto-sl/sn-sto	10	58.01		10.60	3.35	50.43 to 65.59	

TABLE N°26

COMPARISON OF MEANS AND STANDARD DEVIATION OF THIRTY-THREE PROPORTION INDICES OF FACIAL RECONSTRUCTION BY COMPUTING WITH PHOTOGRAPHS, USING P VALUE AND T TEST

	FACIAL RECONSTRUCTION			PHOTOGRAPHS					
PROPORTION INDEX	MEAN	SD		MEAN	SD	P Value	T TEST	P Value > 0.05	
F-1 n-gn/zy-zy	90.43	5.21		90.80	8.84	0.90	0.12	*	
F-2 go-go/zy-zy	87.29	2.04		88.17	4.64	0.57	0.58	*	
F-3 n-sto/zy-zy	55.90	2.94		56.22	4.56	0.86	0.19	*	
F-4 go-go/n-gn	96.77	4.85		98.00	11.60	0.74	0.33	*	
F-5 sto-gn/go-go	41.00	3.63		39.31	7.11	0.52	-0.66	*	
F-9 n-sto/n-gn	61.86	1.58		61.93	3.05	0.94	0.07	*	
F-10 sn-gn/n-gn	58.50	1.37		61.36	4.10	0.026	2.47		
F-11 sto-gn/n-gn	39.53	1.89		37.48	3.07	0.084	-1.87	*	
F-12 sto-gn/n-sto	64.01	4.55		60.86	7.70	0.27	-1.16	*	
F-13 sto-gn/sn-gn	67.55	2.38		61.96	2.68	0.0001	-5.28		
F-32 n-sto/ex-ex	76.65	3.15		84.67	8.62	0.035	2.54		
O-1 en-en/ex-ex	37.48	1.61		39.74	2.93	0.037	2.30		
O-3 en-ex l/en-en	84.56	7.08		79.40	10.10	0.16	-1.45	*	
O-8 ex-ex/zy-zy	72.94	2.63		67.35	4.06	0.0019	-3.81		
O-9 en-en/n-sto	48.92	1.92		47.36	6.99	0.55	-0.62	*	
O-10 en-en/al-al	95.36	3.74		92.99	8.14	0.39	-0.89	*	
O-12 en-en/ch-ch	72.05	3.61		67.57	7.50	0.15	-1.59	*	
L-1 sn-sto/ch-ch	46.63	3.09		51.85	7.44	0.095	1.89	*	
L-5 sn-ls/sn-sto	70.98	5.36		74.18	7.65	0.27	1.14	*	
L-6 ls-sto/sn-sto	32.34	4.62		25.44	6.72	0.014	-2.81		
L-7 ls-sto/sn-ls	46.15	9.38		35.40	12.60	0.038	-2.27		
L-9 ls-sto/sto-li	92.80	24.00		71.20	17.40	0.018	-2.56		
L-10 ch-ch/zy-zy	37.96	1.55		39.25	3.03	0.29	1.13	*	
L-11 sn-sto/n-sto	31.64	1.40		35.42	3.91	0.015	2.93		
Ttest: Null hypothesis test value: 0.05									

TABLE N° 26

(continuation)

COMPARISON OF MEANS AND STANDARD DEVIATION OF THIRTY-THREE PROPORTION INDICES OF FACIAL RECONSTRUCTION BY COMPUTING WITH PHOTOGRAPHS, USING P VALUE AND T TEST

FACIAL RECONSTRUCTION PHOTOGRAPHS

PROPORTION INDEX	MEAN	SD		MEAN	SD	P Value	T Test	P Value > 0.05	
L-12 sn-sto/sto-gn	49.64	3.78		58.76	7.29	0.0035	3.62		
L-14 sn-sto/n-sn	46.20	3.07		56.40	11.10	0.020	2.83		
N-1 al-al/n-sn	74.94	4.25		83.95	9.69	0.0099	2.98		
N-24 al-al/zy-zy	**28.65**	**0.93**		**29.12**	**1.78**	**0.44**	**0.79**	*	
N-25 n-sn/zy-zy	38.35	2.33		35.04	3.59	0.017	-2.65		
N-26 n-sn/n-gn	42.43	1.67		38.83	4.02	0.0066	-3.10		
N-27 n-sn/n-sto	68.58	1.69		63.67	5.23	0.017	-2.86		
N-28 n-sn/sn-gn	72.61	4.33		64.00	11.30	0.017	-2.66		
AL-3 sto-sl/sn-sto	76.71	7.01		58.00	10.60	0.0002	-4.87		
Ttest: Null hypothesis test value: 0.05									

TABLE N° 27

MEAN AND THE 95% CONFIDENCE INTERVALS FOR THE DIFFERENCE OF MEAN OF THIRTY-THREE PROPORTION INDICES

FACIAL RECONSTRUCTION				PHOTOGRAPHS							
PROPORTION INDEX	MEAN	SD		MEAN	SD	Dulfference of means	N	MEAN	SD	SE MEAN	95% Confidence Interval
F-1 n-gn/zy-zy	90.43	5.21		90.80	8.84	F1a-F1b	11	-0.97	9.48	2.86	- 7.34 to 5.40
F-2 go-go/zy-zy	87.29	2.04		88.17	4.64	F2a-F2b	11	0.47	4.18	1.26	- 2.34 to 3.28
F-3 n-sto/zy-zy	55.90	2.94		56.22	4.56	F3a-F3b	9	-0.45	5.48	1.83	- 4.66 to 3.76
F-4 go-go/n-gn	96.77	4.85		98.00	11.60	F4a-F4b	11	2.29	11.67	3.52	- 5.55 to 10.14
F-5 sto-gn/go-go	41.00	3.63		39.31	7.11	F5a-F5b	9	-1.79	6.48	2.16	- 6.77 to 3.19
F-9 n-sto/n-gn	61.86	1.58		61.93	3.05	F9a-F9b	10	-0.18	3.33	1.05	- 2.57 to 2.20
F-10 sn-gn/n-gn	58.50	1.37		61.36	4.10	F10a-F10b	14	2.86	3.99	1.07	0.56 to 5.16
F-11 sto-gn/n-gn	39.53	1.89		37.48	3.07	F11a-F11b	10	-1.61	3.09	0.97	- 3.82 to 0.59
F-12 sto-gn/n-sto	64.01	4.55		60.86	7.70	F12a-F12b	10	-2.16	7.85	2.48	- 7.78 to 3.46
F-13 sto-gn/sn-gn	67.55	2.38		61.96	2.68	F13a-F13b	10	-5.13	2.63	0.83	- 7.01 to -3.25
F-32 n-sto/ex-ex	76.65	3.15		84.67	8.62	F32a-F32b	8	6.81	8.83	3.12	- 0.58 to 14.20
O-1 en-en/ex-ex	37.48	1.61		39.74	2.93	O1a-O1b	11	2.09	2.93	0.88	0.12 to 4.06
O-3 en-ex l/en-en	84.56	7.08		79.40	10.10	O3a-O3b	11	-4.23	9.25	2.79	-10.44 to 1.98
O-8 ex-ex/zy-zy	72.94	2.63		67.35	4.06	O8a-O8b	10	-6.14	4.87	1.54	- 9.62 to -2.66
O-9 en-en/n-sto	48.92	1.92		47.36	6.99	O9a-O9B	8	-0.69	6.49	2.29	- 6.11 to 4.74
O-10 en-en/al-al	95.36	3.74		92.99	8.14	O10a-O10b	11	-3.15	8.11	2.44	- 8.59 to 2.30
O-12 en-en/ch-ch	72.05	3.61		67.57	7.50	O12a-O12b	8	-4.67	6.57	2.32	-10.16 to 0.82
L-1 sn-sto/ch-ch	46.63	3.09		51.85	7.44	L1a-L1b	8	4.06	5.97	2.11	- 0.94 to 9.06
L-5 sn-ls/sn-sto	70.98	5.36		74.18	7.65	L5a-L5a	10	1.78	8.10	2.56	- 4.01 to 7.58
L-6 ls-sto/sn-sto	32.34	4.62		25.44	6.72	L6a-L6b	10	-6.11	6.66	2.11	-10.88 to-1.34
L-7 ls-sto/sn-ls	46.15	9.38		35.40	12.60	L7a-L7B	10	-8.55	12.68	4.01	-17.62 to 0.52
L-9 ls-sto/sto-li	92.80	24.00		71.20	17.40	L9a-L9b	10	-18.21	25.44	8.05	-36.41 to -0.01
L-10 ch-ch/zy-zy	37.96	1.55		39.25	3.03	L10a-L10b	8	0.90	3.25	1.15	- 1.82 to 3.62
L-11 sn-sto/n-sto	31.64	1.40		35.42	3.91	L11a-L11b	10	3.53	3.48	1.10	1.04 to 6.03
L-12 sn-sto/sto-gn	49.64	3.78		58.76	7.29	L12a-L12b	10	8.03	7.75	2.45	2.48 to 13.57

TABLE N° 27
(continuation)
MEAN AND THE 95% CONFIDENCE INTERVALS FOR THE DIFFERENCE OF MEAN OF THIRTY-THREE PROPORTION INDICES

FACIAL RECONSTRUCTION				PHOTOGRAPHS							
PROPORTION INDEX	MEAN	SD		MEAN	SD	Dulfference of means	N	MEAN	SD	SE MEAN	95% Confidence Interval
L-14 sn-sto/n-sn	46.20	3.07		56.40	11.10	L14a-L14b	10	9.57	9.98	3.16	2.43 to 16.71
N-1 al-al/n-sn	74.94	4.25		83.95	9.69	N1a-N1b	12	9.60	10.02	2.89	3.23 to 15.96
N-24 al-al/zy-zy	**28.65**	**0.93**		**29.12**	**1.78**	**N24a-N24b**	**11**	**0.40**	**1.97**	**0.59**	**- 0.92 to 1.73**
N-25 n-sn/zy-zy	38.35	2.33		35.04	3.59	N25a-N25b	11	-3.48	4.65	1.40	- 6.61 to -0.36
N-26 n-sn/n-gn	42.43	1.67		38.83	4.02	N26a-N26a	14	-3.60	3.96	1.06	- 5.89 to -1.31
N-27 n-sn/n-sto	68.58	1.69		63.67	5.23	N27a-N27b	10	-4.52	4.84	1.53	- 7.99 to -1.06
N-28 n-sn/sn-gn	72.61	4.33		64.00	11.30	N28a-N28b	14	-8.63	10.97	2.93	-14.96 to -2.30
AL-3 sto-sl/sn-sto	76.71	7.01		58.00	10.60	AL3a-AL3b	10	-17.02	9.79	3.10	-24.03 to -10.02

TABLE N° 28

COMPARISON OF MEAN AND STANDARD DEVIATION OF THIRTY-THREE PROPORTION INDICES OF FACIAL RECONSTRUCTION WITH PHOTOGRAPHS ACCORDING TO P value

