

THE IDENTIFICATION OF THE UNKNOWN SKULL

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SUMMARY

There is an increasing interest in Forensic Sciences. This is due to many reasons such as the application of modern technology to forensic principles. The identity of an individual from birth, throughout life and in death could be considered a fundamental right. The advances in Forensic Sciences have simplified the identification process through primary and secondary data of far greater scope than ever before.

Natural disasters and those disasters due to criminal and terrorist activities continue to occur worldwide. People from all walks of life of either sex and of different age groups could be the victims of these disasters. It has not always been possible to identify the victims due to a multitude of reasons. This warrants not only the establishment of universally viable and useable international disaster victim identification programs, but also requires programs that are uniform in principle, to cater to disasters involving deaths of multiple nationalities, common in air traffic accidents. This explains why the Disaster Victim Identification protocol of Interpol is gaining increasing acceptance, to cater to the needs of individual countries. The unavailability of ante-mortem records is the primary difficulty and the main reason for the lack of success with this method.

After a criminal act or a disaster, the human remains are presented to forensic practitioners in different forms, ranging from an easily identifiable body to a set of burnt remnants. The methods to be adopted for the identification obviously vary from case to case. The less the available data, the more difficult the identification and the more extensive will be the methods. In order to identify a dead body, the most useful clues are primarily race sex and age. These may be adequate, depending on the number and distribution among race, sex and age of the victims. However when the number of victims increases, the forensic experts have to depend on more specific extensive information and at this point the dental tissues become an encyclopaedia of information.

Identification on a dental basis depends on a variety of factors increasing with the number of man-made and natural changes to the human dentition. In the human body, the most noticeable changes, particularly for recognition, are above the neck. This makes it more important for the forensic experts to be familiar with the measurements of features above the neck and their relationships to one another.

Measurements of distances between accepted landmarks of the skull and the face could be used to establish proportions. These proportions become the basis on which a face is built. This is why, in addition to the tissue thickness with racial variations, these standard ratios of facial dimensions are used for the reconstruction of faces. This is basically done in four ways: from photographs, from plasticine, from video-superimposition, and from computer based programs.

In all these methods, the common links between the skull and the face are ratios, of which some are standard and some are not. Standard ratios are those that are documented where similarities occur in a larger percentage of people. The non-standard ratios are those which are undocumented and have wider variation among individuals, the latter is the thrust of this study.

Therefore the research component of this thesis is to:

- 1 Identify non-standard ratios,
- 2 Assess the feasibility of their use for identification,
- 3 Examine the degree of their sensitivity for an initial identification by elimination
- 4 Document the degree of their specificity.

Data from a set of non-standard facial ratios, based on distances measured between documented landmarks, from a series of samples of different sizes have been selected for this study. These data have been analysed from different statistical perspectives such as analysis of variation, regression analysis, student's t and Chi square tests. The statistical analysis establishes the specificity and the uniqueness of a group of facial ratios. A feature emerging from the statistical study of these non-standard ratios is that, it establishes the uniqueness and the specificity of non-standard vertical and horizontal facial ratios when considered collectively. This supports the hypothesis.

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DEDICATION

THIS THESIS

IS IN

MEMORY

OF MY PARENTS

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1 INTRODUCTION

"SHOW ME THE MANNER IN WHICH A NATION OR A COUNTRY CARES FOR ITS DEAD, AND I WILL MEASURE WITH MATHEMATICAL EXACTNESS THE TENDER SYMPATHIES OF ITS PEOPLE, THEIR RESPECT FOR THE LAWS OF THE LAND AND THE LOYALTIES TO HIGH IDEAL" (Sir Franklyn Gladstone, 1871).

1.1 SOCIAL OBLIGATION

The only certainty of life amidst all uncertainties, which also include the time, place and the nature of its occurrence, is death. It is a moral obligation for all living people to respect the dead.

Death is defined as an irreversible cessation of all the functions of a person's brain and/or an irreversible cessation of circulation of blood in a person's body. The cause of death pertains to the pathological entity, which represents disease or injury, directly responsible for death. The manner of death is a medico-legal classification based upon the post-mortem findings and the circumstances surrounding death; it represents the manner in which the death transpired. (Hilton 1996)

In the chain of reactions that follow death, the starting point of the social obligation of those left behind is to ascertain, "Who is dead? How did he/she die? Is the death due to natural or unnatural causes? If unnatural, what are those causes? Could they have been prevented? If so who should be blamed?" and lastly the steps the society should take, to prevent the causes that resulted in the death, if they were avoidable.

The manner of death is important to many elements: the police, to determine the course of their investigations; the industrialists to prevent repetitions; and the epidemiologists to recognize disease patterns. (Sopher 1976)

One classification of the manner of death would be: Natural; Accident; Suicide; Homicide; or Undetermined. Another would be Natural; Apparently Natural; or Un-natural. Natural causes could be heart attacks, strokes or cancers, whilst unnatural causes could be accidents,

homicides, suicides and those under suspicious circumstances. The Apparently Natural causes are those which were not certified by an attending physician. **(Sopher 1976)**

The attending physician can only certify deaths due to natural causes. According to most legal systems the certification of death has to be done by "The Medical Examiner" in all cases of unnatural and apparently natural deaths. No undertaker can take a body for burial or cremation either from a hospital or from a site of death without a valid certificate. **(Sopher 1976)**

The proper medico-legal investigations regarding community deaths, apprehension of criminals and the imposing of punishments to serve as deterrents, are vital for the emergence of a just and free society for the prevention of crime. It is a rule of thumb that the specificity increases with the number of variables. The records of the dental status of an individual is an area that could have a large number of variables and therefore could be the most specific data for an individual. With dental records occupying a top berth in the list of identification methods it becomes an obligation of all practicing dentists with their professional expertise to assist in medico-legal work. These are in fact fundamental social obligations for the benefit of the community.

There are numerous instances in Sri Lanka where presumably dead soldiers walk to their funerals, sometimes to the amusement and surprise of the relatives, but more often causing a lot of mental trauma to the next of kin. This sad situation cannot be accepted, as it infers that there are no proper ways of identifying even military men when, groups of twenty or thirty are killed by land mines or bomb attacks.

There are many reported instances where dead bodies with varying degrees of decomposition were never identified. It is against this background of gross under-information in the identification of groups of dead bodies, that critical dental information can act as the catalyst. This creates the need for a summary of forensic science principles that could act as a ready reckoner to the young dentist, the military hierarchy, the lawyer, the police officer, the core team of forensic practitioners in the health and defense arena

1.2 IDENTIFICATION OF UNKNOWN HUMAN REMAINS

Unsolved murders are as common as homicides with unidentified bodies. When death occurs in an away-from-home situation, in an outside location, without the knowledge of the next of kin, the dead person becomes an unknown entity. These situations could be listed as war casualties, or deaths from bomb explosions, mine blasts, air and motor traffic disasters, and suicide cases and murders, where the bodies could be decomposed or disfigured beyond recognition.

It should be a basic human, or more a fundamental right for a person who is born with an identity to die with an identity. The identification of an unknown body, presents itself as re-identification, becomes a medical, legal and, above all a social responsibility. **(Sopher 1976)**

There are three salient prerequisites for the issue of a legal death certificate, viz. the identity of the person, cause and the manner of death. An autopsy is requested by the legal authorities essentially to disclose the identity, the cause and the manner of death. Then it becomes a team effort of the group of experts to work in a systematic manner with utmost care and dedication, making use of every possible clue to identify the dead person, in the shortest possible time. The main objective of this exercise is to minimize the legal and social difficulties, faced by the next of kin of the deceased.

General descriptions of the unknown body such as sex, age, body height, stature, colour of the eyes and hair are important as are the specific features which include scars, moles, tattoo marks and abnormalities of various kinds. Therefore, whenever possible, it is important to take full body photographs and radiographs.

Methods of identification of an unknown body are dictated by the post-mortem conditions of the body and also by the availability of ante-mortem data for comparison. The success of any method is based on specificity, which depends on the frequency of occurrence.

The specificity and the reliability of the methods of identification have increased remarkably in the last two decades. The identification by fingerprints and dental data are universally accepted as cost effective and reliable methods, whilst the most reliable identification tool is DNA analysis.

Enumerated below is a list of methods for identification. **(Sopher 1976)**

- 1 Least reliable methods
 - a. Visual recognition by next of kin
 - b. Personal effects

- 2 Scientific methods
 - a. Finger prints
 - b. Dental characteristics
 - c. Skeletal characteristics
 - d. Medical conditions
 - e. Serology
 - f. Hair

- 3 Identification by exclusion

1.3 FORENSIC SCIENCES AND THE DENTIST'S ROLE

The evaluation of evidence, based upon scientific methodology and the establishment of a relationship of such evidence to the legal framework of a particular reference is the spectrum of forensic sciences. Forensic pathology is the application of the science of medicine to the field of law. It includes the:

- 1 study of deceased tissues and organs
- 2 effects of physical and chemical injury on bodily structures
- 3 relationship of disease and injury to the death of the individual (**Sopher 1976**)

Forensic pathologists deal with the cause and manner of death, in cases falling within the legal domain established by legislation designed to handle the medico-legal aspects of certain deaths. In legal terms this is referred to as the Medical Examiner Law. The agency that expedites the medical investigation of cases that fall within the law is the office of the Medical Examiner, where the Forensic Pathologist is the Medical Examiner. An important area of interest of the Forensic Pathologist is the identification of human remains. (**Sopher 1976**) The responsibility of the Forensic Pathologist is to certify the cause and manner of death from the data of the post-mortems and the circumstances surrounding death and present the scientific evidence in court if necessary.

Depending on the legal systems, which vary from state to state and from country to country, the ultimate decision regarding the cause and manner of death lies with different people, who could be the attending physician, the Medical Examiner or the Coroner. The eligibility criteria to become a Coroner also vary from place to place. In some systems the Coroner is a non-physician who ultimately becomes responsible for the final decision regarding the cause and manner of death; in some systems it is a medical practitioner not qualified in Forensic Pathology; whilst in some systems the coroner system is controlled by a physician.

In cases where there is a query about the identity of the deceased, the investigating officers will have to depend on the available circumstantial evidence from the physical property, the autopsy findings, fingerprint evidence, medical; and last but not least, dental evidence.

Basically comparing the ante-mortem and post-mortem data finally makes possible, the identification of the unknown body. Costly DNA analysis requires ante-mortem samples and is very specific if these are available. The identification by dental processes is the most practical and dependable tool in identification of an unknown deceased, provided there are adequate ante-mortem dental records. In these circumstances it is the general dental practitioner who plays a bigger role in this specialty, much more than the forensic dentist, because there is very little the latter can achieve without the former.

Forensic Medicine has been recognised as a separate discipline in a medical student's undergraduate career throughout the world. Forensic Dentistry however is not a structured training program for medical and dental undergraduates. It is also observed that few pursue this specialty at postgraduate level and Australia is no exception. The possible reasons are: the lack of earning potential, the unpleasantness of the job, and the limitations in the specialty.

The four major areas of interest for the Forensic Dentist are:

- 1 Dental identification of the unknown body
- 2 Comparison of bite marks
- 3 Trauma and the oral tissues
- 4 Dental malpractice and negligence

1.4 NEED FOR RESEARCH

In the present context the reasons for failures for the identification of the dead in the third world countries are: the absence of a strict protocol for the management of a disaster; the absence of a well organized missing persons centre; and the absence of dependable medical and dental records. Hence it is both pertinent and necessary to formulate a disaster management plan, with specific policies and objectives, akin to the criteria and guidelines set up by the Interpol Organization.

Therefore it is necessary to probe and find out other cost-effective simpler methods of identification of unknown human remains, in the absence of proper medical and dental records. In this regard the research component has been focused on the feasibility of the development of a cost-effective method of Victim Identification from skeletal remains, purely from a photographic method.

1.5 OBJECTIVES OF THE RESEARCH

With the rise in crime and the increase of disaster victims due to social and ethnic conflicts all over the world, there is a need to delve into the feasibility of using cheaper methods for the identification of disaster victims. These methods should be suitable for a third world country with minimum usage of costly sophisticated equipment.

The main aim of this research is to look at the human skull from a mathematical perspective, using simple mathematical formulae to precipitate specificity for a possible identification. This will consider and evaluate the use of photographs for comparison to facilitate establishing identity of unknown skulls as the most feasible and viable method for third world countries in the absence of up to date, dependable medical and dental records.

The objectives are to:

- 1 review current methods relating to the use of Dental Data in identifying dead bodies.
- 2 adopt a suitable method, by the use of photographs for comparison in the establishment of identity of an unknown skull, without compromising the sensitivity and specificity of the method.
- 3 make recommendations based on the findings of this work, describing the protocol and the relevant methodology of a cost-effective method for the identification of unknown skeletal human remains.

This chapter provides the introduction to this research. Chapters two, three and four provide a comprehensive literature review of the different methods of identification of an unknown skull. Chapter five leads to the research area where an attempt is made to propose and test a cost-effective mathematical method, using standard and non-standard facial ratios. The validity and feasibility of the method suggested from practical and statistical perspectives were examined using larger Sri Lankan samples.

2 DENTAL IDENTIFICATION IN FORENSIC SCIENCES

2.1 IMPORTANCE OF DENTAL RECORDS

Dental identification is the procedure by which dental data collected from human remains are shown to match dental data of a known missing person. The data has to be sufficiently matched for the sample to be acceptable by the investigator. The comparison could be between already established records of a living person, on a case by case basis. (Nielsen 1980)

Two groupings suggested by Sassouni (1963) were: "re-constructive" where a probable identity, could be suggested, depending on age, sex, height and race; and "comparative", where matching of the ante-mortem data with the post-mortem data could be done. A confirmation of identity by comparison is referred to as "affirmative" in contrast to "exclusion" where narrowing the numbers depends on available data for identification.

In males the osseous age and the dental age are similar, whereas in females the former is greater than the latter. This phenomenon also could be used to decide the sex of unknown skeletal remains in addition to the more established bony differences. Comparisons were made by Hunt and Gleiser (1955) using Greulich and Pyle (1950) charts for the osseous age and the Schour and Massler (1941) charts, for the dental age. Though there are no defined methods of determining race by a study of the teeth Haines (1972) suggested that shovel shaped incisors were characteristic of Chinese, Mongoloid, Eskimo and American Indian groups but on the contrary Lasker and Lee (1957) found the same characteristics in Caucasians. A feature present in the Negro race and absent in the Mongoloid race, according to Kraus (1957) was the presence of the two lingual cusps of the mandibular first premolar.