	PHOTOGRAPHS			FACIAL RECONSTRUCTION			
PROPORTION INDEX	**MEAN**	**SD**		**MEAN**	**SD**	**P Value**	**T test**
P value: > 0.5							
F-9 n-sto/n-gn	61.93	3.05		61.86	1.58	0.94	0.07
F-1 n-gn/zy-zy	90.80	8.84		90.43	5.21	0.90	0.12
F-3 n-sto/zy-zy	56.22	4.56		55.90	2.94	0.86	0.19
F-4 go-go/n-gn	98.00	11.60		96.77	4.85	0.74	0.33
F-2 go-go/zy-zy	88.17	4.64		87.29	2.04	0.57	0.58
O-9 en-en/n-sto	47.36	6.99		48.92	1.92	0.55	-0.62
F-5 sto-gn/go-go	39.31	7.11		41.00	3.63	0.52	-0.66
P value: 0.5-0.2							
N-24 al-al/zy-zy	29.12	1.78		28.65	0.93	0.44	0.79
O-10 en-en/al-al	92.99	8.14		95.36	3.74	0.39	-0.89
L-10 ch-ch/zy-zy	39.25	3.03		37.96	1.55	0.29	1.13
F-12 sto-gn/n-sto	60.86	7.70		64.01	4.55	0.27	-1.16
P value: 0.2-0.1							
L-5 sn-ls/sn-sto	74.18	7.65		70.98	5.36	0.27	1.14
O-3 ex-en l/en-en	79.40	10.10		84.56	7.08	0.16	-1.45
O-12 en-en/ch-ch	67.57	7.50		72.05	3.61	0.15	-1.59
P value 0.1-0.05							
L-1 sn-sto/ch-ch	51.85	7.44		46.63	3.09	0.095	1.89
F-11 sto-gn/n-gn	37.48	3.07		39.53	1.89	0.084	-1.87

TABLE N° 28
(continuation)
COMPARISON OF MEAN AND STANDARD DEVIATION OF THIRTY-THREE PROPORTION INDICES OF FACIAL RECONSTRUCTION WITH PHOTOGRAPHS ACCORDING TO P value

PHOTOGRAPHS **FACIAL RECONSTRUCTION**

PROPORTION INDEX	MEAN	SD		MEAN	SD	P Value	T test
P value 0.05-0.02							
L-7 ls-sto/sn-ls	35.40	12.60		46.15	9.38	0.038	-2.27
O-1 en-en/ex-ex	39.74	2.93		37.48	1.61	0.037	2.30
F-32 n-sto/ex-ex	84.67	8.62		76.65	3.15	0.035	2.54
F-10 sn-gn/n-gn	61.36	4.10		58.50	1.37	0.026	2.47
L-14 sn-sto/n-sn	56.40	11.10		46.20	3.07	0.020	2.83
P value 0.02-0.01							
L-9 ls-sto/sto-li	71.20	17.40		92.80	24.00	0.018	-2.56
N-25 n-sn/zy-zy	35.04	3.59		38.35	2.33	0.017	-2.65
N-27 n-sn/n-sto	63.67	5.23		68.58	1.69	0.017	-2.86
N-28 n-sn/sn-gn	64.00	11.30		72.61	4.33	0.017	-2.66
L-11 sn-sto/n-sto	35.42	3.91		31.64	1.40	0.015	2.93
L-6 ls-sto/sn-sto	25.44	6.72		32.34	4.62	0.014	-2.81
P value 0.01-0.005							
N-1 al-al/n-sn	83.95	9.69		74.94	4.25	0.0099	2.98
N-26 n-sn/n-gn	38.83	4.02		42.43	1.67	0.0066	-3.10
P value 0.005-0.002							
L-12 sn-sto/sto-gn	58.76	7.29		49.64	3.78	0.0035	3.62
P value 0.002-0.001							
O-8 ex-ex/zy-zy	67.35	4.06		72.94	2.63	0.0019	-3.81

TABLE N° 29-1

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value > 0.5

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index F-9 n-sto/n-gn	Proportion Index F-1 n-gn/zy-zy	Proportion Index F-3 n-sto/zy-zy	Proportion Index F-4 go-go/n-gn	Proportion Index F-2 go-go/zy-zy	Proportion Index O-9 en-en/n-sto	Proportion Index F-5 sto-gn/go-go
1 Facial Reconstruction	2832	1	61.34	92.78	56.91	92.19	85.54	47.64	45.85
Photographs			58.18	107.843	62.74	83.63	90.19	34.37	48.91
2 Facial Reconstruction	2915	2	64.27	81.39	52.32	104.91	85.40	50.34	34.15
Photograph			62.50	*	*	*	*	*	*
3 Facial Reconstruction	2950	3	61.02	89.71	54.74	97.65	87.61	48.75	41.64
Photograph			*	92.39	*	97.64	90.21	*	*
4 Facial Reconstruction	2973	4	61.88	92.46	57.22	92.86	85.86	48.59	44.13
Photograph			*	*	*	*	*	*	*
5 Facial Reconstruction	3018	5	58.73	95.42	56.22	89.77	85.67	50.48	47.68
Photograph			*	85.88	*	105.47	90.58	*	*
6 Facial Reconstruction	3019	6	63.17	82.68	52.23	104.11	86.08	49.87	36.50
Photograph			*	*	*	*	*	*	*
7 Facial Reconstruction	3039	7	62.50	92.42	57.77	98.08	90.65	51.42	39.51
Photograph			58.22	91.86	53.48	102.53	94.18	56.52	39.50

TABLE N° 29-1

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value > 0.5

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index F-9 n-sto/n-gn	Proportion Index F-1 n-gn/zy-zy	Proportion Index F-3 n-sto/zy-zy	Proportion Index F-4 go-go/n-gn	Proportion Index F-2 go-go/zy-zy	Proportion Index O-9 en-en/n-sto	Proportion Index F-5 sto-gn/go-go
8	3052	8							
Facial Reconstruction			60.72	98.41	59.75	89.57	88.15	48.13	44.37
Photograph			60.19	99.03	59.61	90.29	89.42	46.77	44.08
9	3055	9							
Facial Reconstruction			64.24	88.20	56.66	97.26	85.79	46.39	38.73
Photograph			61.11	94.73	57.89	83.33	78.94	45.45	46.66
10	2831	10							
Facial Reconstruction			61.14	94.08	57.52	95.99	90.31	48.17	41.85
Photograph			60.00	80.35	48.21	115.55	92.85	55.55	33.65
11	2996	11							
Facial Reconstruction			59.67	81.73	48.77	103.29	84.42	52.52	39.38
Photograph			64.35	86.32	55.55	100.00	86.32	*	35.64
12	2850	12							
Facial Reconstruction			61.73	93.35	57.63	95.01	88.69	46.90	41.02
Photograph			64.94	89.81	58.33	98.96	88.88	44.44	35.41
13	2938	13							
Facial Reconstruction			62.71	92.85	58.23	96.98	90.05	45.88	39.56
Photograph			67.69	75.58	51.16	115.38	87.20	50.00	26.66

TABLE N° 29-1

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value > 0.5

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index F-9 n-sto/n-gn	Proportion Index F-1 n-gn/zy-zy	Proportion Index F-3 n-sto/zy-zy	Proportion Index F-4 go-go/n-gn	Proportion Index F-2 go-go/zy-zy	Proportion Index O-9 en-en/n-sto	Proportion Index F-5 sto-gn/go-go
14 Facial Reconstruction Photograph	3009	14	62.71 62.10	90.44 95.00	56.79 59.00	97.03 85.26	87.76 81.00	49.80 45.76	39.58 43.20
P value > 0.5									

TABLE N° 29-2
Individual Proportion Indices of Facial Reconstruction with Photographs. according to P value

P value 0.5-0.2

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index N-24 Al-al/zy-zy	Proportion Index O-10 en-en/al-al	Proportion Index L-10 ch-ch/zy-zy	Proportion Index F-12 sto-gn/n-sto
1	2832	1				
Facial Reconstruction			27.55	98.42	38.44	68.91
Photographs			28.43	75.86	38.23	70.31
2	2915	2				
Facial Reconstruction			27.77	94.82	38.87	55.75
Photograph			*	*	*	60.00
3	2950	3				
Facial Reconstruction			28.59	93.33	38.62	66.63
Photograph			31.52	93.10	*	*
4	2973	4				
Facial Reconstruction			28.71	96.83	39.25	66.22
Photograph			*	95.23	*	*
5	3018	5				
Facial Reconstruction			27.48	102.96	34.81	72.87
Photograph			27.05	104.34	*	*
6	3019	6				
Facial Reconstruction			28.77	90.54	37.87	60.17
Photograph			*	*	*	*
7	3039	7				
Facial Reconstruction			30.02	98.94	38.78	61.99
Photograph			30.23	100.00	40.69	69.56

TABLE N° 29-2

(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs. according to P value

P value 0.5-0.2

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **N-24** al-al/zy-zy	Proportion Index **O-10** en-en/al-al	Proportion Index **L-10** ch-ch/zy-zy	Proportion Index **F-12** sto-gn/n-sto
8	3052	8				
Facial Reconstruction			30.87	93.16	39.15	65.46
Photograph			28.84	96.66	39.42	66.12
9	3055	9				
Facial Reconstruction			28.68	91.65	36.69	58.65
Photograph			31.57	83.33	42.10	63.63
10	2831	10				
Facial Reconstruction			28.48	97.27	37.53	65.71
Photograph			28.57	93.75	33.92	64.81
11	2996	11				
Facial Reconstruction			27.80	92.15	35.20	68.18
Photograph			29.91	*	*	55.38
12	2850	12				
Facial Reconstruction			28.88	93.59	37.38	63.13
Photograph			29.62	87.50	42.59	53.96
13	2938	14				
Facial Reconstruction			29.23	91.40	38.62	61.18
Photograph			25.58	100.00	36.04	45.45

TABLE N° 29-2

(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs. according to P value

P value 0.5-0.2

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **N-24** al-al/zy-zy	Proportion Index **O-10** en-en/al-al	Proportion Index **L-10** ch-ch/zy-zy	Proportion Index **F-12** sto-gn/n-sto
14	3009	15				
Facial Reconstruction			28.31	99.89	40.21	61.16
Photograph			29.00	93.10	41.00	5932
P value 0.5-0.2						

TABLE N° 29-3

Individual Proportion Indices of Facial Reconstruction with Photographs, according to P value

P Value 0.2-0.1

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index L-5 sn-ls/sn-sto	Proportion Index O-3 en-ex l/en-en	Proportion Index O-12 en-en/ch-ch
1 Facial Reconstruction	2832	1	69.88	87.17	70.53
Photographs			68.18	95.45	56.41
2 Facial Reconstruction	2915	2	81.32	89.93	67.74
Photograph			80.00	*	*
3 Facial Reconstruction	2950	3	67.97	89.29	69.10
Photograph			*	92.59	*
4 Facial Reconstruction	2973	4	66.50	88.71	70.83
Photograph			*	85.00	*
5 Facial Reconstruction	3018	5	74.01	69.21	81.52
Photograph			*	75.00	*
6 Facial Reconstruction	3019	6	61.21	88.83	68.77
Photograph			*	*	*
7 Facial Reconstruction	3039	7	66.78	76.43	76.60
Photograph			70.58	61.53	74.28