The variations that exist between the dentitions of two adults are due to the possible combinations of differences in 160 possible surfaces, differences in macroscopic positioning, anomalous nature of some teeth, impactions, dilacerations, retained root canal fillings, periodontal bone loss, bone marrow spaces, trabecular patterns, nutrient canals, pathological conditions, and a multitude of appliances. These variations make the dental records a valuable confirmatory identifying tool

bettered only by fingerprints (**Mertz 1977**) and more recently by DNA techniques.

For the identification of unknown human remains, dental data become an encyclopaedia of information and an important tool, but only if the ante-mortem records are available. Most of the armed services, throughout the world, are concerned about maintaining correct dental records. In the present day the maintaining of dental records should be a necessity not only for service personnel but also for persons in high-risk groups such as flyers, miners, and divers.

To get the optimum results through dental identification, there should be a central agency for recording these dental data under the same guidelines as the maintenance of finger print records in the USA, with dedicated experts for the comparison of these data. For comparison with post-mortem data the most recent ante-mortem dental records are mandatory, to effectively establish the identity of an individual.

The methods and the criteria used for charting dental data vary from country to country and dentist to dentist. In countries where, by statute, the dentists are not required to adhere to one particular system, the FDI Two digit system is followed. This is the internationally accepted system to be followed. For the benefit of the different experts who will be interpreting evidence it is necessary to indicate the system or the systems used in a particular country.

Of a large number of charting systems available the most common are the Universal System, the Palmer Notation System and the FDI Two Digit system. In the Universal System the permanent teeth are numbered from 1 to 32 starting from the upper right third molar as 1, to the upper left maxillary molar as 16, and from the lower left mandibular molar as 17 to the right mandibular third molar as 32.

In the deciduous teeth the same frequency is used from A to T. In the Palmer Notation System used in Sri Lanka the teeth are numbered from 1 to 8 starting from the incisor up to the third molar in each quadrant. The deciduous teeth are marked from a to e, from the central incisor to the second molar.

The Palmer Notation System is very simple. In this system the four quadrants were designated another digit from 1 to 4 in addition to the 1 to 8 used for the teeth and this Two Digit System was accepted as the system of choice by the FDI. The deciduous quadrants were designated 5 to 8 in contrast to the 1 to 4 for the permanent. (Mertz 1977)

2.2 THE VALIDITY OF DENTAL IDENTIFICATION

The selection of a suitable medium for the establishment of valid data for identification based on the principle of comparison should be in accordance with the following criteria. (Sopher 1976)

- 1 A medium which possesses multiple, permanent, measurable or observable points of specificity so that relative individuality of the medium exists.
- 2 Previous accurate registration of the characteristics of individuality (the Ante-mortem data) that must be available for comparison with any subsequent retrieved data (Post-mortem data).
- 3 A medium, complete with its contained features of specificity, that must be resistant to destructive forces, so that it persists as a pillar of individuality in the absence of other identifying features.

The human dentition, satisfies the criteria 1 and 3 and if the second criteria could be satisfied, then undoubtedly the dentition could well provide an important tool in the identification process.

However based on a logical sequence for the establishment of valid data for identification a medium should ideally possess the following prerequisites for comparison purposes:

- 1 Show high resistance to physical and thermal injuries and to decomposition.
- 2 Be of such a shape as to be distinctive.
- 3 Be contained in a small area of the body so that even when the body is crushed or fragmented, a sufficient area containing the material will be intact.
- 4 Be in a part of a body that is readily accessible for examination and does not need special dissection or preparation.

2.2.1 The individuality of the dentition

The 160 available dental surfaces, could be subjected to either one or more of the following events which could change the features with a significant increase of specificity:

- 1 Hereditary, congenital or developmental alteration.
- 2 Acquired natural or traumatic alteration.
- 3 Presence or absence in multiple combination of one, many or most of the thirty two units.

The combinations and permutations of the variable constructions, constitution and morphological array of various restorative procedures, materials and prosthetic devices employed by the dental profession, largely contribute to the individuality of the dentition. (Sopher 1976) The radiographs

together with those changes occurring in the dental tissues due to the aging process also add to the specificity of the medium.

2.2.2 Previous registration

Previous registrations depend on the availability and accuracy of the ante-mortem records. Except in most advanced countries with dental literacy and statutory requirements, one cannot depend on dental data. The contributory factors are: the dead may have visited more than one dentist; the records available could be the state of the dentition at an earlier visit to a particular dentist; and it could be only the treatment carried out by one particular dentist. Therefore it becomes a requirement to build up an ante-mortem record, taking into consideration not only what is in the available charts, but also the notes made by the attending dentists.

Computerisation of dental records would be theoretically an ideal situation, but whether this is a practical reality is another question altogether. However it may be possible to ascertain certain dental peculiarities particular to an individual, by immediate family members, such as diastemas and gold crowns, though this is a very weak source of information.

2.2.3 Indestructibility of the dentition

The teeth, both physically and chemically, are the hardest substrate in the human body and most of the materials used for restorations are extremely resistant. Teeth and the accompanying restorations take the longest time to be destroyed under post-mortem putrefaction, normal burial conditions and even upon direct effect of fire, where the destruction will depend on the temperature and the period of exposure. (Sopher 1976) The effect of rapid exposure to heat will result in bursting of the enamel shell leaving the dentine, whilst gradual and prolonged exposure will result in a clean separation at the coronal/root line of the intact crown, and total brittleness. It is mandatory that the investigators take radiographs of the dental tissues without disturbing them when examining burnt human remains.

2.3 ANTE-MORTEM DATA

The important ante-mortem data are:

- 1 Written dental records.
- 2 Medical and dental radiographs.
- 3 Available casts and models.
- 4 Recollection of the dentist or the acquaintances.
- 5 Medical and dental photographs.

Written data consists of charts and the dentist's own notes. For comparison purposes the notes and particularly the date on which those notes were made are important. The investigator must also be aware of all institutions that provide dental care so that, requests could be made to obtain the required ante-mortem data.

The dental radiographs provide supplementary information for comparison of ante-mortem and post-mortem data in areas missed by visual observations. These include inter tooth relationships, root angulations, tooth and pulp canal outlines, jaw bone trabeculae patterns, periapical pathology and different stages of endodontic therapy. In addition to these, the radiolucent pathological conditions coupled with radio-opacities of most of the restorations, provide detailed specific features, which may enable one to make a positive identification.

Any available models and casts could be traced either to the dentist, dental technician or to the individual for later comparison. Matching could be done with a post mortem cast in relation to specific features such as palatal rugae configurations.

However even without dental records, instances have been reported where dentists could identify their advanced restorative appliances, for example extensive bridgework, which might provide the all-important clue for a positive identification.

2.4 POST-MORTEM DATA

Though there may be individual variations in recording data by dentists, the following is a check list of the features an examiner should look for, preferably in the given order of priority. (Sopher 1976)

- 1 The number of teeth
- 2 Restorations and prosthesis
- 3 Decay (dental caries)
- 4 Malpositions and malrotations
- 5 Peculiar shapes of teeth
- 6 Root canal therapy and endodontics
- 7 Bone patterns & relationship of the bite
- 8 Oral pathology
- 9 Radiological examinations
- 10 Age determination

1 The number of teeth

The number of teeth has to be based on the absence of teeth, which could be congenital, or traumatic. Extra teeth or supernumeraries are a rare occurrence and of great importance in the identification process. The mere absence of third molars is not conclusive evidence for a person to be considered less than seventeen years of age, as the teeth may be present embedded or they may have been removed surgically. Therefore the guideline for the determination of age, based on third molars should be, when present with closed root apices, the age of the subject is about twenty to twenty-two years.

Another reason for wrong judgments to be made in ante-mortem and post-mortem examinations, is the drifting of teeth. The commonest is the drifting of the second molar after an extraction of the first molar and rarely the drift of the third molar into the place of the second molar. Teeth could be lost ante-mortem, peri-mortem, or post-mortem. The ante-mortem teeth loss could be recent or old. Recent losses could be a few hours or a few days before death, and one would find a clot within the socket, which could be due to either a surgical intervention or to a traumatic action. Teeth could also be lost due to trauma even at the time of death.

In the case of post-mortem teeth loss, the sockets have sharp alveolar rims, unlike the filled in appearance of the sockets in the case of the ante-mortem teeth loss. The criteria are that, within three to five months new bone formation is almost complete, and by the end of one year complete bony obliteration has taken place.

2 Restorations and prosthesis

The number of restorations, their localities and the types of filling materials are valid pieces of information. In the case of prosthesis the number of prosthetic teeth, the nature of abutment teeth for the prosthesis, and the positions of attachment of hooks and clasps are of importance. With the improvement of the quality of synthetic materials, it is becoming increasingly difficult to identify synthetic fillings in a post-mortem dental examination.

It is possible for an experienced person to identify a porcelain restoration by using the probe. A more satisfactory method has been to use a plant dye that stains synthetic filling materials. In the absence of teeth, where only a denture is available, rugae patterns in the hard palate could be used as a tool for identification since these are found to be unique for any particular individual.

3 Decay (Dental caries)

With death the process of caries is terminated and lesions may remain evident. Depending on the state of the remains, these caries lesions could be easily missed. In the living, caries could be from a pit to an extensive area, which may or may not be visible to the naked eye. For inter-proximal caries a radiograph is required when the decayed areas are not observable by the naked eye and radiographs are also required for post-mortem dental examinations. It is obligatory that the most recent ante-mortem radiographs be used for comparison. Teeth fractures could be either ante-mortem or post-mortem. In the former the fracture sites are stained with foodstuff or cigarette stains whereas in the latter the sites are sharp, clean and unstained.

4 Malpositions and malrotations

The dependable method of identifying teeth is by their morphological features and not by the position they occupy. This is because overlapping, crowding and spacing abnormalities due to drifting can present a particular tooth in a wrong position just as much as a rotation could present a particular surface in a wrong position. It is rarely that a private practitioner marks a malposition or a rotation except in the case of children, who come to him for orthodontic treatment. This is because one really does not see either an importance or significance in rotated or malpositioned teeth in adults. But in the absence of other specific dental features these could be of significant importance in identifications.

5 Peculiar shapes of teeth

These could be either acquired or congenital. The acquired are due to certain vocations, whereas the congenital ones are the Hutchinson's incisors and the peg shaped lateral incisors. Peculiarities of teeth are rare but when present they serve as valuable identification factors.

6 Root canal therapy (Endodontics)

The teeth treated by endodontics, the types of materials used for the filling of such teeth and even the final picture of the filling (whether it is overfilled, under-filled or correctly filled) also contribute towards establishment of specificity in an individual. One drawback in this area is that there are certain radio-lucent endodontic filling materials in the market today. In these cases it is only the written dental record that could be used to find out whether endodontic treatment has been carried out or not.

7 Bone pattern and relationship of the bite

The angulation of the teeth, the manner of the trabeculae and the inter-proximal bone loss due to periodontitis are important features. The closing pattern of the jaws such as protrusion of the lower, the upper or both are also important factors to be noted.

8 Oral pathology

Mandibular and palatine tori on the lingual surface near the premolar region of the mandible and the midline of the maxilla are also important features of identification. The abnormalities of the tongue such as geographic, black hairy, scrotal and possible lacerations could also be factors of importance.

9 Radiological examination

The radiographs help in the determination of age, height and sex. Radiology could reveal the cause of death caused by firearms through determining the entry, exit and the path of the bullets. It could lead for the establishing the cause of death by the fracture sites in assault cases. In a disaster situation it is also possible to determine where the explosives were by radiographic examination of the victims. In general radiological examination should follow initial examination and precede tissue removal. Radiographs of skulls could be used for comparisons as the outlines of sinuses are also specific according to **Schuller (1921) and Culbert and Law (1972)**. However in disaster situations, radiographs of full skulls may not be a possibility and dental radiographs in such instances may provide an important clue for positive identification.

The importance of teeth as a medium of identification has already being discussed. The radiographic examination drives this point home as the two dimensional pictures of the three dimensional teeth, with their specific shapes and sizes of decay and diversified restorative procedures, make the comparison of ante-mortem and post-mortem records a lot easier. There could be relatively more changes in the crown between the time the radiograph is taken and the time of death, than in the tooth root. Dental radiographs provide a useful tool in the identification process, as one could compare the shapes, and the sizes of not only the crowns but also the roots, which are less susceptible to caries and possible trauma at peri- or post-mortem.

10 Age estimation

It is important to place on record that in infant deaths and paternity suits, estimation of age becomes a legal requirement to establish the alleged date of conception. **Seward (1972) and Nolla (1958)** describe 10 stages of tooth development, with a point system of 1 to 10 along with the possible age determined by the total of these figures. **Gleiser and Hunt (1955)** selected the first permanent molar to determine age by lateral oblique radiographs. **Johanson (1971)** selected the third molar though its development cannot be relied on, due to a multitude of reasons. Whilst all these methods do give a reasonably accurate age primarily by radiographs, there are a large number of variables such as the angulation, the specific positioning of the cusps and various pathological and nutritional conditions that affect the results.

2.5 COMPARISON OF ANTE-MORTEM AND POST-MORTEM RECORDS

Human error being a natural phenomenon and the time factor being a criteria for making hurried charting without a proper history, it is always possible for a second molar to be charted as the first molar, or a second premolar to be charted as the first premolar. Though these discrepancies do occur in ante-mortem records, it is of paramount importance to go through the treatment records and all available radiographs before doing a comparison of the ante-mortem records with the post-mortem records. Once these are found it is left to the forensic dentist to take the post-mortem radiographs both peri-apical and bite wings, with necessary adjustments in exposure times and wattage. This should cover all available dental tissues.

The types of filling materials used according to the dentist's notes and their radio-opacities should be specially noted. Some restorative and root filling materials are not radio-opaque. Even without teeth or restorations the bony trabecular patterns or pathologic processes could be useful identification areas. The OPGs vary from one to another depending on the machines and it may be a difficult procedure to take post-mortem OPGs unless the head is severed or the head is skeletonised.