TABLE N° 29-3
(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs, according to P value

P Value 0.2-0.1

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **L-5** sn-ls/sn-sto	Proportion Index **O-3** en-ex l/en-en	Proportion Index **O-12** en-en/ch-chl
8	3052	8			
Facial Reconstruction			78.67	85.72	73.46
Photograph			78.57	75.86	70.73
9	3055	9			
Facial Reconstruction			70.75	89.71	71.65
Photograph			75.00	80.00	62.50
10	2831	10			
Facial Reconstruction			68.48	77.97	73.84
Photograph			63.15	66.66	78.94
11	2996	11			
Facial Reconstruction			72.30	85.72	72.77
Photograph			85.71	*	*
12	2850	12			
Facial Reconstruction			68.86	80.32	72.30
Photograph			82.60	85.71	60.86
13	2938	14			
Facial Reconstruction			77.32	96.09	69.18
Photograph			64.28	77.27	70.96

TABLE N° 29-3
(continuation)

Individual Proportion Indices of Facial Reconstruction with Photographs, according to P value

P Value 0.2-0.1

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **L-5** sn-ls/sn-sto	Proportion Index **O-3** en-ex l/en-en	Proportion Index **O-12** en-en/ch-chl
14	3009	15			
Facial Reconstruction			69.54	78.75	70.34
Photograph			73.68	77.77	65.85
P value 0.2-0.1					

TABLE N°29-4

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.1-0.05

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **L-1** sn-sto/ch-ch	Proportion Index **F-11** sto-gn/n-gn
1	2832	1		
Facial Reconstruction			47.11	42.27
Photographs			56.41	40.90
2	2915	2		
Facial Reconstruction			41.43	35.83
Photograph			*	37.50
3	2950	3		
Facial Reconstruction			45.81	40.66
Photograph			*	*
4	2973	4		
Facial Reconstruction			42.69	40.98
Photograph			*	*
5	3018	5		
Facial Reconstruction			49.37	42.80
Photograph			*	*
6	3019	6		
Facial Reconstruction			43.95	38.01
Photograph			*	*
7	3039	7		
Facial Reconstruction			46.03	38.75
Photograph			48.57	40.50

TABLE N° 29-4
(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.1-0.05

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index L-1 sn-sto/ch-ch	Proportion Index F-11 sto-gn/n-gn
8	3052	8		
Facial Reconstruction			51.57	39.75
Photograph			68.29	39.80
9	3055	9		
Facial Reconstruction			50.34	37.68
Photograph			50.00	38.88
10	2831	10		
Facial Reconstruction			50.27	40.18
Photograph			50.00	38.88
11	2996	11		
Facial Reconstruction			47.19	40.68
Photograph			*	35.64
12	2850	12		
Facial Reconstruction			48.34	38.97
Photograph			50.00	35.05
13	2938	14		
Facial Reconstruction			44.74	38.37
Photograph			45.16	30.76

TABLE N° 29-4

(continuation)

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.1-0.05

N°	**CASE N°**	**PERSONAL IDENTITY N°**	**Proportion Index** **L-1** **sn-sto/ch-ch**	**Proportion Index** **F-11** **sto-gn/n-gn**
14 Facial Reconstruction Photograph	3009	15	43.87 46.34	38.41 36.84
P value 0.1-0.05				

TABLE N° 30-5

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P VALUE 0.05-0.02

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index L-7 ls-sto/sn-ls	Proportion Index O-1 en-en/ex-ex	Proportion Index F-32 n-sto/ex-ex	Proportion Index F-10 sn-gn/n-gn	Proportion Index L-14 sn-sto/n-sn
1	2832	1					
Facial Reconstruction			49.17	37.35	78.41	58.12	48.42
Photographs			46.66	36.06	104.91	61.81	52.32
2	2915	2					
Facial Reconstruction			42.04	36.22	71.95	56.42	44.21
Photograph			29.16	*	*	59.72	51.72
3	2950	3					
Facial Reconstruction			51.23	36.16	74.17	60.21	47.05
Photograph			*	42.18	*	63.52	*
4	2973	4					
Facial Reconstruction			51.42	37.31	76.79	58.67	40.85
Photograph			*	37.73	*	63.23	*
5	3018	5					
Facial Reconstruction			38.23	41.38	81.97	59.85	44.00
Photograph			*	40.00	*	65.75	*
6	3019	6					
Facial Reconstruction			65.34	37.22	74.63	57.76	46.68
Photograph			*	*	*	61.53	*
7	3039	7					
Facial Reconstruction			41.14	39.20	76.23	57.71	44.59
Photograph			41.66	45.61	80.70	63.29	58.62

TABLE N° 30-5
(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.05-0.02

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index L-7 ls-sto/sn-ls	Proportion Index O-1 en-en/ex-ex	Proportion Index F-32 n-sto/ex-ex	Proportion Index F-10 sn-gn/n-gn	Proportion Index L-14 sn-sto/n-sn
8	3052	8					
Facial Reconstruction			30.79	37.60	78.10	59.63	50.80
Photograph			27.27	39.72	84.93	66.99	82.35
9	3055	9					
Facial Reconstruction			48.54	36.00	77.58	57.30	48.32
Photograph			33.33	38.46	84.61	66.66	66.66
10	2831	10					
Facial Reconstruction			50.03	39.09	81.14	59.59	48.77
Photograph			58.33	42.85	77.14	61.11	54.28
11	2996	11					
Facial Reconstruction			39.05	37.14	70.71	61.01	51.10
Photograph			16.66	*	*	56.43	47.72
12	2850	12					
Facial Reconstruction			47.59	37.12	79.14	58.33	45.06
Photograph			21.05	35.89	80.76	58.76	57.50
13	2938	14					
Facial Reconstruction			30.84	34.84	75.93	56.69	42.07
Photograph			44.44	40.00	80.00	52.30	45.16

TABLE N° 30-5

(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.05-0.02

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index L-7 ls-sto/sn-ls	Proportion Index O-1 en-en/ex-ex	Proportion Index F-32 n-sto/ex-ex	Proportion Index F-10 sn-gn/n-gn	Proportion Index L-14 sn-sto/n-sn
14	3009	15					
Facial Reconstruction			46.16	37.99	76.28	57.70	44.80
Photograph			35.71	38.57	84.28	57.89	47.50
P value 0.05-0.02							

TABLE N° 30-6

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P VALUE 0.02-0.01

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index L-9 ls-sto/sto-li	Proportion Index N-25 n-sn/zy-zy	Proportion Index N-27 n-sn/n-sto	Proportion Index N-28 n-sn/sn-gn	Proportion Index L-11 sn-sto/n-sto	Proportion Index L-6 ls-sto/sn-sto
1	2832	1						
Facial Reconstruction			98.93	37.40	65.71	69.34	31.81	34.36
Photographs			100.00	41.17	65.62	61.76	34.37	31.81
2	2915	2						
Facial Reconstruction			83.02	36.43	69.62	79.32	30.78	34.19
Photograph			77.77	*	64.44	67.44	33.33	23.33
3	2950	3						
Facial Reconstruction			95.65	37.61	68.69	69.62	32.32	34.82
Photograph			*	33.69	*	57.40	*	*
4	2973	4						
Facial Reconstruction			90.00	41.03	71.70	75.63	29.29	34.20
Photograph			*	*	*	58.13	*	*
5	3018	5						
Facial Reconstruction			71.15	38.94	69.48	68.18	30.57	28.29
Photograph			*	30.58	*	54.16	*	*
6	3019	6						
Facial Reconstruction			67.17	35.66	68.27	74.66	31.87	26.86
Photograph			*	*	*	64.58	*	*
7	3039	7						
Facial Reconstruction			74.00	40.03	69.29	75.04	30.90	27.47
Photograph			71.42	33.72	63.04	58.00	36.95	29.41

TABLE N° 30-6
(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.02-0.01

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **L-9** ls-sto/sto-li	Proportion Index **N-25** n-sn/zy-zy	Proportion Index **N-27** n-sn/n-sto	Proportion Index **N-28** n-sn/sn-gn	Proportion Index **L-11** sn-sto/n-sto	Proportion Index **L-6** ls-sto/sn-sto
8	3052	8						
Facial Reconstruction			63.04	39.74	66.50	67.72	33.79	24.22
Photograph			75.00	32.69	54.83	49.27	45.16	21.42
9	3055	9						
Facial Reconstruction			90.76	38.22	67.46	75.63	32.60	34.34
Photograph			50.00	31.57	54.54	50.00	36.36	25.00
10	2831	10						
Facial Reconstruction			98.09	38.68	67.24	68.99	32.79	34.26
Photograph			70.00	31.25	64.81	63.63	35.18	36.84
11	2996	11						
Facial Reconstruction			85.98	32.50	66.64	65.18	34.06	28.23
Photograph			37.50	37.60	67.69	77.19	32.30	14.28
12	2850	12						
Facial Reconstruction			87.68	40.11	69.59	73.65	31.36	32.77
Photograph			80.00	37.03	63.49	70.17	36.50	17.39
13	2938	14						
Facial Reconstruction			62.20	41.07	70.52	78.01	29.67	23.85
Photograph			66.66	36.04	70.45	91.17	31.81	28.57

TABLE N° 30-6

(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.02-0.01

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index L-9 ls-sto/sto-li	Proportion Index N-25 n-sn/zy-zy	Proportion Index N-27 n-sn/n-sto	Proportion Index N-28 n-sn/sn-gn	Proportion Index L-11 sn-sto/n-sto	Proportion Index L-6 ls-sto/sn-sto
14	3009	15						
Facial Reconstruction			88.94	39.38	69.34	75.47	31.06	32.10
Photograph			83.33	40.00	67.79	72.72	32.20	26.31
P value 0.02<P<0.01								

TABLE N° 30-7

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P VALUE 0.01-0.005

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index N-1 al-al/n-sn	Proportion Index N-26 n-sn/n-gn
1	2832	1		
Facial Reconstruction			73.66	40.30
Photographs			69.04	38.18
2	2915	2		
Facial Reconstruction			76.24	44.75
Photograph			*	40.27
3	2950	3		
Facial Reconstruction			76.03	41.92
Photograph			93.54	36.47
4	2973	4		
Facial Reconstruction			69.97	44.37
Photograph			84.00	36.76
5	3018	5		
Facial Reconstruction			70.56	40.81
Photograph			88.46	35.61
6	3019	6		
Facial Reconstruction			80.67	43.13
Photograph			*	39.74
7	3039	7		
Facial Reconstruction			75.00	43.31
Photograph			89.65	36.70

TABLE N° 30-7
(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.01-0.005

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index N-1 al-al/n-sn	Proportion Index N-26 n-sn/n-gn
8	3052	8		
Facial Reconstruction			77.69	40.38
Photograph			88.23	33.00
9	3055	9		
Facial Reconstruction			75.03	43.34
Photograph			100.00	33.33
10	2831	10		
Facial Reconstruction			73.64	41.11
Photograph			91.42	38.88
11	2996	11		
Facial Reconstruction			85.52	39.76
Photograph			79.54	43.56
12	2850	12		
Facial Reconstruction			72.01	42.96
Photograph			80.00	41.23
13	2938	14		
Facial Reconstruction			71.17	44.23
Photograph			70.96	47.69

TABLE N° 30-7

(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.01-0.005

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index N-1 al-al/n-sn	Proportion Index N-26 n-sn/n-gn
14	3009	15		
Facial Reconstruction			71.89	43.55
Photograph			72.50	42.10
P value 0.01<P<0.005				

TABLE N° 30-8

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P VALUE 0.005-0.002

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index L-12 sn-sto/sto-gn
1 Facial Reconstruction Photographs	2832	1	 46.16 48.88
2 Facial Reconstruction Photograph	2915	2	 55.21 55.55
3 Facial Reconstruction Photograph	2950	3	 48.50 *
4 Facial Reconstruction Photograph	2973	4	 44.23 *
5 Facial Reconstruction Photograph	3018	5	 41.95 *
6 Facial Reconstruction Photograph	3019	6	 52.97 *
7 Facial Reconstruction Photograph	3039	7	 49.84 53.12

TABLE N° 30-8
(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.005-0.002

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index L-12 sn-sto/sto-gn
8	3052	8	
Facial Reconstruction			51.62
Photograph			68.29
9	3055	9	
Facial Reconstruction			55.57
Photograph			57.14
10	2831	10	
Facial Reconstruction			49.90
Photograph			54.28
11	2996	11	
Facial Reconstruction			49.95
Photograph			58.33
12	2850	12	
Facial Reconstruction			49.67
Photograph			67.64
13	2938	14	
Facial Reconstruction			48.50
Photograph			70.00

TABLE N° 30-8

(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.005-0.002

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **L-12** sn-sto/sto-gn
14 Facial Reconstruction Photograph	3009	15	 50.79 54.28
P value 0.005<P<0.002			

TABLE N° 30-9

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P VALUE 0.002-0.001

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **O-8** ex-ex/zy-zy
1	2832	1	
Facial Reconstruction			72.59
Photographs			59.80
2	2915	2	
Facial Reconstruction			72.70
Photograph			*
3	2950	3	
Facial Reconstruction			73.80
Photograph			69.56
4	2973	4	
Facial Reconstruction			74.51
Photograph			*
5	3018	5	
Facial Reconstruction			68.59
Photograph			70.58
6	3019	6	
Facial Reconstruction			69.98
Photograph			*
7	3039	7	
Facial Reconstruction			75.78
Photograph			66.27

TABLE N° 30-9
(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.002-0.001

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index O-8 ex-ex/zy-zy
8	3052	8	
Facial Reconstruction			76.50
Photograph			70.19
9	3055	9	
Facial Reconstruction			73.03
Photograph			68.42
10	2831	10	
Facial Reconstruction			70.89
Photograph			62.50
11	2996	11	
Facial Reconstruction			68.96
Photograph			*
12	2850	12	
Facial Reconstruction			72.81
Photograph			72.22
13	2938	14	
Facial Reconstruction			76.68
Photograph			63.95

TABLE N° 30-9

(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value 0.002-0.001

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index O-8 ex-ex/zy-zy
14 Facial Reconstruction Photograph	3009	15	 74.46 70.00
P value 0.002<P<0.001			

TABLE N°30-10

Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P VALUE > 0.001

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **AL-3** sto-sl/sn-sto	Proportion Index **F-13** sto-gn/sn-gn
1	2832	1		
Facial Reconstruction			69.02	72.73
Photographs			54.54	66.17
2	2915	2		
Facial Reconstruction			79.88	63.51
Photograph			53.33	62.79
3	2950	3		
Facial Reconstruction			76.48	67.53
Photograph			*	*
4	2973	4		
Facial Reconstruction			90.21	69.85
Photograph			*	*
5	3018	5		
Facial Reconstruction			87.25	71.51
Photograph			*	*
6	3019	6		
Facial Reconstruction			69.69	65.79
Photograph			*	*
7	3039	7		
Facial Reconstruction			82.73	67.14
Photograph			64.70	64.00

TABLE N° 30-10

(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value > 0.001

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **AL-3** sto-sl/sn-sto	Proportion Index **F-13** sto-gn/sn-gn
8	3052	8		
Facial Reconstruction			72.82	66.65
Photograph			42.85	59.42
9	3055	9		
Facial Reconstruction			68.40	65.75
Photograph			62.50	58.33
10	2831	10		
Facial Reconstruction			81.93	67.42
Photograph			73.68	63.63
11	2996	11		
Facial Reconstruction			70.36	66.68
Photograph			61.90	63.15
12	2850	12		
Facial Reconstruction			72.55	66.81
Photograph			39.13	59.64
13	2938	14		
Facial Reconstruction			79.60	67.68
Photograph			64.28	58.82

TABLE N° 30-10

(continuation)
Individual Proportion Indices of Facial Reconstruction with Photographs according to P value

P Value > 0.001

N°	CASE N°	PERSONAL IDENTITY N°	Proportion Index **AL-3** sto-sl/sn-sto	Proportion Index **F-13** sto-gn/sn-gn
14 Facial Reconstruction Photograph	3009	15	73.01 63.15	66.56 63.63
P value > 0.001				

TABLE N°31
Comparison of mean of thirty Proportion Indices selected of other studies with the present study

Proportion Index		Facial Reconstruction	Photographs	Farkas 1981 (age 18)	Our own study 1993 (age 18-73)	Average Face
F-1 (n-gn/zy-zy)		90.43	90.80	88.5	86.98	83.19
F-2 (go-go/zy-zy)		87.29	88.17	70.8	88.76	90.04
F-3 (n-sto/zy-zy)		55.90	56.22	54.0	54.12	52.74
F-4 (go-go/n-gn)		96.77	98.00	80.3	102.53	108.23
F-5 (sto-gn/go-go)		41.00	39.31	51.8	38.29	34.87
F-9 (n-sto/n-gn)		61.86	61.93	61.0	62.26	63.39
F-10 (sn-gn/n-gn)		**58.50**	**61.36**	**59.2**	**58.48**	**56.93**
F-11 (sto-gn/n-gn)		39.53	37.48	41.2	38.89	37.74
F-12 (sto-gn/n-sto)		64.01	60.86	67.7	62.70	59.53
F-13 (sto-gn/sn-gn)		**67.55**	**61.96**	**69.6**	**66.50**	**66.28**
F-32 (n-sto/ex-ex		76.65	84.67	82.9	78.35	72.71
O-1 (en-en/ex-ex)		**37.48**	**39.74**	**36.8**	**38.01**	**35.59**
O-3 (en-exl/en-en)		84.56	79.40	95.4	87.21	92.22
O-8 (ex-ex/zy-zy)		**72.94**	**67.35**	**65.2**	**69.92**	**72.53**
O-9 (en-en/n-sto)		48.92	47.36	44.6	48.27	48.95
O-10 (en-en/al-al)		95.36	92.99	95.1	94.67	95.98
O-12 (en-en/ch-ch)		72.05	67.57	61.9	73.83	74.06
L-1 (sn-sto/ch-ch)		46.63	51.85	41.1	55.05	45.82
L-5 (sn-ls/sn-sto)		70.98	74.18	66.4	64.98	71.47
L-6 (ls-sto/sn-sto)		**32.34**	**25.44**	**41.1**	**39.98**	**30.61**
L-7 (ls-sto/sn-ls)		46.15	35.40	64.8	63.41	42.82
L-9 (ls-sto/sto-li)		**92.80**	**71.20**	**87.8**	**109.67**	**89.40**
L-10 (ch-ch/zy-zy)		37.96	39.25	38.9	33.53	34.86
L-11 (sn-sto/n-sto)		**31.64**	**35.42**	**29.5**	**33.88**	**30.28**
L-12 (sn-sto/sto-gn)		**49.64**	**58.76**	**43.8**	**54.06**	**50.87**
L-14 (sn-sto/n-sn)		**46.20**	**56.40**	**41.3**	**45.14**	**42.20**
N-1 (al-al/n-sn)		**74.94**	**83.95**	**65.8**	**61.27**	**71.06**
N-24 (al-al/zy-zy)		28.65	29.12	25.3	27.65	26.89
N-25 (n-sn/zy-zy)		**38.35**	**35.04**	**38.6**	**40.53**	**37.85**
N-26 (n-sn/n-gn)		**42.43**	**38.83**	**43.7**	**46.68**	**45.50**
N-27 (n-sn/n-sto)		**68.58**	**63.67**	**71.6**	**75.07**	**71.77**
N-28 (n-sn/sn-gn)		**72.61**	**64.00**	**74.1**	**79.72**	**79.91**
AL-3 (sto-sl/sn-sto)		**76.71**	**58.00**	**86.23**	**74.64**	**77.23**
Bold-type=p value < 0.05						

TABLE N° 32

Comparison of mean of measurements involved in the calculation of thirty-three proportion indices of other studies with the present study.