For dental identification photographs may also be used (with limitations). Lip prints may be used for the identification of criminals, provided the imprints are copied without alterations immediately after the crime. Once all available data are scrutinized and compared with the post-mortem data a Forensic Dental Report has to be submitted.

The dental expert may be called to do an examination either at the site or more often in the mortuary. Wherever it may be, these examinations should be carefully done and attention should be paid to minute details in order not to miss a vital clue for identification such as a displaced post crown, a bridge or a part of a broken denture.

2.6 ORAL AUTOPSY

It is always prudent for the dentist to visit the site of recovery as they are in the best position to identify misplaced dental tissues or items of dental origin. It is necessary to be properly equipped for a post-mortem dental examination.

The requirements are: protective clothing and appropriate gloves; a mobile X Ray unit with 16 periapical films per body; a polaroid camera; adequate lighting preferably in the form of a diagnostic torch; a plastic ruler; polythene specimen bags with suitable labels; and the forms that are used to record the data according to the accepted standards of the country concerned.

Once the police examination is over the forensic dentist should look out for all displaced skeletal remains of dental origin. The dental expert should try to recover such items and also indicate diagrammatically where they were found, in relation to the body and to known landmarks. All recovered parts should be safely secured in labeled bags and the head preferably covered with a plastic bag to avoid any unforeseen losses during transportation to the morgue. (Nielsen 1980)

For bodies recovered from water it is very unlikely that one would be able to locate displaced dental material. In bodies found decomposed for a long period it is quite possible to collect fallen teeth, particularly the single rooted ones from the surrounding area. In instances where the bodies are charred due to excessive heat, photographic and radiographic examination should precede physical examination as the tissues would be very brittle.

Facilities must be available at the morgue for the dentists to perform their task with no hindrance to maintain 100% accuracy. It is always advisable to have a second person for writing and also a second opinion. It is of vital importance to make very clear notes to indicate whether the teeth are present, removed, un-erupted, or lost post-mortem and to make no mistake in the identification of a tooth in relation to decay or the type of filling and its relation to the other teeth.

The charting could be in any notation depending on the systems commonly used in a particular country, but preferably in an internationally acceptable form.

It is obligatory to keep the collected post-mortem data recorded, even when one fails to identify the remains. The jaws should be separated and kept for later comparisons. The collection of ante-mortem data of all missing persons from the different dentists who have been treating them could be a very useful prerequisite for comparison with post-mortem data.

TYPES OF MEASUREMENTS USED FOR IDENTIFICATION PURPOSES

3.1 DENTAL MEASUREMENTS AND THEIR USE

Experience has shown that, irrespective of the yardsticks or different types of methods used, the human dentition still occupies a top berth in the identification process. In the absence of dental records, as often happens in South East Asian Countries, a photograph with a smiling face becomes the only piece of material left for comparisons. The measurements of individual teeth and inter tooth relationships could be used for identification purposes. The photographic representation of the anterior teeth could therefore be used as reliable data. According to **Randorf (1893)** characteristics of a dentition useful in identification could be irregularities of form, position, structure and number of individual teeth.

The relevant information of the anterior teeth could be classified into two variable features and attributes. The variable features are discrete and continuous and the attributes are tooth contours, occlusal profiles and special features. The discrete variations are limited to the presence and absence of teeth. The continuous variations are limited to two planes, three types of distances, and seven angles. The planes are the sagittal and the coronal; the distances are the heights, widths, and the distance between two visible landmarks. As numbered below, the continuous variations 1 - 7 is shown in **Fig 1a**; 8 - 9 attributes in **Fig 1b**; and the attribute 10 in **Fig 1c**. (**Adams 1982**)

- 1 Coronal angle
- 2 Mesio incisal angle
- 3 Disto incisal angle
- 4 Maximum width
- 5 Maximum height
- 6 Cuspal angle (canines)
- 7 Cuspal displacement
- 8 Inclination of coronal to sagittal plane
- 9 Inclination of one coronal axis to another
- 10 Distance between two landmarks

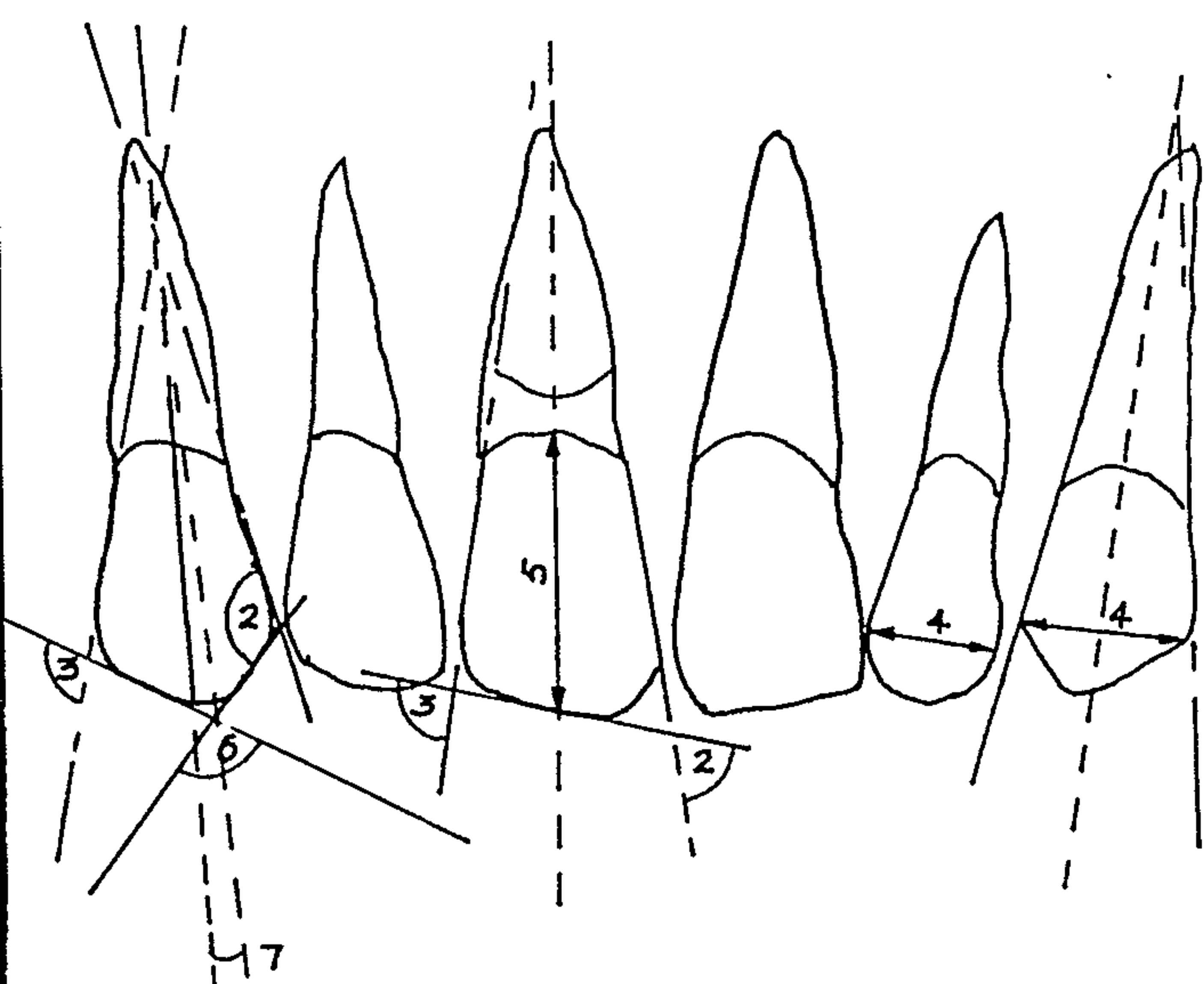


Fig 1a Schematic representation of the measurable characteristics of the continuous variables of the individual anterior teeth as numbered 1-7 in the text

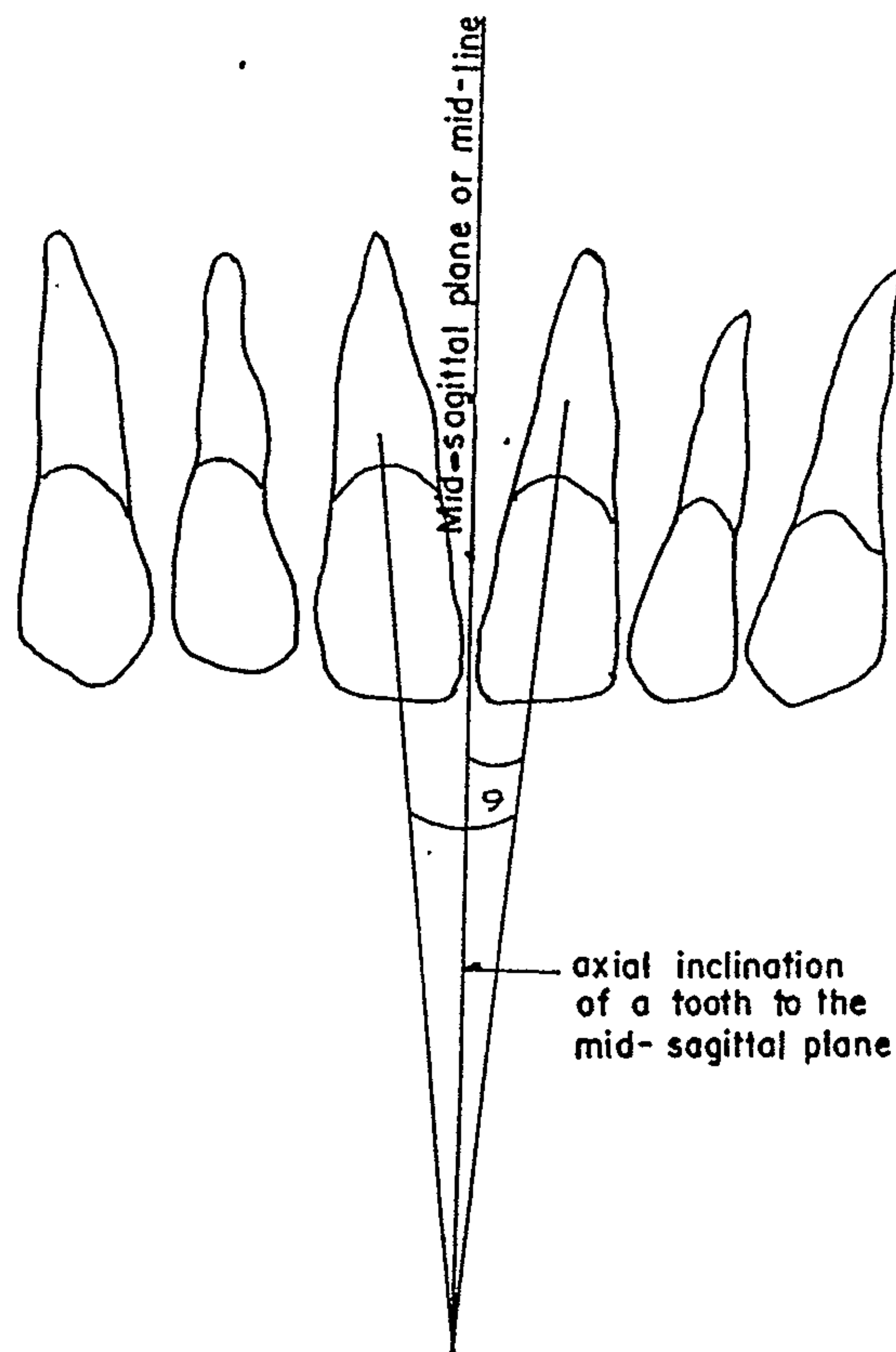


Fig 1b Schematic representation of the measurable characteristics of the attributes of the anterior dentition as numbered 8 and 9 in the text.

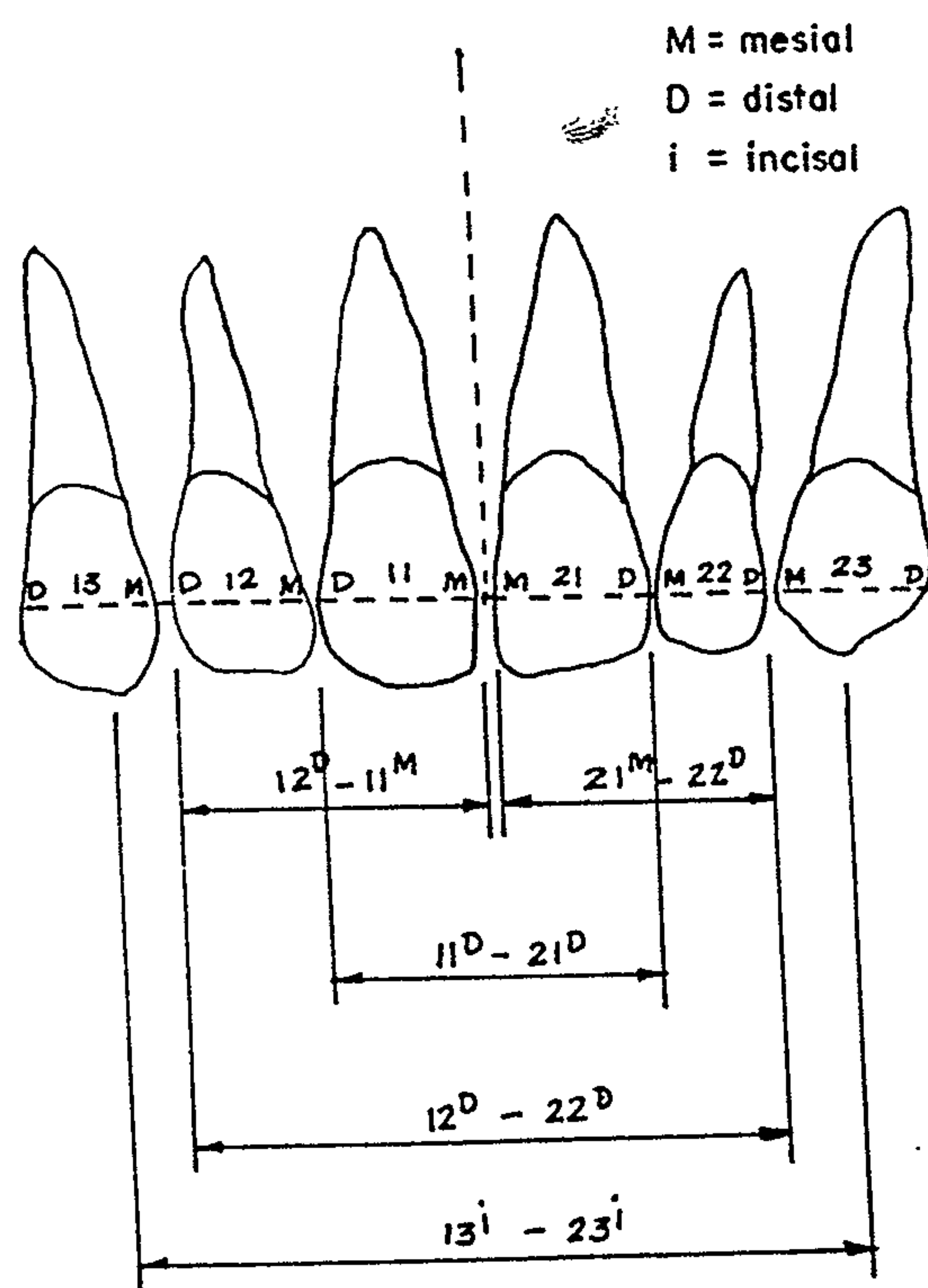


Fig 1c Schematic representation to show the intertooth mesiodistal widths <...> and the intertooth distances <...> of the maxillary anterior teeth