Measurements	Facial Reconstruction	Photographs	Farkas 1971(age 18)	Farkas 1994 (age19-25)	Our own study 1993 (age 18-73)
(n-gn/zy-zy)	116.15/ 128.74	81.00/ 91.91	121.3/ 137.1	124.7/139.1	121.47/ 139.89
(go-go/zy-zy)	112.32/ 128.74	81.64/ 91.91	97.1/ 137.1	105.6/139.1	124.29/ 139.89
(n-sto/zy-zy)	71.84/ 128.74	51.30/ 91.91	74.0/ 137.1	76.6/139.1	75.54/ 139.89
(go-go/n-gn)	112.32/ 116.15	83.85/ 81.00	97.1/ 121.3	105.6/124.7	124.29/ 121.47
(sto-gn/go-go)	45.93/ 112.32	31.20/ 81.64	50.1/ 97.1	50.7/105.6	47.35/ 121.47
(n-sto/n-gn)	71.84/ 116.15	51.30/ 81.00	74.0/ 121.3	76.6/124.7	75.54/ 124.29
(sn-gn/n-gn)	**67.93/ 116.15**	**49.50/ 81.00**	**71.9/ 121.3**	**72.6/124.7**	**71.13/ 121.47**
(sto-gn/n-gn)	45.93/ 116.15	31.20/ 81.13	50.1/ 121.3	50.7/124.7	47.35/ 121.47
(sto-gn/n-sto)	45.93/ 71.84	31.20/ 51.00	50.1/ 74.0	50.7/ 76.6	47.35/ 75.54
(sto-gn/sn-gn)	**45.93/ 67.93**	**31.20/ 49.50**	**50.1/ 71.9**	**50.7/ 72.6**	**47.35/ 71.13**
(n-sto/ex-ex)	71.84/ 93.80	51.30/ 59.45	74.0/ 89.4	76.6/ 91.2	75.54/ 96.41
(en-en/ex-ex)	**35.12/ 93.80**	**23.64/ 59.45**	**32.9/ 89.4**	**33.3/ 91.2**	**36.63/ 96.41**
(en-exl/en-en)	29.65/ 35.12	18.64/ 23.64	31.2/ 32.9	31.3/ 33.3	31.66/ 36.63
(ex-ex/zy-zy)	**93.80/ 128.74**	**59.45/ 91.91**	**89.4/ 137.1**	**91.2/139.1**	**96.41/ 139.89**
(en-en/n-sto)	35.12/ 71.84	23.64/ 51.60	32.9/ 74.0	33.3/ 76.6	36.63/ 75.54
(en-en/al-al)	35.12/ 36.84	23.64/ 26.17	32.9/ 34.7	33.3/ 34.9	36.63/ 38.69
(en-en/ch-ch)	35.12/ 48.84	23.64/ 34.87	32.9/ 53.3	33.3/ 54.5	36.63/ 46.91
(sn-sto/ch-ch)	22.68/ 48.84	18.20/ 34.87	21.8/ 53.3	22.3/ 54.5	25.60/ 46.91
(sn-ls/sn-sto)	16.09/ 22.68	13.60/ 18.20	14.8/ 21.8	15.9/ 22.3	16.70/ 25.60
(ls-sto/sn-sto)	**7.36/ 22.68**	**4.55/ 18.20**	**8.9/ 21.8**	**8.0/ 22.3**	**10.15/ 25.60**
(ls-sto/sn-ls)	7.36/ 16.09	4.55/ 13.58	8.9/ 14.8	8.0/ 15.9	10.15/ 16.70
(ls-sto/sto-li)	**67.36/ 8.10**	**4.55/ 6.35**	**8.9/ 10.4**	**8.0/ 9.3**	**10.15/ 9.52**
(ch-ch/zy-zy)	48.84/ 128.74	34.87/ 91.91	53.3/ 137.1	54.5/ 139.1	46.91/ 139.89
(sn-sto/n-sto)	**22.70/ 71.84**	**18.20/ 51.60**	**21.8/ 74.0**	**22.3/ 76.6**	**25.60/ 75.54**
(sn-sto/sto-gn)	**22.70/ 45.93**	**18.20/ 31.20**	**21.8/ 50.1**	**22.3/ 50.7**	**25.60/ 47.35**
(sn-sto/n-sn)	**22.70/ 49.28**	**18.20/ 31.64**	**21.8/ 53.0**	**22.3/ 54.8**	**25.60/ 56.71**

TABLE N° 32
(continuation)
Comparison of mean of measurements involved in the calculation of thirty-three proportion indices of other studies with the present study.

Measurements	Facial Reconstruction	Photographs	Farkas 1971(age 18)	Farkas 1994 (age19-25)	Our own study 1993 (age 18-73)
(al-al/n-sn)	**36.95/ 49.28**	**26.17/ 31.64**	**34.7/ 53.0**	**34.9/ 54.8**	**38.69/ 56.71**
(al-al/zy-zy)	36.84/ 128.74	26.17/ 91.91	34.7/ 137.1	34.9/ 139.1	38.69/ 139.89
(n-sn/zy-zy	**49.28/ 128.74**	**31.64/ 91.91**	**53.0/ 137.1**	**54.8/ 139.1**	**56.71/ 139.89**
(n-sn/n-gn)	**49.28/ 116.15**	**31.64/ 81.13**	**53.0/ 121.3**	**54.8/ 124.7**	**56.71/ 121.47**
(n-sn/n-sto)	**49.28/ 71.84**	**31.64/ 51.30**	**53.0/ 74.0**	**54.8/ 76.6**	**56.71/ 75.54**
(n-sn/sn-gn)	**49.28/ 68.00**	**31.64/ 49.50**	**53.0/ 71.9**	**54.8/ 72.6**	**56.71/ 71.13**
(sto-sl/sn-sto)	**17.38/ 22.70**	**10.25/ 18.20**	**18.8/ 21.8**	**19.7/ 22.3**	**19.11/ 25.60**
Bold-type= p value< 0.05					

TABLE N° 33
SUMMARY OF THE DISTRIBUTION OF THIRTY-THREE PROPORTION INDICES ACCORDING TO P VALUE

P VALUE RANGE	P. INDEX P VALUE	P. INDEX P VALUE	P. INDEX P VALUE	P. INDEX P VALUE	P. INDEX P VALUE	P. INDEX P VALUE	P. INDEX P VALUE
> 0.5	F-9$_{\text{-nsto-n-gn}}$ P VALUE: 0.94 T: 0.07	F-1$_{\text{n-gn/zy-zy}}$ P VALUE: 0.90 T: 0.12	F-3$_{\text{n-sto/zy-zy}}$ P VALUE: 0.86 T: 0.19	F-4$_{\text{go-go/n-gn}}$ P VALUE: 0.74 T:0.33	F-2$_{\text{go-go/zy-zy}}$ P VALUE: 0.57 T: 0.58	O-9$_{\text{en-en/n-sto}}$ P VALUE: 0.55 T:-0.62	F-5$_{\text{sto-gn/go-go}}$ P VALUE: 0.52 T: -0.66
0.5-0.2	N-24$_{\text{al-al/zy-zy}}$ P VALUE: 0.44 T: 0.79	O-10$_{\text{en-en/al-al}}$ P VALUE: 0.39 T:-0.89	L-10$_{\text{ch-ch/zy-zy}}$ P VALUE: 0.29 T:1.13	F-12$_{\text{sto-gn/n-sto}}$ P VALUE: 0.27 T: -1.16			
0.2-0.1	L-5$_{\text{sn-ls/sn-sto}}$ P VALUE: 0.27 T:-1.14	O-3$_{\text{en-ex l/en-en}}$ P VALUE: 0.16 T: -1.45	O-12$_{\text{en-en/ch-ch}}$ P VALUE: 0.15 T:-1.59				
0.1-0.05	L-1 $_{\text{sn-sto/ch-ch}}$ P VALUE: 0.095 T:1.89	F-11$_{\text{sto-gn/n-gn}}$ P VALUE: 0.084 T: -1.87					
0.05-0.02	L-7 $_{\text{ls-sto/sn-ls}}$ P VALUE: 0.038 T: -2.27	O-1$_{\text{en-en/ex-ex}}$ P VALUE: 0.037 T:2.30	F-32$_{\text{n-sto/ex-ex}}$ P VALUE: 0.035 T: 2.54	F-10$_{\text{sn-gn/n-gn}}$ P VALUE: 0.026 T:2.47	L-14 $_{\text{sn-sto/n-sn}}$ P VALUE: 0.020 T:-2.83		
0.02-0.01	L-9$_{\text{ls-sto/sto-li}}$ P VALUE: 0.018 T: -2.56	N-25$_{\text{n-sn/zy-zy}}$ P VALUE: 0.017 T: -2.65	N-27$_{\text{n-sn/n-sto}}$ P VALUE: 0.017 T: -2.86	N-28$_{\text{n-sn/sn-gn}}$ P VALUE: 0.017 T: -2.66	L-11$_{\text{sn-sto/n-sto}}$ P VALUE: 0.015 T: 2.93	L-6 $_{\text{ls-sto/sn-sto}}$ P VALUE: 0.014 T: -2.81	
0.01-0.005	N-1$_{\text{al-al/n-sn}}$ P VALUE: 0.0099 T: 2.98	N-26$_{\text{n-sn/n-gn}}$ P VALUE: 0.0066 T: -3.10					
0.005-0.002	L-12 $_{\text{sn-sto/sto-gn}}$ P VALUE: 0.0035 T: 3.62						
0.002-0.001	O-8$_{\text{ex-ex/zy-zy}}$ P VALUE: 0.0019 T: -3.81						
> 0.001	AL-3$_{\text{sto-al/sn-sto}}$ P VALUE: 0.0002 T: -4.87	F-13$_{\text{sto-gn/sn-gn}}$ P VALUE: 0.0001 T: -5.28					

APPENDIX 10
THE 1993STUDY
TABLES

FACE

TABLE 1 PROPORTION INDICES SELECTED

1) Facial Index (F1)
2) Mandible-Face Width Index (F2)
3) Upper Face Index (F3)
4) Mandible Width -Face Height Index (F4)
5) Mandibular Index (F5)
6) Mandible Width-Lower Face Depth Index (F6)
7) Face Height Index (F8)
8) Upper Face-Face Height Index (F9)
9) Lower Face-Face Height Index (F10)
10) Mandible-Face Height Index (F11)
11) Mandible-Upper Face Height Index (F12)
12) Mandible-Lower Height Index (F13)
13) Upper Face Height-Upper Third Face Depth Index (F14)
14) Mandible Height-Lower Third Face Depth Index (F15)
15) Upper-Middle Third Face Depth Index (F20)
16) Middle-Lower Third Face Depth Index (F21)
17) Mandible Width Total-Face Height Index (F28)

TABLE 2 MALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	MEAN	SD	+1SD	+2SD
SINGLE HORIZONTAL						
1.Width of the face(zy-zy)	125.07	132.48	139.89	7.41	147.3	154.71
2.Width of the lower face (go-go)	103.83	114.06	124.29	10.23	134.52	144.75
SINGLE VERTICAL						
3.Physiognomical height of the face (tri-gn)	158.13	172.39	186.65	14.26	200.91	215.17
4.Morphological height of the face (n-gn)	107.39	114.43	121.47	7.04	128.51	135.55
5.Phisiognomical height of the upper face (n-sto)	68.54	72.04	75.54	3.50	79.04	82.04
6.Height of the lower face (sn-gn)	58.75	64.94	71.13	6.19	77.32	83.51
7.Height of the lower third of the face (sto-gn)	37.27	42.31	47.35	5.04	52.39	57.43
PAIRED HORIZONTAL						
8.Depth of the upper third of the face (n-t)						
Left Side	107.63	112.77	117.91	5.14	123.05	128.19
Right Side	109.38	114.67	119.96	5.29	125.25	130.54
9.Depth of the middle third of the face (sn-t)						
Left Side	116.47	121.55	126.63	5.08	131.71	136.79
Right Side	117.86	123.43	129.00	5.57	134.57	140.14
10.Depth of the lower third of the face (gn-t)						
Left Side	134.08	141.39	148.70	7.31	156.01	163.32
Right Side	135.00	142.43	149.86	7.43	157.29	164.72
11.Depth of the lower jaw (gn-go)						
Left Side	89.99	97.86	105.73	7.87	113.6	121.47
Right Side	93.81	101.13	108.45	7.32	115.77	123.09

TABLE 3 FEMALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	MEAN	SD	+1SD	+2SD
SINGLE HORIZONTAL						
1.Width of the face(zy-zy)	115.9	122.76	129.62	6.86	136.48	143.34
2.Width of the lower face (go-go)	95.34	102.7	110.06	7.36	117.42	124.78
SINGLE VERTICAL						
3.Physiognomical height of the face(tri-gn)	160.08	169.65	178.92	9.42	188.34	197.76
4.Morphological height of the face(n-gn)	99.24	103.72	108.20	4.48	112.68	117.16
5.Physiognomical height of the upper face (n-sto)	61.21	64.23	68.05	3.42	71.47	74.89
6.Height of the lower face (sn-gn)	54.73	58.46	62.19	3.73	65.92	69.65
7.Height of the lower third of the face(sto-gn)	35.46	38.18	40.90	2.72	43.62	46.34
PAIRED HORIZONTAL						
8.Depth of the third of the face (n-t)						
Left Side	99.61	104.49	109.37	4.88	114.25	119.13
Right Side	101.16	106.00	110.84	4.84	115.68	120.52
9.Depth of the middle third of the face (sn-t)						
Left Side	107.21	112.42	117.63	5.21	122.84	128.05
Right Side	108.69	113.87	119.05	5.18	124.23	129.41
10.Depth of the lower third of the face (gn-t)						
Left Side	124.17	130.43	136.69	6.26	142.95	149.21
Right Side	126.36	131.93	137.50	5.57	143.07	148.64
11. Depth of the lower jaw (gn-go)						
Left Side	88.93	94.84	100.75	5.91	106.66	112.57
Right Side	81.61	89.44	97.27	7.83	105.1	112.93

TABLE 4 COMPARATIVE ANALYSIS OF MEASUREMENTS BETWEEN MALES AND FEMALES

Measure	Male mm	Female mm	Absolute Difference mm	Percentage %
SINGLE HORIZONTAL				
1. Width of the face(zy-zy)	139.89	129.62	10.27	7.34
2. Width of the lower face (go-go)	124.29	110.06	14.23	11.44
SINGLE VERTICAL				
3. Physiognomical height of the face (tri-gn)	186.65	178.92	7.73	4.14
4. Morphological height of the face (n-gn)	121.47	108.20	13.27	10.92
5. Physiognomical height of the upper face (n-sto)	75.54	62.19	7.49	9.91
6. Height of the lower face (sn-gn)	71.13	62.19	8.94	12.56
7. Height of the lower third of the face (sto-gn)	47.35	40.90	6.45	13.62
PAIRED HORIZONTAL				
8. Depth of the upper third of the face (n-t)				
Left Side	117.91	109.37	8.54	7.24
Right Side	119.96	110.84	9.12	7.60
9. Depth of the middle third of the face (sn-t)				
Left Side	126.63	117.63	9.00	7.10
Right Side	129.00	119.05	9.95	7.71
10. Depth of the lower third of the face (gn-t)				
Left Side	148.70	136.69	12.01	8.07
Right Side	149.86	137.50	12.36	8.24
11. Depth of the lower jaw (gn-go)				
Left Side	105.73	100.75	4.98	4.71
Right Side	108.45	97.27	11.18	10.30

TABLE 5 MALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

INDEX	-2SD	-1SD	MEAN	SD	+1SD	+2SD
F-1	75.84	81.41	86.98	5.57	92.55	98.12
F-2	80.62	84.69	88.76	4.07	92.83	96.9
F-3	47.86	50.99	54.12	3.13	57.25	60.38
F-4	84.43	93.48	102.53	9.05	111.58	120.63
F-5	28.73	33.51	38.29	4.78	43.07	47.85
F-6	72.01	77.8	83.59	5.79	89.38	95.17
F-8	57.06	61.17	65.28	4.11	69.39	73.5
F-9	57.48	59.87	62.26	2.39	64.65	67.04
F-10	53.34	55.91	58.48	2.57	61.05	63.62
F-11	33.87	36.38	38.89	2.51	41.4	43.91
F-12	50.14	56.42	62.70	6.28	68.98	75.26
F-13	60.18	63.34	66.50	3.16	69.66	72.82
F-14	57.98	61.05	64.12	3.07	67.19	70.26
F-15	25.94	28.88	31.82	2.94	34.76	37.7
F-20	88.31	90.79	93.27	2.48	95.75	98.23
F-21	79.72	82.4	85.08	2.68	87.76	90.44
F-28	53.88	60.37	66.86	6.49	73.35	79.84

TABLE 6 FEMALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

INDEX	-2SD	-1SD	MEAN	SD	+1SD	+2SD
F-1	73.3	78.48	83.66	5.18	88.84	94.02
F-2	78.28	81.59	84.90	3.31	88.21	91.52
F-3	45.11	48.87	52.63	3.76	56.39	60.15
F-4	87.77	94.8	101.83	7.03	108.86	115.89
F-5	31.38	34.32	37.26	2.94	40.2	43.14
F-6	71.04	75.8	80.56	4.76	85.32	90.08
F-8	55.45	58.0	60.55	2.55	63.1	65.65
F-9	59.21	61.05	62.89	1.84	64.73	66.57
F-10	52.47	54.97	57.47	2.50	59.97	62.47
F-11	33.8	35.8	37.80	2.00	39.8	41.8
F-12	50.52	55.38	60.24	4.86	65.1	69.96
F-13	59.8	62.8	65.80	3.00	68.8	71.8
F-14	54.92	58.61	62.30	3.69	65.99	69.68
F-15	26.24	28.09	29.94	1.85	31.79	33.64
F-20	87.29	90.15	93.01	2.86	95.87	98.73
F-21	80.22	83.16	86.10	2.94	89.04	91.98
F-28	51.83	56.74	61.65	4.91	66.56	71.47

ORBITS

TABLE 1 PROPORTION INDICES SELECTED

1) Intercanthal Index (O-1)
2) Orbital width Index(O-3)
3) Biocular-Skull base width Index (O-5)
4) Intercanthal-Skull base width Index (O-6)
5) Intercanthal-Forehead Index (0-7)
6) Biocular-Face width Index (O-8)
7) Intercanthal width-Upper face height Index (O-9)
8) Intercanthal-Mouth width Index (O-12)
9) Orbital height Index (AO-1)
10) Orbit Eyebrow height Index (AO-2)
11) Upper face height Index (F-32)

TABLE 2 MALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	MEAN	SD	+1SD	+2SD
SINGLE HORIZONTAL						
1. Supraorbital diameter (fs-fs)	102.09	108.13	114.17	6.04	120.21	126.25
2. Intercanthal width(en-en)	29.69	33.16	36.63	3.47	40.1	43.57
3. Biocular width (ex-ex)	85.31	90.86	96.41	5.55	101.96	107.51
PAIRED HORIZONTAL						
4. Supraorbital half diameter (fs-g)						
Left Side	60.31	65.01	69.71	4.70	74.41	79.11
Right Side	61.16	65.41	69.66	4.25	73.91	78.16
5. Orbito-aural distance (ex-obs)						
Left Side	65.97	72.17	78.37	6.20	84.57	90.77
Right Side	65.39	71.44	77.49	6.05	83.54	89.59
6. Orbito tragion distance (ex-t)						
Left Side	61.76	67.08	72.40	5.32	77.72	83.04
Right Side	61.73	67.33	72.93	5.60	78.53	84.13
7. Orbito gonial distance (ex-go)						
Left Side	78.86	84.98	91.10	6.12	97.22	103.34
Right Side	79.74	85.83	91.92	6.09	98.01	104.1
8. Orbito glabellar distance (ex-g)						
Left Side	51.42	55.23	59.04	3.81	62.85	66.66
Right Side	50.92	54.94	58.96	4.02	62.98	67.00
9. Endocanthion facial midline distance (en-m)						
Left Side	22.2	25.0	27.80	2.80	30.6	33.4
Right Side	20.47	23.65	26.83	3.18	30.01	33.19
10.Eye fissure width (en-ex)						
Left Side	25.94	28.8	31.66	2.86	34.52	37.38
Right Side	25.53	28.66	31.79	3.13	34.92	38.05
PAIRED VERTICAL						
11.Orbit height (os-or)						
Left Side	28.00	31.41	34.82	3.41	38.23	41.64
Right Side	26.46	29.64	32.82	3.18	36.0	39.18
12.Eyebrow height (sci-or)						
Left Side	33.91	38.14	42.37	4.23	46.6	50.83
Right Side	34.58	38.24	41.90	3.66	45.56	49.22

TABLE 3 FEMALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	MEAN	SD	+1SD	+2SD
SINGLE HORIZONTAL						
1.Supraorbital diameter (fs-fs)	94.83	100.35	105.87	5.52	111.39	116.91
2.Intercanthal width (en-en)	25.59	28.59	31.59	3.00	34.59	37.59
3.Biocular width(ex-ex)-	82.71	87.62	92.53	4.91	97.44	102.35
PAIRED HORIZONTAL						
4.Supraorbital half diameter (fs-g)						
Left Side	52.02	56.56	61.10	4.54	65.64	70.18
Right Side	53.83	57.97	62.11	4.14	66.25	70.39
5.Orbito aural distance (ex-obs)						
Left Side	63.37	68.64	73.91	5.27	79.18	84.45
Right Side	60.93	66.69	72.45	5.76	78.21	83.97
6.Orbito tragion distance (ex-t)						
Left Side	62.54	68.05	73.56	5.51	79.07	84.58
Right Side	62.05	66.68	71.31	4.63	75.94	80.57
7.Orbito gonial distance (ex-go)						
Left Side	74.26	79.1	83.94	4.84	88.78	93.62
Right Side	74.81	80.11	85.41	5.30	90.71	96.01
8.Orbito glabellar distance (ex-g)						
Left Side	49.3	52.53	55.76	3.23	58.99	62.22
Right Side	51.39	54.37	57.35	2.98	60.33	63.31
9.Endocanthion facial midline distance (en m)						
Left Side	18.42	20.79	23.16	2.37	25.53	27.9
Right Side	18.81	21.45	24.09	2.64	26.73	29.37
10.Eye fissure width (en-ex)						
Left Side	28.29	30.11	31.93	1.82	33.75	35.57
Right Side	27.85	29.86	31.87	2.01	33.88	35.89
PAIRED VERTICAL						
11.Orbit height (os-or)						
Left Side	25.58	28.66	31.74	3.08	34.82	37.9
Right Side	24.74	27.94	31.14	3.20	34.34	37.54
12.Eyebrow height (sci-or)						
Left Side	30.36	34.0	37.64	3.64	41.28	44.92
Right Side	30.73	34.06	37.39	3.33	40.72	44.05