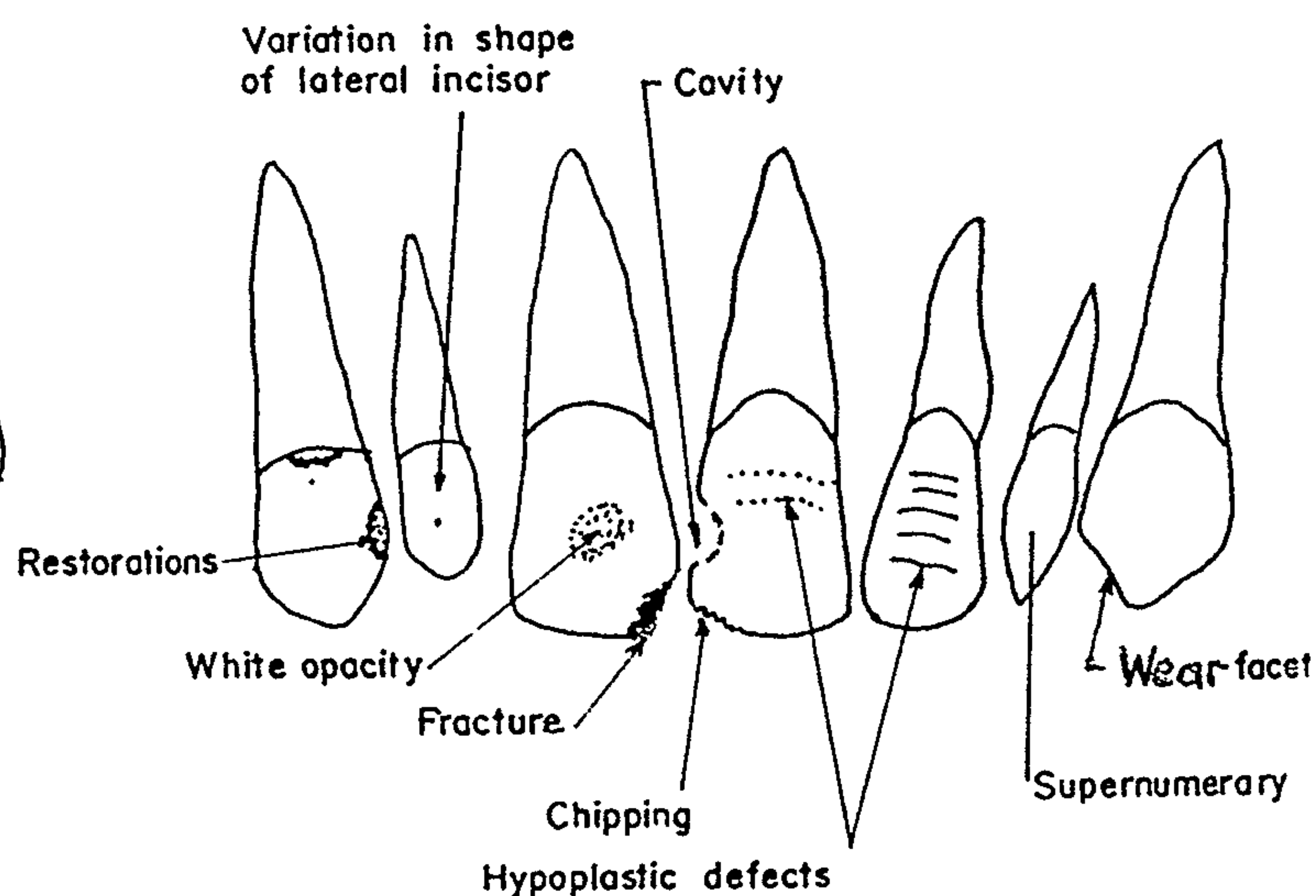


Fig 1d Schematic representation of some the special features which may be unique to an individual upper anterior dentition

The five inter-tooth distances given for attribute 10, besides the six individual widths of the teeth, shown in **Fig 1c** are described below.

- 1 Distance between Cuspal Angle of 13 - 23
- 2 Distance between the Distal Margin 12 - 22
- 3 Distance between the Distal Margin of 11 -21
- 4 Distance between the Distal Margin of 12 and Mesial Margin of 11
- 5 Distance between the Distal Margin of 22 and Mesial Margin of 21

The two instruments used for measurement of lengths are the calipers and the moving microscope. The use of calipers is recommended. The facial profile is used for deciding the contours of anterior teeth. The negatives of the skeletal dentition could be compared with the positive transparencies of the portraits, for identification purposes.

Development defects of enamel may be defined as disturbances in hard tissue matrices and in their mineralisation arising during odontogenesis. The following developmental defects as shown in **Fig 1d**, adopted from the report to Federation Dentaire Internationale and World Health Organization of " An epidemiological index of developmental defects of dental enamel (DDE Index)" could also be used for identification purposes. **(FDI/WHO 1981)**

- | | | | |
|---|------------------|----|----------------|
| 1 | Hypoplasia | 7 | Opacity |
| 2 | Spacing | 8 | Overlapping |
| 3 | Proclination | 9 | Retroclination |
| 4 | Anomalous shapes | 10 | Crossbites |
| 5 | Rotations | 11 | Fractures |
| 6 | Wear facets | 12 | Marks |

3.2 RELATIONSHIP BETWEEN CEPHALOMETRIC AND CRANIOMETRIC LANDMARKS

Anthropometry is a technique for measuring living and dead persons to take anthropometric measurements one must learn the proper positioning of bones and points or anthropometric landmarks from which measurements are made. There are primarily two types of anthropometric landmarks: paired and unpaired. An unpaired landmark is one where a single point falls on the mid-sagittal plane, whilst paired landmarks are those where two points are equidistant on either side of the mid-sagittal plane: Anthropometry can be divided into four branches:

Somatometry	-	measurements of the body
Cephalometry	-	measurements of the head and the face
Osteometry	-	measurement of the skeleton and its parts
Craniometry	-	measurement of the skull

Measurements are taken between points or anatomic landmarks. Thus the distance between two points (eg length of the skull is 190 mm). Indices express the ratio of one distance to another of an object (e.g. the cranial index expresses the ratio of the width of the skull to the length). **Bass (1987)**

Each of us has a pair of eyes and ears, a nose and a mouth, but what differentiates one from another is the alignment of these facial features depending on their individual sizes, spaces between them, their proportions, and the relationships to one another.

Craniometric and Cephalometric landmarks and their relationships or in simpler words the soft - hard tissue relationships are important bottom line requirements for the forensic scientist. These are essential for super-impositions and facial re-constructions, primarily used for disaster victim identification.

The cephalometric and craniometric landmarks of importance are enumerated below with their respective relationships to one another. (Cephalometric landmarks are printed in bold to differentiate from craniometric landmarks). For easy reference to denote a particular landmark the first letter or the two letters of the landmark are written within brackets.

Wherever the same nomenclature is used both for the Cephalometric and the Craniometric landmark the craniometric landmark is differentiated by adding an apostrophe after the second letter. The correlation between the cephalometric and the craniometric landmark denoted by a slash between the shortened version. The guideline for facial reconstruction is given in Italics.

Craniometric and Cephalometric Landmarks and their Relationships

- 1.1 **Inion (I)**
The intersection of the MSP with a line drawn tangent to the uppermost convexity of the right and left superior nuchal line.
- 1.2 Inion (I')
- 1.3 *I/I' A direct perpendicular*

- 2.1 **Lambda (L)**
The intersection of the sagittal and the lambdoidal sutures in the midline.
- 2.2 Lambda (L')
- 2.3 *L/L' A direct perpendicular*

- 3.1 **Bregma (B)**
The intersection of the coronal and sagittal sutures
- 3.2 Bregma (B')
- 3.3 *B/B' A direct perpendicular*

- 4.1 **Glabella (G)**
The most forward projecting point in the midline of the forehead
- 4.2 Glabella (G')
- 4.3 *G/G' A direct perpendicular*

- 5.1 **Nasion (N)**
The uppermost landmark for the measurement of the nasal height
- 5.2 Nasion (N')
- 5.3 *N/N' N' is usually 2 - 3 mm lower than N*

- 6.1 **Nasale (Na)**
The anterior tip of the nasal bone at their junction with the lateral nasal cartridges
- 6.2 Nasale (N')
- 6.3 *Na/Na' A direct perpendicular*

Fig 2a Craniometric points lateral view

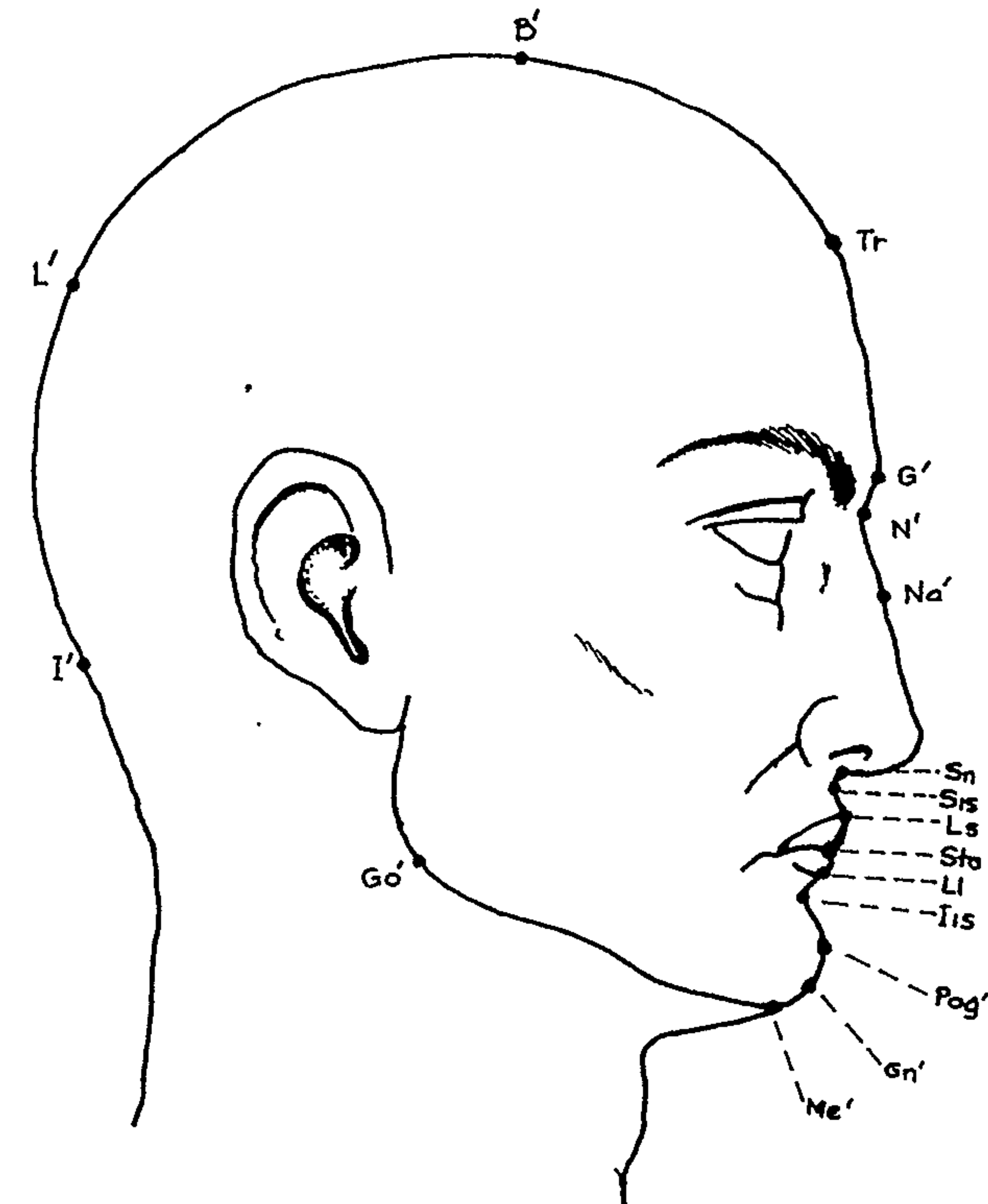
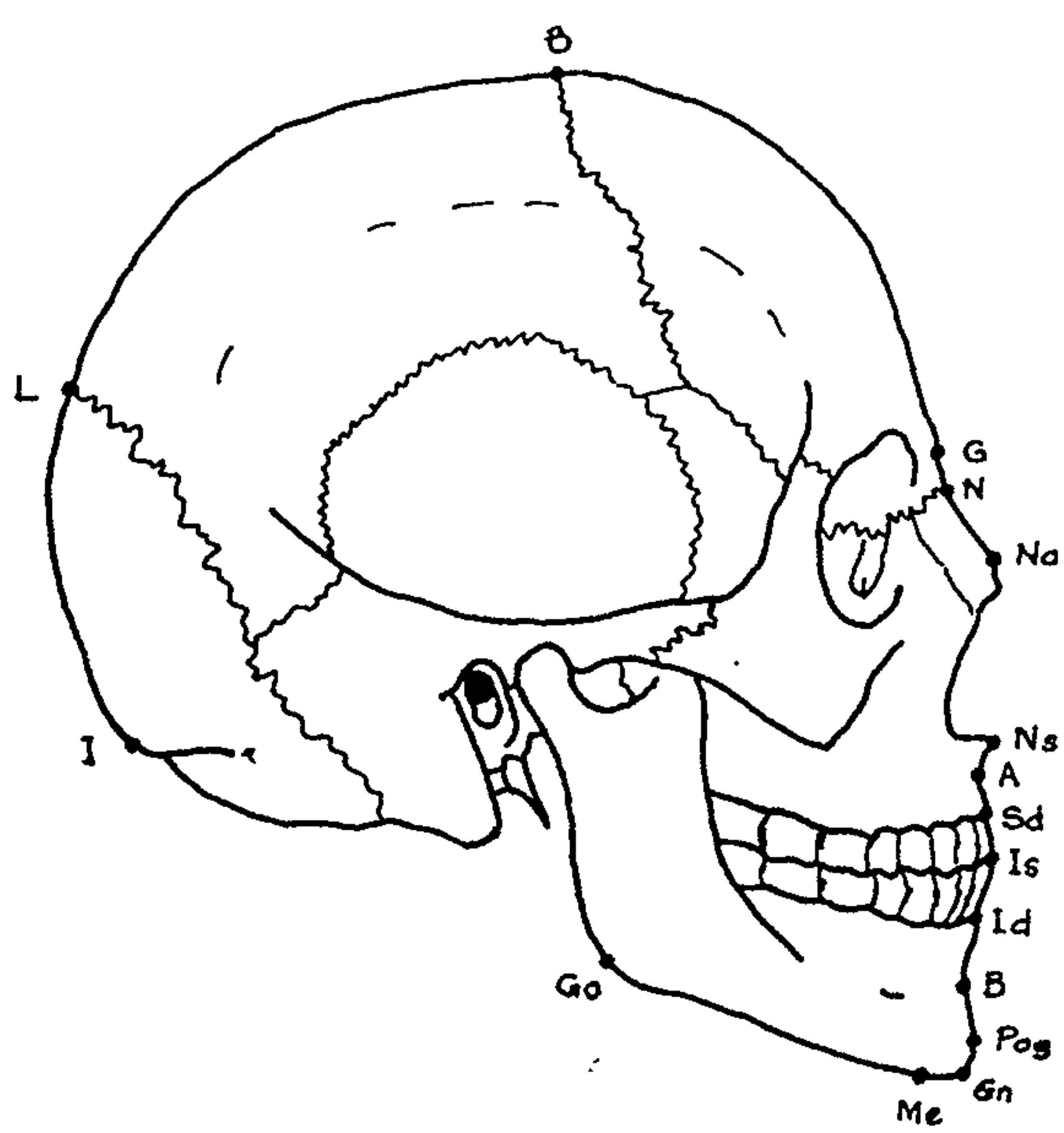