TABLE 4 COMPARATIVE ANALYSIS OF MEASUREMENTS BETWEEN MALES AND FEMALES

Measure	Male mm	Female mm	Absolute Difference mm	Percentage %
SINGLE HORIZONTAL				
1. Supraorbital diameter (fs-fs)	114.17	105.87	8.3	7.26
2. Intercanthal width (en-en)	36.63	31.59	5.04	13.75
3. Biocular width (ex-ex)	96.41	92.53	3.88	4.02
PAIRED HORIZONTAL				
4. Supraorbital half diameter (fs-g)				
Left Side	69.71	61.10	8.61	12.35
Right Side	69.66	62.11	7.55	10.83
5. Orbito-aural distance (ex-obs)				
Left Side	78.37	73.91	4.46	5.69
Right Side	77.49	72.45	5.04	6.50
6. Orbito-tragion distance (ex-t)				
Left Side	72.40	73.56	1.16	1.57
Right Side	67.33	66.68	0.65	0.96
7. Orbito-gonial distance (ex-go)				
Left Side	91.10	83.94	7.16	7.85
Right Side	91.92	85.41	6.51	7.08
8. Orbito-glabellar distance (ex-g)				
Left Side	59.04	55.76	3.28	5.55
Right Side	58.96	57.35	1.61	2.73
9. Endocanthion-facial midline distance (en-m)				
Left Side	27.80	23.16	4.64	16.69
Right Side	26.83	24.09	2.74	10.21
10.Eye fissure width (en-ex)				
Left Side	31.66	31.93	0.27	0.84
Right Side	31.79	31.87	0.08	0.25
PAIRED VERTICAL				
11.Orbit height (os-or)				
Left Side	34.82	31.74	3.08	8.84
Right Side	32.82	31.14	1.68	5.11
12.Eyebrow height (sci-or)				
Left Side	42.37	37.64	4.73	11.16
Right Side	41.90	37.39	4.51	10.76

TABLE 5 MALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

INDEX	-2SD	-1SD	MEAN	SD	+1SD	+2SD
O-1	31.77	34.89	38.01	3.12	41.13	44.25
O-3	63.31	75.26	87.21	11.95	99.16	111.11
O-5	63.15	66.82	70.49	3.67	74.16	77.83
O-6	22.47	24.61	26.75	2.14	28.89	31.03
O-7	23.69	26.36	29.03	2.67	31.7	34.37
O-8	62.64	66.28	69.92	3.64	73.56	77.2
O-9	38.83	43.55	48.27	4.72	52.99	57.71
O-12	51.63	62.73	73.83	11.10	84.93	96.03
AO-1	81.89	96.33	110.77	14.44	125.21	139.65
AO-2	70.21	76.31	82.41	6.10	88.51	94.61
F-32	68.29	73.66	79.03	5.37	84.4	89.77

TABLE 6 FEMALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

INDEX	-2SD	-1SD	MEAN	SD	+1SD	+2SD
O-1	28.81	31.47	34.13	2.66	36.79	39.45
O-3	78.8	90.39	101.98	11.59	113.57	125.16
O-5	66.29	69.56	72.83	3.27	76.1	79.37
O-6	19.89	22.39	24.89	2.50	27.39	29.89
O-7	20.53	23.32	26.11	2.79	28.9	31.69
O-8	65.57	68.7	71.83	3.13	74.96	78.09
O-9	35.24	40.52	45.80	5.28	51.08	56.36
O-12	51.5	59.05	66.60	7.55	74.15	81.70
AO-1	76.9	88.31	99.72	11.41	111.13	122.54
AO-2	72.93	78.6	84.27	5.67	89.94	95.61
F-32	63.89	69.44	74.99	5.55	80.54	86.09

NOSE

TABLE 1 PROPORTION INDICES SELECTED

1. Nasal Index (N-1)
2. Nasal root-nose width Index (N-2)
3. Nostril-Nose width Index (N-4)
4. Nostril width -Nose Height Index (N-5) (
5. Nasal root-Nose Height Index (N-13)
6. Nasal root-Intercanthal width Index (N-30)
7. Nasal bridge Index (AN-1)
8. Intercanthal-Nasal width Index (O-10)
9. Nasal root Index (O-11).

TABLE 2 MALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	MEAN	SD	+1SD	+2SD
1. Width of the nasal root (mf-mf)	17.89	20.36	22.83	2.47	25.30	27.77
2. Width of the nose (al-al)	32.45	35.57	38.69	3.12	41.81	44.93
3. Intercanthal width (en-en)	28.95	32.92	36.89	3.97	40.86	44.83
4. Nose height (n-sn)	50.5	53.38	56.71	3.33	60.04	63.37
5. Nasal bridge length (n-prn)	41.82	45.02	48.22	3.20	51.42	54.62
6. Width of the nostril floor (sbal-sn)						
Right Side	5.7	8.82	11.94	3.12	15.06	18.18
Left Side	6.1	8.96	11.82	2.86	14.68	17.64
7. Nasal root length (en-m)						
Right Side	19.86	23.07	26.28	3.21	29.49	32.7
Left Side	21.26	24.38	27.50	3.12	30.62	33.74

TABLE 3 FEMALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	MEAN	SD	+1SD	+2SD
1. Width of the nasal root (mf-mf)	15.5	17.91	20.32	2.41	22.73	25.14
2. Width of the nose (al-al)	24.61	27.34	30.07	2.73	32.8	35.53
3. Intercanthal width (en-en)	26.28	29.9	33.52	3.62	37.14	40.76
4. Nose height (n-sn)	43.29	46.81	50.33	3.52	53.85	57.37
5. Nasal bridge length (n-prn)	35.25	38.89	42.53	3.64	46.17	49.81
6. Width of the nostril floor (sbal-sn)						
Right Side	7.22	10.25	13.28	3.03	16.31	19.34
Left Side	6.57	9.56	12.55	2.99	15.54	18.53
7. Nasal root length (en-m)						
Right Side	17.41	20.27	23.13	2.86	25.99	28 85
Left Side	18.12	20.84	23.56	2.72	26.28	29.00

TABLE 4 COMPARATIVE ANALYSIS OF MEASUREMENTS BETWEEN MALES AND FEMALES

Measure	Male mm	Female mm	Absolute Difference mm	Percentage %
1. Width of the nasal root	22.83	20.32	2.51	10.99
2. Width of the nose	38.69	30.07	8.62	22.27
3. Intercanthal width.	36.89	33.52	3.37	9.13
4. Nose height	56.71	50.33	6.38	11.25
5. Nasal bridge length	48.22	42.53	5.69	11.80
6. Width of the nostril floor				
Right Side	11.94	13.28	1.34	10.09*
Left Side	11.82	12.55	0.73	5.81*
7. Nasal root length				
Right Side	26.28	23.13	3.15	11.98
Left Side	27.50	23.56	3.94	14.32

* greater in females

TABLE 5 MALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

INDEX	-2SD	-1SD	MEAN	SD	+1SD	+2SD
N-1	48.31	54.79	61.27	6.48	67.75	74.23
N-2	49.1	57.73	66.36	8.63	74.99	83.62
N-4	42.73	55.32	67.91	12.59	80.05	93.09
N-5	12.37	16.42	20.47	4.05	24.52	28.57
N-13	36.96	42.68	48.40	5.72	54.12	59.84
N-30	48.59	55.41	62.23	6.82	69.05	75.87
AN-1	73.3	78.35	83.4	5.05	88.45	93.5
O-10	79.55	93.41	107.27	13.86	121.13	134.99
O-11	58.14	63.56	68.98	5.42	74.4	79.82

TABLE 6 FEMALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

INDEX	-2SD	-1SD	MEAN	SD	+1SD	+2SD
N-1	49.56	55.35	61.14	5.79	66.93	72.72
N-2	48.97	57.85	66.73	8.88	75.61	84.49
N-4	54.31	70.25	86.19	15.94	102.13	118.07
N-5	14.76	20.05	25.34	5.29	30.63	35.92
N-13	33.11	40.11	47.11	7.00	54.11	61.11
N-30	44.39	52.16	59.93	7.77	67.7	75.47
AN-1	76.21	80.35	84.49	4.14	88.63	92.77
O-10	79.03	95.71	112.39	16.68	129.07	145.75
O-11	60.45	66.26	72.07	5.81	77.88	83.69

MOUTH

TABLE 1 PROPORTION INDICES SELECTED

1. Upper lip height-mouth width index (L-1)
2. Mouth width contour index (L-2)
3. Philtrum-mouth width index (L-3)
4. Medial-lateral cutaneous upper lip height index (L-4)
5. Cutaneous-total upper lip height index (L-5)
6. Vermilion-total upper lip height index (L-6)
7. Vermilion-cutaneous upper lip height index (L-7)
8. Upper lip vertical contour index (L-8)
9. Vermilion height index (L-9)
10. Lower-upper lip height index (AL-3)
11. Cutaneous lower-upper lip height index (AL-4)
12. Vermilion-total lower lip height index (AL-5)
13. Vermilion-cutaneous lower lip height index (AL-6)
14. Cutaneous-total lower lip height index (AL-7)

TABLE 2 MALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	Mean	SD	+1SD	+2SD
1. Width of the mouth (chr-chl)	36.89	41.90	46.91	5.01	51.92	56.93
2. Philtrum width (cphr-cphl)	7.09	8.21	9.33	1.12	10.45	11.57
3. Medial height of the cutaneous upper lip (sn-ls)	10.94	13.82	16.70	2.88	19.58	22.46
4. Medial vertical upper lip length (sn-sto)	18.82	22.21	25.60	3.39	28.99	32.38
5. Medial vermilion height of the upper lip (ls-sto)	6.19	8.17	10.15	1.98	12.13	14.11
6. Medial vermilion height of the lower lip (sto-li)	5.54	7.53	9.52	1.99	11.51	13.5
7. Medial height of the cutaneous lower lip (li-sl)	6.84	9.32	11.80	2.48	14.28	16.76
8. Medial vertical lower lip length (sto-sl)	13.01	16.06	19.11	3.05	22.16	25.21
9. Width of the half mouth (ch-sto)						
Right side	19.25	23.09..	26.93	3.84	30.77	34.61
Left side	18.19	22.10	26.01	3.91	29.92	33.83
10. Lateral vertical upper lip height (sbal-ls)						
Right side	12.45	15.57	18.69	3.12	21.81	24.93
Left side	12.02	15.51	19.00	3.49	22.49	25.98