Fig 2b Cephalometric points lateral view

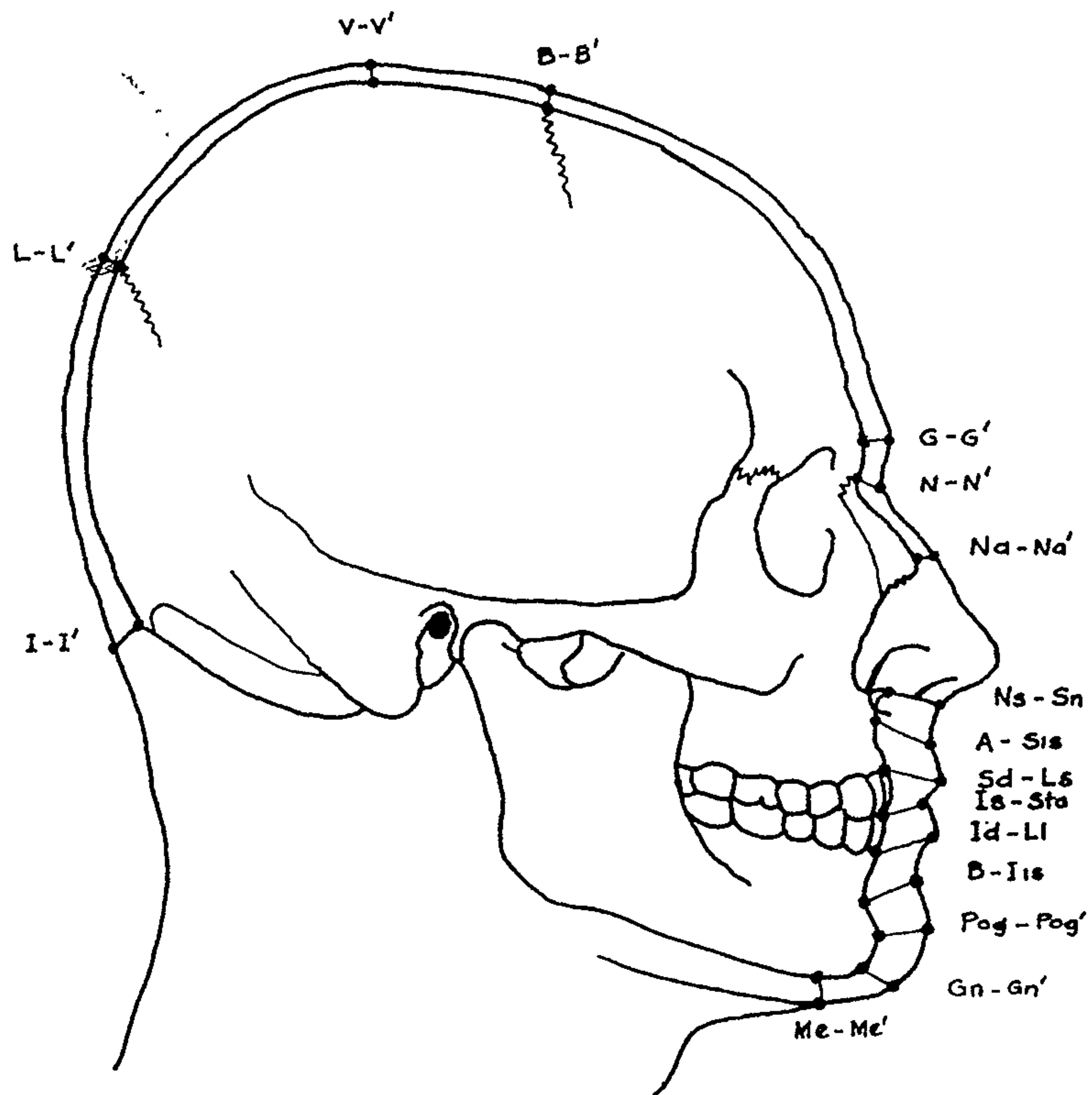


Fig 2c Craniofacial correlations lateral view
Source George 1993

Fig 3a Craniometric points frontal view

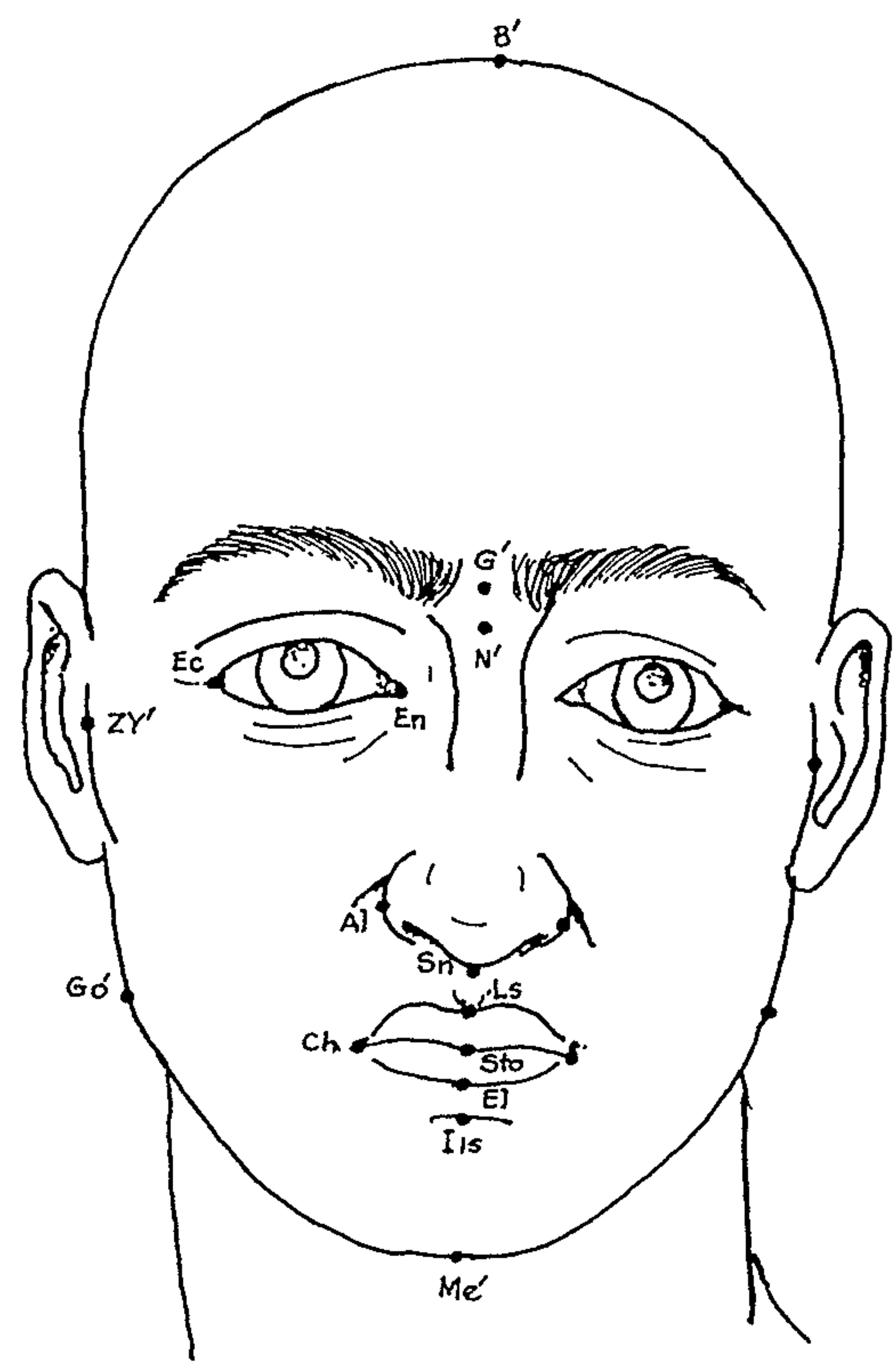
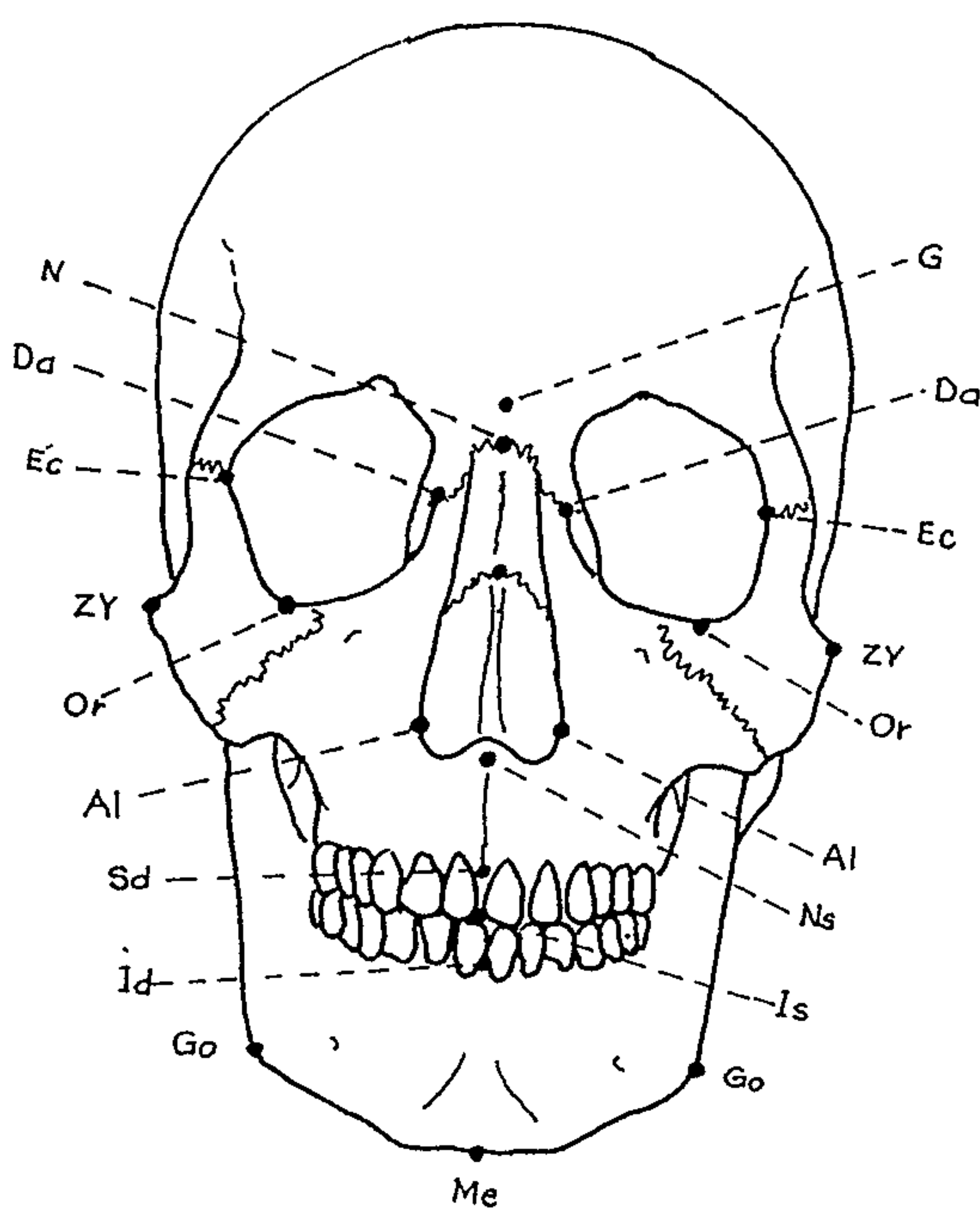


Fig 3b Cephalometric points frontal view

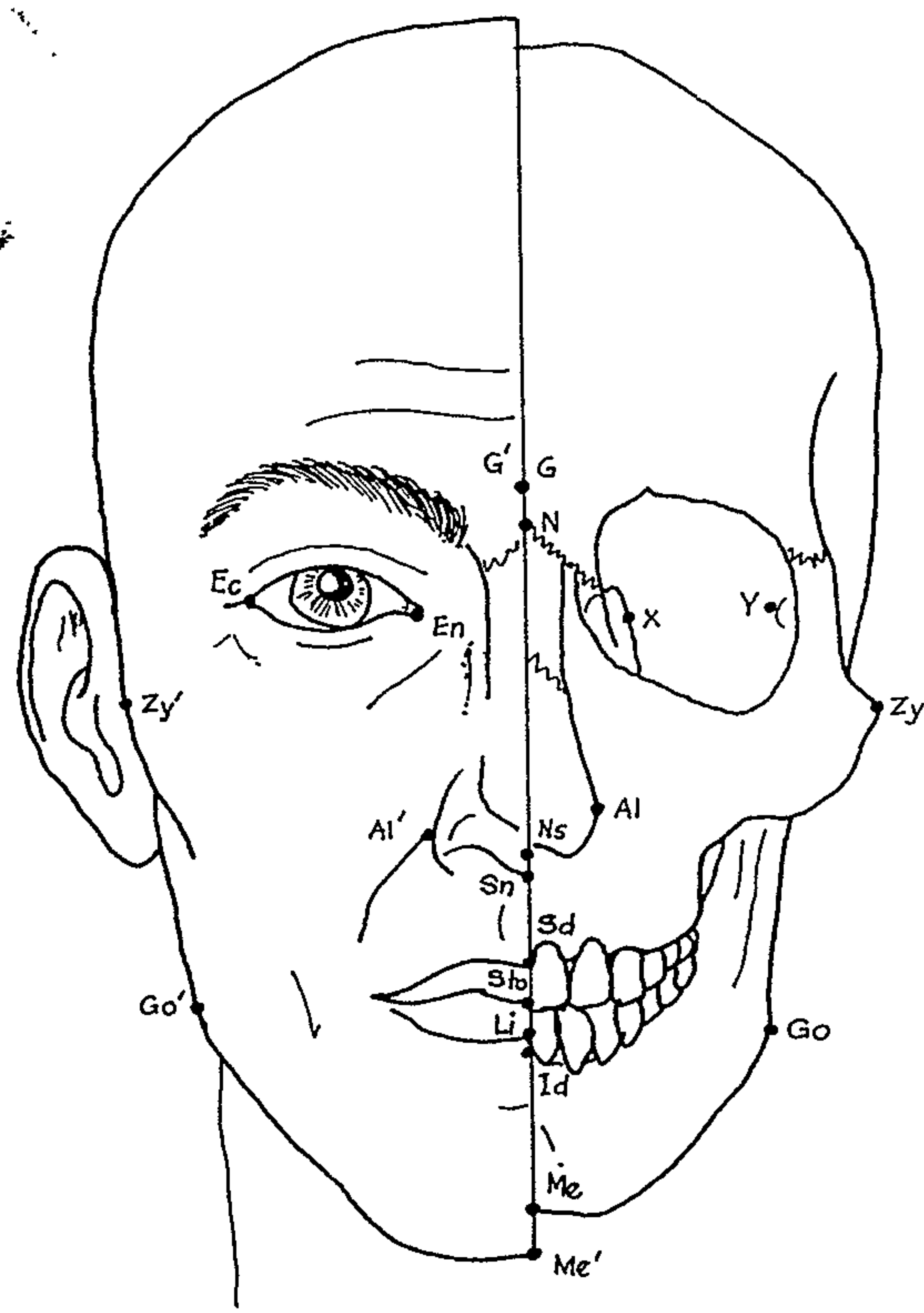


Fig 3c Craniofacial correlations frontal view
Source George 1993

Fig 4a Selected anthropometric landmarks frontal view

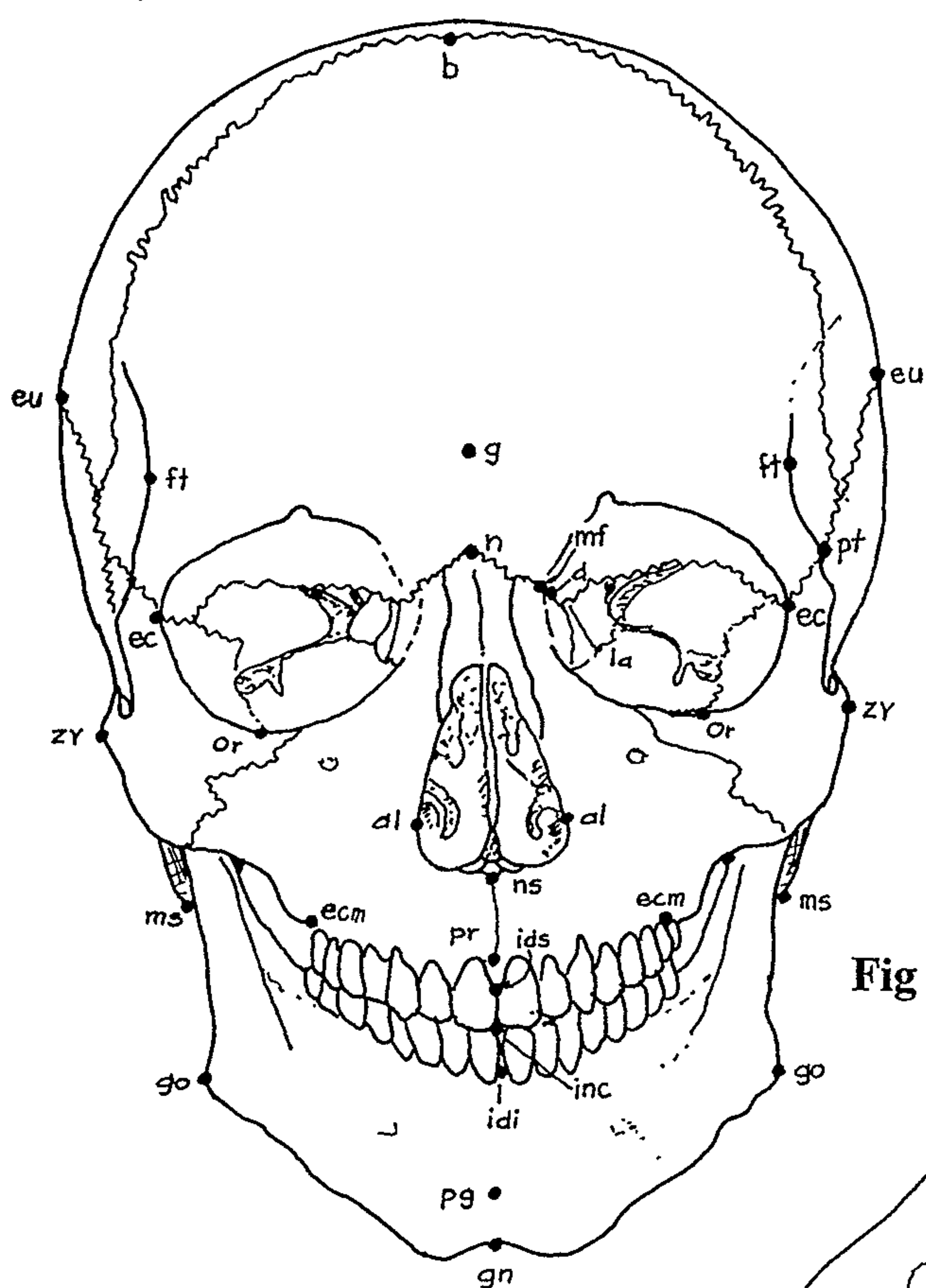


Fig 4b Selected antropometric landmarks lateral view

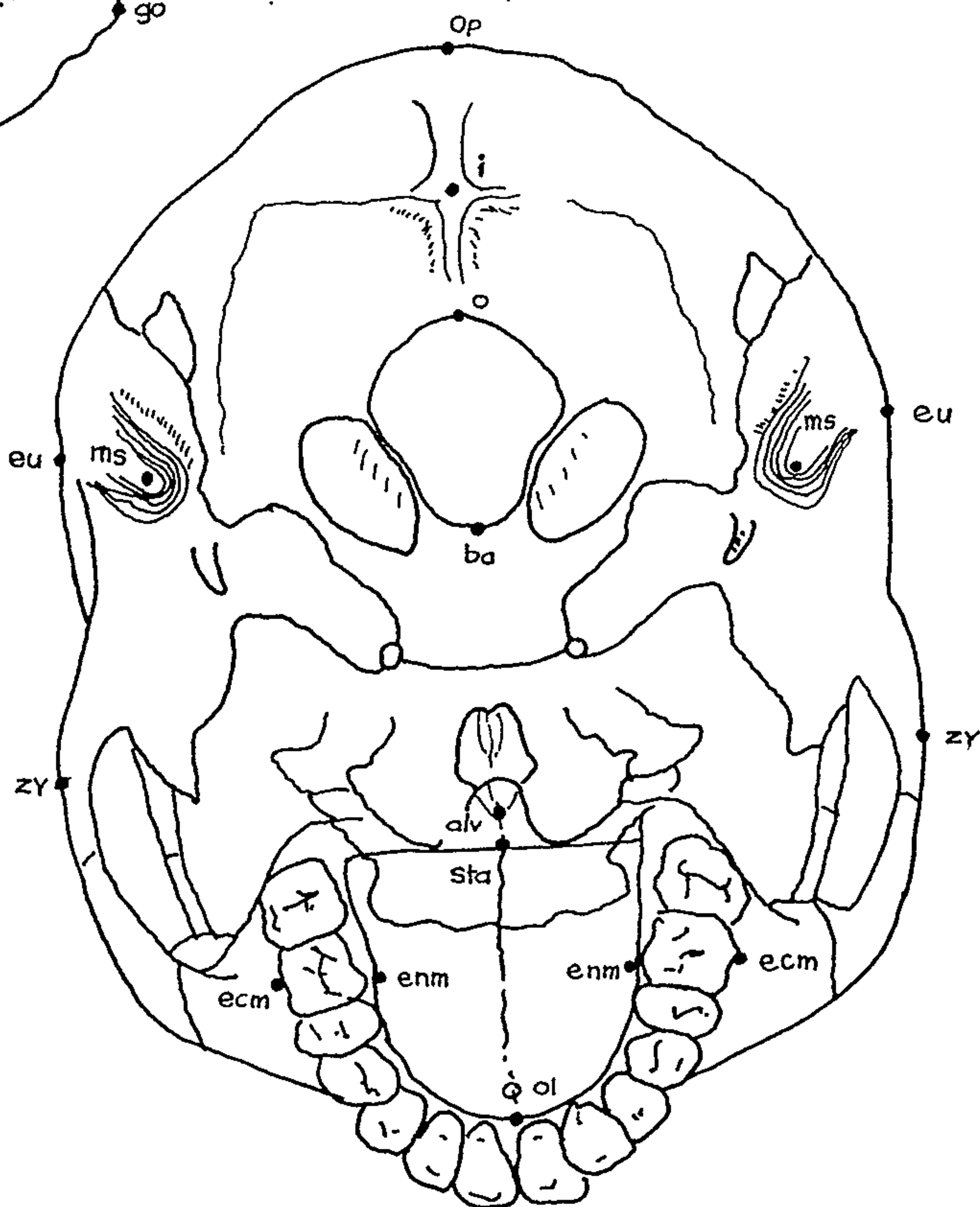
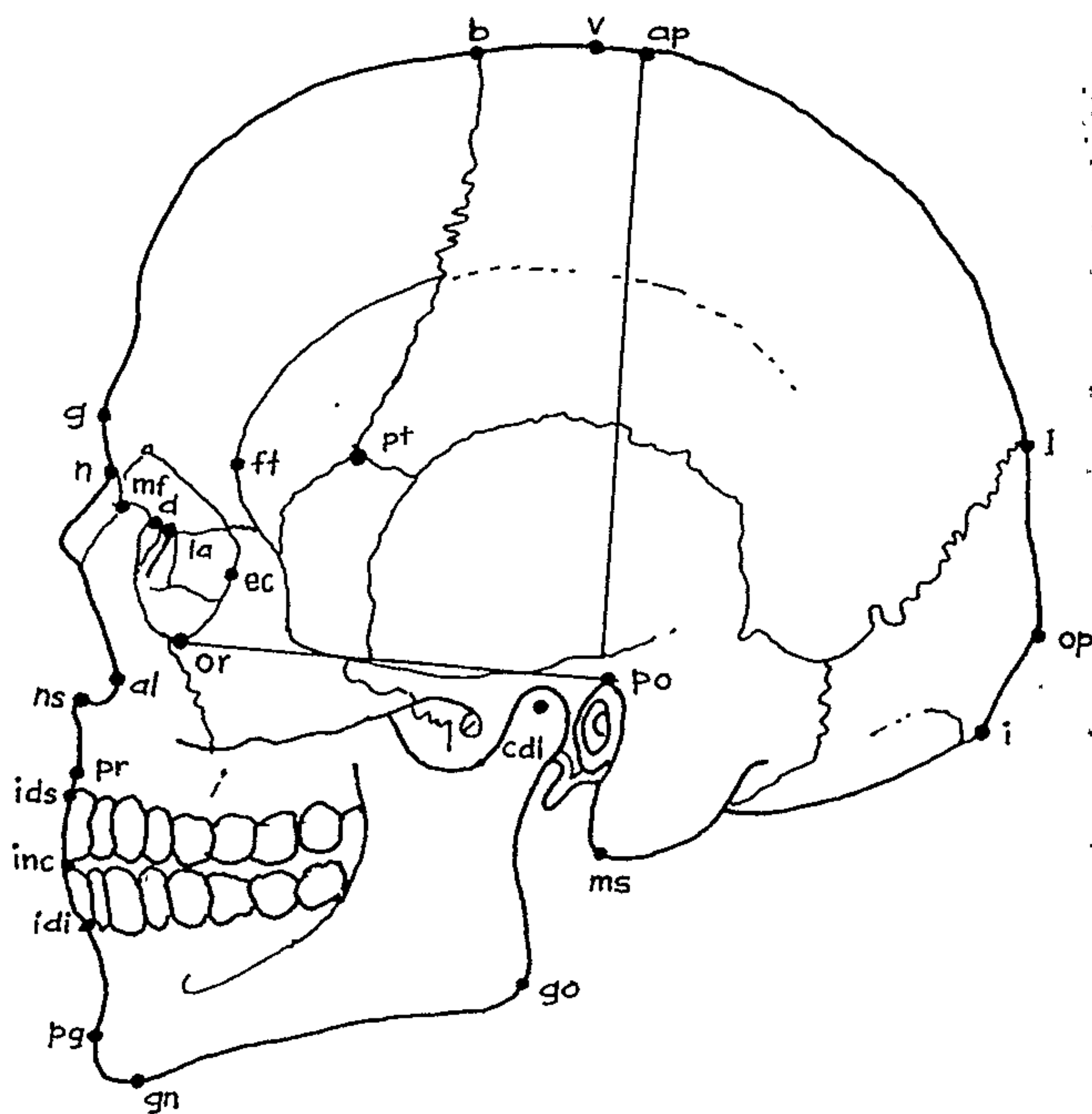