TABLE 3 FEMALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	Mean	SD	+1SD	+2SD
1. Width of the mouth (chr-chl)	35.26	38.57	41.88	3.31	45.19	48.5
2. Philtrum width (cphr-cphl)	6.97	8.00	9.03	1.03	10.06	11.09
3. Medial height of the cutaneous upper lip (sn-ls)	9.22	11.15	13.08	1.93	15.01	16.94
4. Medial vertical upper lip length (sn-sto)	16.58	19.1	21.62	2.52	24.14	26.66
5. Medial vermilion height of the upper lip (ls-sto)	6.02	7.74	9.46	1.72	11.18	12.9
6. Medial vermilion height of the lower lip (sto-li)	5.7	7.37	9.04	1.67	10.71	12.38
7. Medial height of the cutaneous lower lip (li-sl)	6.87	8.75	10.63	1.88	12.51	14.39
8. Medial vertical lower lip length (sto-sl)	14.13	15.9	17.67	1.77	19.44	21.21
9. Width of the half mouth (ch-sto)						
Right side	18.09	21.06	24.03	2.97	27.00	29.97
Left side	16.8	19.77	22.74	2.97	25.71	28.68
10. Lateral vertical upper lip height (sbal-ls)						
Right side	11.59	13.6	15.61	2.01	17.62	19.63
Left side	12.51	14.29	16.07	1.78	17.85	19.63

TABLE 4 COMPARATIVE ANALYSIS OF MEASUREMENTS BETWEEN MALES AND FEMALES

Measure	Male mm	Female mm	Absolute Difference mm	Percentage %
1. Width of the mouth	46.91	41.88	5.03	10.72
2. Philtrum width	9.33	9.03	0.3	3.21
3. Medial height of the cutaneous upper lip	16.70	13.08	3.62	21.67
4. Medial vertical upper lip length	25.60	21.62	3.98	15.54
5. Medial vermilion height of the upper lip	10.15	9.46	0.69	6.79
6. Medial vermilion height of the lower lip	9.52	9.04	0.48	5.04
7. Medial height of the cutaneous lower lip	11.80	10.63	1.17	9.91
8. Medial vertical lower lip length	19.11	17.67	1.44	7.53
9. width of the half mouth				
Rigth side	26.93	24.03	2.9	10.76
Left side	26.01	22.74	3.27	12.57
10. Lateral vertical upper lip height				
Right side	18.69	15.61	3.08	16.47
Left side	19.00	16.07	2.93	15.42

TABLE 5 MALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

Index	-2SD	-1SD	Mean	SD	+1SD	+2SD
L-1	37.67	46.36	55.05	8.69	63.74	72.43
L-2	82.63	85.93	89.23	3.30	92.53	95.83
L-3	15.33	17.66	19.99	2.33	22.32	24.65
L-4	69.71	78.90	88.09	9.19	97.28	106.47
L-5	52.02	58.50	64.98	6.48	71.46	77.94
L-6	24.46	32.22	39.98	7.76	47.74	55.50
L-7	25.15	44.28	63.41	19.13	82.54	101.67
L-8	89.56	92.45	95.34	2.89	98.23	101.12
L-9	60.59	85.13	109.67	24.54	134.21	158.75
AL-3	50.26	62.80	75.34	12.54	87.88	100.42
AL-4	41.04	56.56	72.08	15.52	87.60	103.12
Al-5	31.44	40.85	50.26	9.41	59.67	69.08
Al-6	34.66	59.41	84.16	24.75	108.91	133.66
Al-7	46.46	54.11	61.76	7.65	69.41	77.06

TABLE 6 FEMALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

Index	-2SD	-1SD	Mean	SD	+1SD	+2SD
L-1	37.5	44.51	51.92	7.01	58.93	65.94
L-2	82.74	86.32	89.90	3.58	93.48	97.06
L-3	15.95	18.8	21.65	2.85	24.5	27.35
L-4	65.3	73.88	82.46	8.58	91.04	99.62
L-5	50.88	55.64	60.40	4.76	65.16	69.92
L-6	31.35	37.57	43.79	6.22	50.01	56.23
L-7	43.45	58.51	73.57	15.06	88.63	103.69
L-8	89.77	92.92	96.07	3.15	99.22	102.37
L-9	65.57	86.15	106.63	20.48	127.11	147.59
AL-3	59.02	70.9	82.74	11.88	94.62	106.5
AL-4	48.58	65.3	82.02	16.72	98.74	115.46
Al-5	31.22	41.37	51.52	10.15	61.67	71.82
AL-6	36.75	62.94	89.13	26.19	115.32	141.51
AL-7	45.76	52.6	59.44	6.84	66.28	73.12

EAR

TABLE 1 PROPORTION INDICES SELECTED

1) Ear Index (E-1)
2) Ear Height Index (E-2)
3) Ear Width -Temple Index(E-3)
4) Ear-Face Height Index (E-5)
5) Ear-Lower Face Height Index (E-6)

TABLE 2 MALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	MEAN	SD	+1SD	+2SD
PAIRED HORIZONTAL						
1. Upper naso-aural distance (n-obs)						
Left Side	102.86	108.93	115.0	6.07	121.07	127.14
Right Side	102.16	108.3	114.44	6.14	120.58	126.72
2. Lower naso-aural distance (n-obi)						
Left Side	106.5	111.7	116.90	5.20	122.1	127.3
Right Side	107.1	112.67	118.24	5.57	123.81	129.38
3. Upper subnasale-aural distance (sn-obs)						
Left Side	116.23	122.56	128.89	6.33	135.22	141.55
Right Side	114.85	121.52	128.19	6.67	134.86	141.53
4. Lower subnasale- aural distance (sn-obi)						
Left Side	101.41	106.94	112.47	5.53	118.0	123.53
Right Side	101.78	108.02	114.26	6.24	120.5	126.74
5. Upper gnathion-aural distance (gn-obs)						
Left Side	139.34	145.92	152.50	6.58	159.08	165.66
Right Side	137.44	144.41	151.38	6.97	158.35	165.32
6. Lower gnathion-aural distance (gn-obi).						
Left Side	104.45	110.69	116.93	6.24	123.17	129.41
Right Side	105.81	112.05	118.29	6.24	124.53	130.77
7. Width of the auricle (pra-pa)						
Left Side	25.07	28.65	32.23	3.58	35.81	39.39
Right Side	24.57	28.33	32.09	3.76	35.85	39.61
PAIRED VERTICAL						
8. Length of the auricle (sa-sba)						
Left Side	50.97	54.99	59.01	4.02	63.03	67.05
Right Side	50.21	54.38	58.55	4.17	62.72	66.89
9. Morphological width of the auricle (obs-obi)						
Left Side	40.61	44.17	47.73	3.56	51.29	54.85
Right Side	40.11	43.49	46.87	3.38	50.25	53.63

TABLE 3 FEMALE : STATISTICAL DISTRIBUTION OF THE MEASUREMENTS

Measure	-2SD	-1SD	MEAN	SD	+1SD	+2SD
PAIRED HORIZONTAL						
1. Upper naso-aural distance (n-obs)						
Left Side	112.03	118.7	125.37	6.67	132.04	138.71
Right Side	113.47	118.95	124.43	5.48	129.91	135 39
2. Lower naso-aural distance (n-obi)						
Left Side	115.94	121.86	127.78	5.92	133.7	139.62
Right Side	116.6	122.55	128.50	5.95	134.45	140.4
3. Upper subnasale- aural distance (sn-obs)						
Left Side	128.51	134.74	140.97	6.23	147.2	153.43
Right Side	129.71	135.39	141.07	5.68	146.75	152.43
4. Lower subnasale- aural distance (sn-obi)						
Left Side	109.97	115.78	121.59	5.81	127.4	133.21
Right Side	111.41	117.44	123.47	6.03	129.5	135.53
5. Upper gnathion- aural distance (gn-obs)						
Left Side	153.13	160.5	167.87	7.37	175.24	182.61
Right Side	153.18	160.77	168.36	7.59	175.95	183.54
6. Lower gnathion- aural distance (gn-obi)						
Left Side	112.19	119.23	126.27	7.04	133.31	140.35
Right Side	114.26	121.3	128.34	7.04	135.38	142.42
7. Width of the auricle (pra-pa)						
Left Side	25.76	29.95	34.14	4.19	38.33	42.52
Right Side	26.99	30.55	34.11	3.56	37.67	41.23
PAIRED VERTICAL						
8. Length of the auricle (ear height) (sa-sba)						
Left Side	54.89	59.9	64.91	5.01	69.92	74.93
Right Side	54.78	59.15	63.52	4.37	67.89	72.26
9. Morphological width of the ear (ear insertion height) (obs-obi)						
Left Side	46.62	50.58	54.54	3.96	58.5	62.46
Right Side	46.48	50.23	53.98	3.75	57.73	61.48

TABLE 4 COMPARATIVE ANALYSIS OF MEASUREMENTS BETWEEN MALES AND FEMALES

Measure	Male mm	Female mm	Absolute Difference mm	Percentage %
PAIRED HORIZONTAL				
1. Upper naso-aural distance (n-obs)				
Left Side	125.37	115.0	10.37	8.27
Right Side	124.43	114.44	9.99	8.02
2. Lower naso-aural distance (n-obi)				
Left Side	127.78	116.90	10.88	8.51
Right Side	128.50	118.24	10.26	7.98
3. Upper subnasale-aural distance (sn-obs)				
Left Side	140.97	128.89	9.12	7.50
Right Side	141.07	128.19	12.88	9.13
4. Lower subnasale-aural distance (sn-obi)				
Left Side	121.59	112.47	9.12	7.50
Right Side	123.47	114.26	9.21	7.45
5. Upper gnathion-aural distance (gn-obs)				
Left Side	167.87	152.50	15.37	9.15
Right Side	168.36	151.38	16.98	10.08
6. Lower gnathion-aural distance (gn-obi)				
Left Side	126.27	116.93	9.34	7.39
Right Side	128.34	118.29	10.05	7.83
7. Width of the auricle (pra-pa)				
Left Side	34.14	32.23	1.91	5.59
Right Side	34.11	32.09	2.02	5.92
PAIRED VERTICAL				
8. Length of the auricle (ear Height) (sa-sba)				
Left Side	64.91	59.01	5.9	9.08
Right Side	63.52	58.55	4.97	7.82
9. Morphological width of the ear (ear insertion height) (obs-obi)				
Left Side	54.54	47.73	6.81	12.48
Right Side	53.98	46.87	7.11	13.17

TABLE 5 MALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

INDEX	-2SD	-1SD	MEAN	SD	+1SD	+2SD
E-1	40.62	46.67	52.72	6.05	58.77	64.82
E-2	76.71	80.42	84.13	3.71	87.84	91.55
E-3	33.28	38.91	44.54	5.63	50.17	55.8
E-5	43.56	48.2	52.84	4.64	57.48	62.12
E-6	70.87	80.76	90.65	9.89	100.54	110.43

TABLE 6 FEMALE : PROPORTION INDICES SELECTED. STATISTICAL DISTRIBUTION OF THE PROPORTION INDICES

INDEX	-2SD	-1SD	MEAN	SD	+1SD	+2SD
E-1	42.32	48.54	54.76	6.22	60.98	67.2
E-2	69.79	75.41	81.03	5.62	86.65	92.27
E-3	34.7	40.1	45.50	5.40	50.9	56.3
E-5	45.83	49.77	53.71	3.94	57.65	61.59
E-6	73.56	82.74	91.92	9.18	101.1	110.28