Fig 4c Selected anthropometric landmarks base of the skull

Source: Bass (1987)

- 7.1 Nasospinale (Ns)**
The lowest landmark for the measurement of the nasal height also described as the point where a line drawn between the lower margins of the right and left nasal apertures is intersected by the MSP
- 7.2 Sub nasale (Sn)**
The mid point of the columella base, where the lower border of the nasal septum meets the upper lip
- 7.3** *Ns/Sn Sn is lower than Ns*
- 8.1 Alare (Al)**
The instrumentally determined most lateral point on nasal aperture taken perpendicular to the nasal height
- 8.2 Alare (Al')**
The most lateral point in the alar contour
- 8.3** *Al/Al' Highly variable Al' is about 3 mm lateral to Al*
- 9.1 Point A (Subspinale)**
The deepest midline point in the indentation between the anterior nasal spine and the superdentale
- 9.2 Superior Labial Sulcus (Sls)**
The point of maximum indentation of the upper lip
- 9.3** *A/Sls A is fixed, Sls is generally lower than A though the lip could be concave straight or convex*
- 10.1 Supra dentale (Sd) (Alveolare in antropology)**
The apex of the septum between the upper central incisors
The apex of the alveolus in the mid line between the maxillary central incisors
- 10.2 Labiale Superius (Ls)**
The mid point on the vermillion line of the upper lip
- 10.3** *Sd/Ls In Caucasoids Ls is lower than Sd*
- 11.1 Incisor superius (Is)**
The tip of the crown of the most anterior maxillary incisor
- 11.2 Stomion (Sto)**
The point at the intersection of the MSP with the horizontal labial fissure between gently closed lips, with teeth shut in the natural position
- 11.3** *Is/Sto Sto is variable but usually higher than the Is*
- 12.1 Infradentale (Id)**
The apex of the septum between the lower central incisors
- 12.2 Labiale inferius (Li)**
The mid point on the vermillion line of the lower lip
- 12.3** *Id/Li Li is slightly higher than the Id*

- 13.1 **Point B (Supra mentale)**
The deepest midline point on the indentation between Id and Pog
- 13.2 Inferior Labial sulcus (Ils)
The point of maximum indentation of the lower lip
- 13.3 *Point B/ Ils Highly variable, Ils is usually higher than Point*

- 14.1 **Pogonion (Pog)**
The most anterior point in the midline on the chin.
- 14.2 Pogonion'(Pog')
The most anterior point of the soft tissue chin
- 14.3 *Pog/Pog' Pog' is usually higher (slightly) than Pog especially in males*

- 15.1 **Gnathion (Gn)**
The lowest median point in the lower border of the mandible.
- 15.2 Gnathion (Gn?)
The point on the chin midway between Pog' and Me'.
- 15.3 *Gn/Gn' Gn' is a constructed point and will be anterior and inferior to Gn*

- 16.1 **Menton (Me)**
The lowest point on the mandible
- 16.2 Menton (Me')
The lowest point on the MSP of the soft tissue chin
- 16.3 *Me/ Me'A direct perpendicular*

- 17.1 **Gonion (Go)**
The mid point of the angle of the mandible between the body and the ramus.
- 17.2 Gonion (Go')
The most lateral point of the jawline in the mandibular angle.
- 17.3 *Go/Go' By definition Go is lateral and inferior to Go'*

- 18.1 **Zygion (Zy)**
The instrumentally determined most lateral point in the zygomatic arch.
- 18.2 Zygion (Zy')
The most lateral point on the cheek
- 18.3 *Zy/Zy' A Direct lateral perpendicular*

The different cephalometric and craniometric landmarks with their co-relation from frontal and lateral perspectives are shown diagrammatically in Fig 2 and Fig 3 whilst the selected anthropometric landmarks from a lateral and a frontal perspective are shown in Fig 4. George (1993)

The paired craniometric points lateral to the mid-sagittal plane

- 1 Euryon (eu)
The two points on the opposite sides of the skull that form the termini of the lines of the greatest breadth.
- 2 Porion (po)
The uppermost lateral point in the margin of the external auditory meatus.
- 3 Mastoidale (ms)
The lowest point on the mastoid process.
- 4 Dacryon (d)
The point on the medial wall of the orbit at the junction of the lacrimomaxillary suture and the frontal bone.
- 5 Lacrimale (la)
The point of intersection of the posterior lacrimal crest with the frontolacrimal suture
- 6 Maxillofrontale (mf)
The point of intersection of the anterior lacrimal crest with the frontomaxillary suture.
- 7 Alare (al)
The instrumentally determined most lateral point of the nasal aperture
- 8 Orbitale (or)
The lowest point in the margin of the orbit.
- 9 Zygion (zy)
The most lateral point on the cheek
- 10 Ectoconchion (ec)
The point of maximum breadth on the lateral wall of the eye orbit.
- 11 Ectomolare (ecm)
The most lateral point on the outer surface of the alveolar margin.
- 12 Pterion (pt)
The upper end of the greater wing of the sphenoid.
- 13 Endomolare (enm)
The most medial point on the inner surface of the alveolar ridge, opposite the middle of the second upper molar tooth.
- 14 Condylion laterale (cdl)
The most lateral point on the condyle of the mandible.
- 15 Gonion (go)
The mid point of the angle of the mandible between the body and the ramus.
- 16 Frontotemporale (ft)
The most medial point on the incurve of the temporal ridge.

Cephalometric measurements that do not have craniometric counterparts

Cheilion (Ch)

The point located at each labial commissure.

-/Ch The Chelion has no direct cr point, lateral view projects to the maxillary canine tooth, frontally in between canine and the premolar.

Ectocanthion (Ec)

The point at the outer commissure of the palpebral fissure just medial to the malar tubercle

-/Ec No direct cr point projects into the orbit just medial to the malar tubercle

Endocanthion (En)

The point at the inner commissure of the palpebral fissure.

-/En No direct cr point. It is important to note that the medial canthus is lower in the orbital projection than the lateral canthus.

3.3 COMPARISON OF SOMATOMETRY AND CEPHALOMETRY

In matching an unknown skull against a limited number of photographs, determination of the race, sex and age would make the task easier, as these factors will limit the number of probabilities. If an unknown skull could be initially confirmed to be of a Caucasian female of more than 25 years and the examination of other skeletal features suggest, that the female should have had children, then the photographs of missing persons, to be compared with this particular skull, should be limited to Caucasian females over 25 years of age with children. To obtain a life size photograph or to enlarge or reduce the available photograph to the life size of the suspected missing person would be the starting point for comparison. Different authors have indicated different methods for determining the degree to which the existing photograph should be adjusted, for a one to one comparison with the skull. The commonest ones are to find outside structures, or items worn by the missing person, which would enable the photographer to modify the photograph to the same size.

Some authors even describe using the same photographer and the same equipment for the modification of the photograph. The writer is of the opinion that this is neither a scientific nor a realistic approach, as at most times these prerequisites cannot be met. Under such a situation, the forensic expert is left with three alternatives where two 2D images are compared:

- 1 First alternative would be to try to match cephalometric measurements with modified known somatometric measurements. The cephalometric measurements are obtained by standard radiographic procedures, or by physical measurements from the unidentified skull, and the somatometric ones are from the known photographic material.
- 2 The second alternative would be to obtain the tilts, rotations, flexions and extensions mathematically or by visual judgments (the former being more scientific), place the skull in a similar position, and obtain an unorthodox radiograph for comparison.
- 3 The third would be to reconstruct the face using the accepted tables of tissue thickness and to match a photograph of the reconstructed face with the available photograph.

3.4 CRANIOMETRIC MEASUREMENTS

Craniometric measurements refer to the distance between two craniometric landmarks. Various anatomists and anthropologists have established relationships between distances expressed as percentages taking two or three measurements at a time, whilst others have used varying degrees of statistically recognisable combinations of different measurements for this purpose. Bass (1987)

The most commonly used lengths in craniometry are 22 in number and are listed below.

- | | | |
|---|-------------------------|--|
| 1 | Maximum length | - from glabella to opisthocranium. |
| 2 | Maximum breadth | - from eurion to eurion. |
| 3 | Basion to Bregma height | |
| 4 | Porion Bregma height | |
| 5 | Basion Porion height | |
| 6 | Auricular height | - from porion to the apex. |
| 7 | Minimum frontal breadth | - from fronto temporale to fronto temporale. |

FACIAL SKELETON

- | | | |
|----|---------------------|--|
| 8 | Total facial height | - from nasion to gnathion. |
| 9 | Upper facial height | - from nasion to alveolare. |
| 10 | Facial widths | - The greatest breadth between the zygomatic arches. |

NOSE

- | | | |
|----|---------------|-------------------------------|
| 11 | Nasal height | - from nasion to nasospinale. |
| 12 | Nasal breadth | - from alare to alare. |

ORBIT

- | | | |
|----|-----------------|--|
| 13 | Orbital height | - maximum height from the upper to the lower border. |
| 14 | Orbital breadth | - from maxillofrontale to ectochonchion. |

PALATE

- | | | |
|----|------------------------------------|---|
| 15 | Maxillo-Alveolar length | - from prosthion to alveolan. |
| 16 | Maxillo-Alveolar breadth | - from ectomolare to ectomolare. |
| 17 | Palatal length | - from orale to staphylion. |
| 18 | Palatal breadth | - from endomolare to endomolare. |
| 19 | Bicondylar breadth | - from condylion to condylion. |
| 20 | Bigonial breadth | - from gonion to gonion. |
| 21 | Height of the ascending ramus | - from gonion to uppermost part of condyle. |
| 22 | Height of the mandibular symphysis | - from gnathion to infradentale. |

4 METHODS OF THE IDENTIFICATION OF THE UNKNOWN SKULL

4.1 FACIAL RECONSTRUCTION

An Englishman at first sight may find it difficult to identify one Negro from another and similarly all white men will appear to be the same at first sight to a Negro. It is difficult to locate two people other than identical twins with same facial characteristics. This is because "the face is specific to an individual". The establishment of a relationship between a skull and a face is the starting point in the identification process of an unknown skull. It has been documented that even the suture patterns of skulls are specific, in a study of 300 skulls where no two skulls showed the same type of sutures. (Chandra 1985)

Under the circumstances a reconstruction of a face is an attempt at creating one of specificity by using standard measurements and accepted proportions. The intention of the writer at this stage is to give the reader a clear understanding of the method of reconstruction of the face. Even after using the tissue thickness tables of Krogman and Iscan (1986) given in Table 1, the facial proportion cannons of George (1993), the face to skull relationships put forward by Fedosyutkin and Nainys (1993) as guidelines it is very unlikely that a sculptor would be able to reconstruct a face with precision.

It is doubtful whether two sculptors without any artistic talents, using all the principles and guidelines put forward by different authors, could produce the same face using two identical models of one skull. Even if they do it might still differ from the actual face of the owner of the skull, showing the inconsistency of the method of identification of an unknown skull by facial reconstruction.

Table 1 Soft Tissue Thickness Table
Source Krogman and Iscan (1986)

O'GRADY AND TAYLOR (1990)														
DEPTH SITES	WELCKER (1883)	HIS (1895)		KOLLMAN & BUCHLY (1898)		SUZUKI (1948)		RHINE & CAMPBELL (1980)		MALE		FEMALE		
												THIN	WELLNOURISHED	
GERMANS	M	F	M	F	M	F	M	F	AV	SD	AV	SD		
OCCIPITAL	6.8													
MIDDLE OF PARIETAL	5.3													
UPPER FORFEHEAD HAIRLINE		4.06	4.16	3.07	3.02									
MIDDLE OR FOREHEAD	4.3					3.0	2.0	4.75	4.6	4.6	1.4	2.5	1.1	
GLABELLA		5.10	4.75	4.29	3.90	3.8	3.2	6.25	6.25	6.6	2.0	4.8	1.2	
NASION / NASAL ROOT	5.9	6.55	5.0	4.31	4.1	4.1	3.4	6.00	5.75	6.8	1.2	4.9	1.0	
MID NASAL BONE	3.3	3.37	3.0	3.13	2.57					3.3	1.3	2.7	1.1	
TIP OF NASAL BONE	2.2			2.12	2.07	2.2	1.6	3.75	3.75	3.9	1.6	2.5	0.8	
MID PHILTRUM AKANTHION		11.49	9.75	11.65	10.1			12.25	11.25	12.9	4.1	8.9	2.1	
UPPER LIP MARGIN PROSTHION	11.0	9.51	8.26	9.46	8.1			14.0	13.0	11.0	3.0	7.3	2.7	
MENTAL SULCUS	10.6	10.26	9.75	9.84	10.95	10.5	8.5	12.0	12.0	11.9	2.9	10.4	1.3	
MENTAL EMINENCE	8.5	11.43	10.75	9.02	9.37	6.2	5.3	12.25	12.25	9.1	2.3	5.4	1.0	
BENEATH CHIN		6.18	6.5	5.98	5.86	4.8	2.8	8.0	7.75	9.4	3.3	5.3	1.3	
MILD SUPRA - ORBITAL		5.89	5.6	5.41	5.15	4.5	3.6	4.75	4.50	8.0	1.6	5.4	1.3	
MID SUB - ORBITAL		5.08	5.25	3.51	3.65	3.7	3.0	7.5	8.5	11.6	4.4	5.6	1.9	
LETERAL ORBIT						5.4	4.7	13.0	14.25	13.0	5.0	7.7	1.9	
MID ZYGOMATIC ARCH				4.33	5.32	4.4	2.9	8.75	9.25	10.3	3.7	6.3	2.3	
SUPRA GLENOID / BASE OF		6.07	6.75	7.42	7.1			11.75	12.0	13.3	4.4	7.6	3.8	
ZYGOMATIC ARCH														
IN FRONT OF MASSETER		8.65	8.1	7.76	6.16					13.5	4.8	9.0	3.2	
MID RAMUS		18.05	17.05	17.01	14.83					24.3	6.2	14.3	2.7	
GONION		12.21	11.5	8.72	7.56	6.8	4.0	14.25	14.25	15.5	7.1	8.3	2.2	

Farkas and Munro (1987) after an extensive study on North American and Western European Caucasoid children have established a relationship between standard anthropometric measurements. These proportions, which were condensed to seven canons of facial proportions, are given below.

- 1 Facial Height Cannons
 - (a) Two section division
 $V' - N' = N' - Me'$
 - (b) Three section division
 $Tr - N' = N' - Sn = Sn - Me'$
 - (c) Four section division
 $V' - Tr = Tr - G' = G' - Sn = Sn - Me'$

- 2 Naso-labio-mental proportions
 - (a) Three section division
 $Sn - Sto = Sto - Ils = Ils - Me'$
 - (b) Four Section division
 $Sn - Sto = Sto - Ils = Ils - Pog' = Pog' - Me'$

- 3 Orbital proportion cannon
 Distance between the eyes is equal to the width of an eye
 $En - En = Ec - En$

- 4 Orbito-nasal proportion cannon
 Distance between the eyes is equal to the width of the nose
 $En - En = Al' - Al$

- 5 Iridio-oral proportion cannon
 The width of the mouth is equal to the distance between the two iridio-cheilial lines: the distance between the medial edges of the irides.

- 6 Facial triangle
 The triangle formed between the lateral canthi, and the midpoint of the lower lip is equilateral, i.e. $Ec. Ec. Li$

- 7 Facial X
 Lines drawn from the lateral canthi to the corners of the mouth will cross very close to Sn

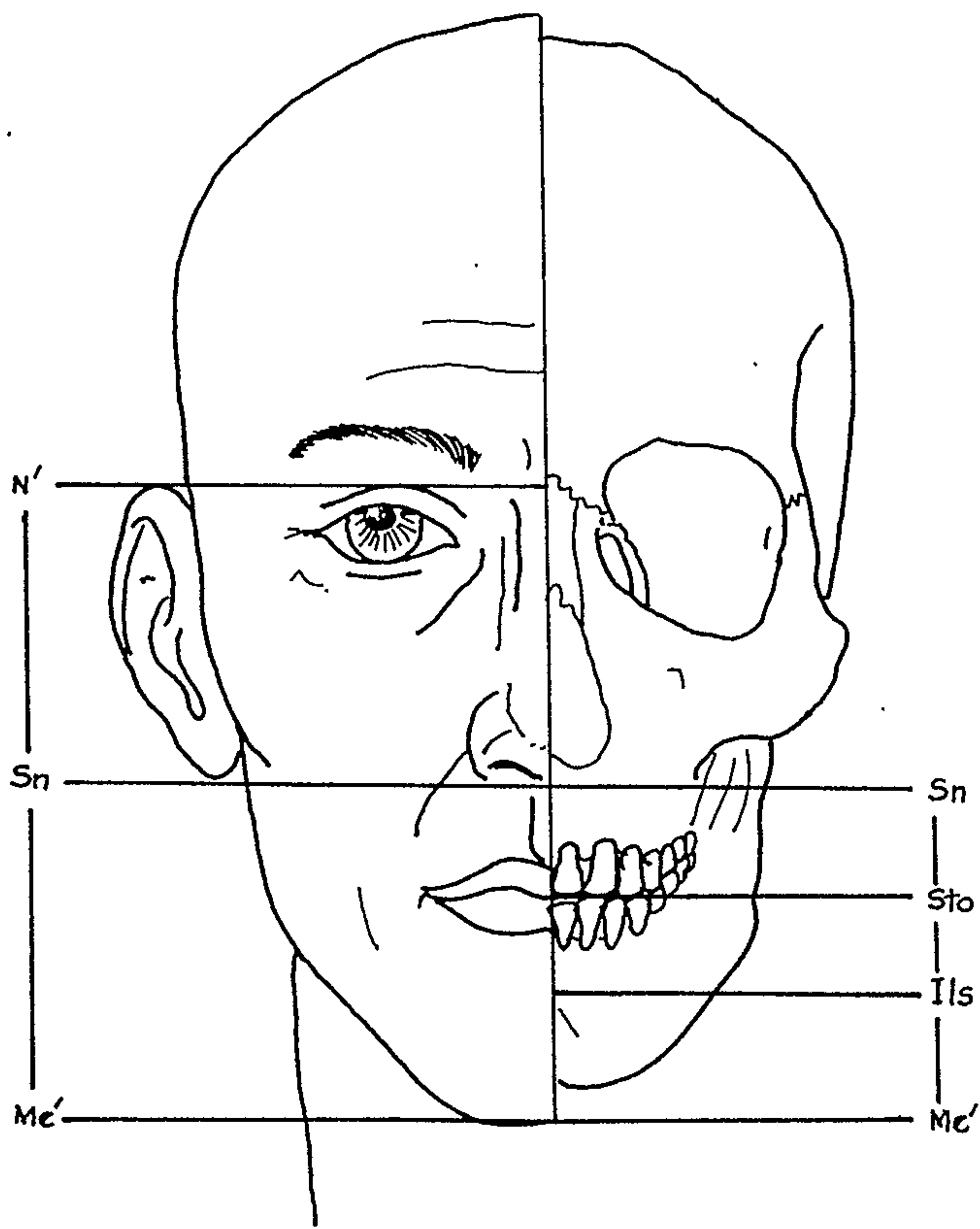


**Fig 5a Facial height
Naso labial mental proportion**

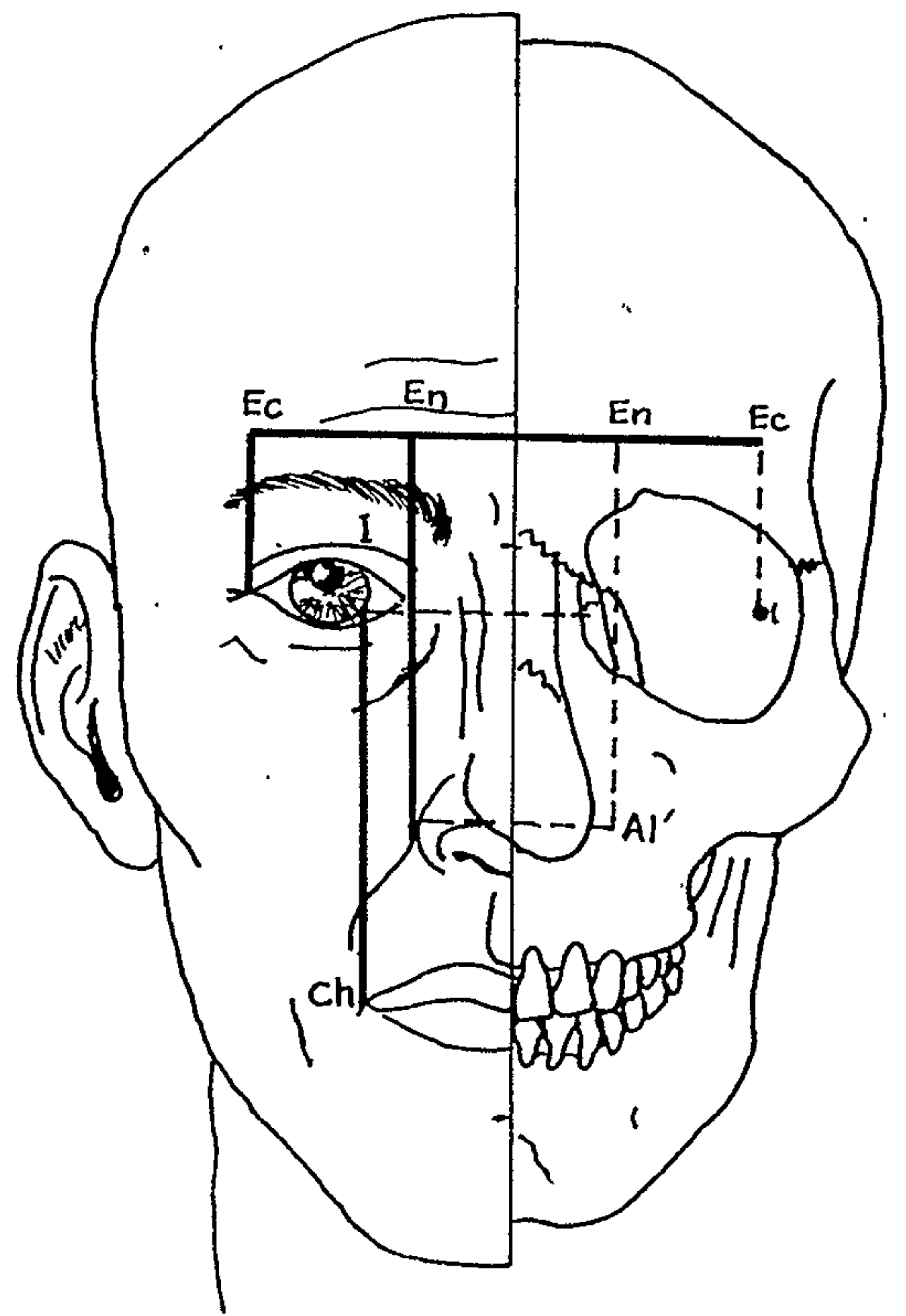


**Fig 5b Facial height
Orbital proportion**

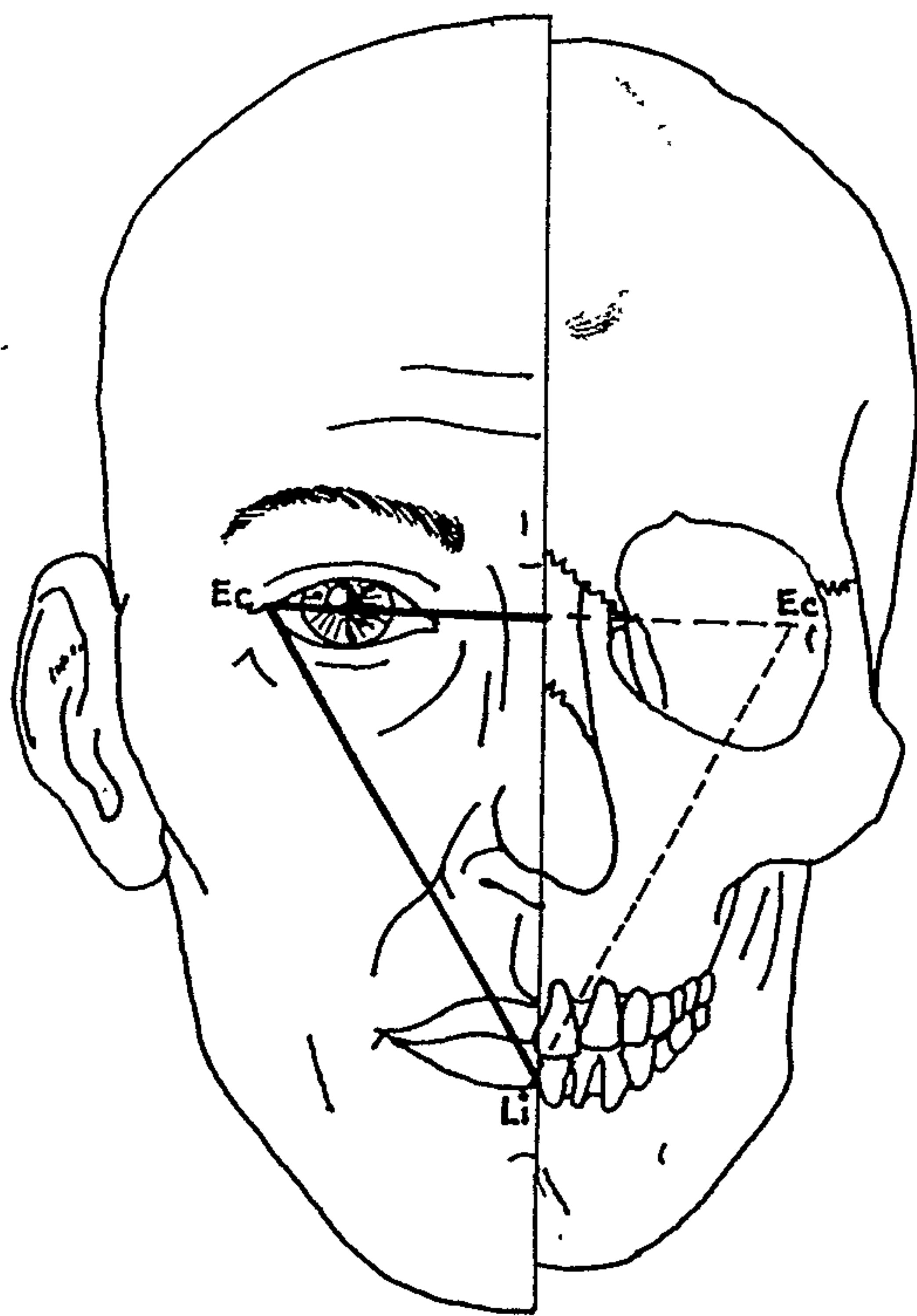


Fig 5c Facial triangle

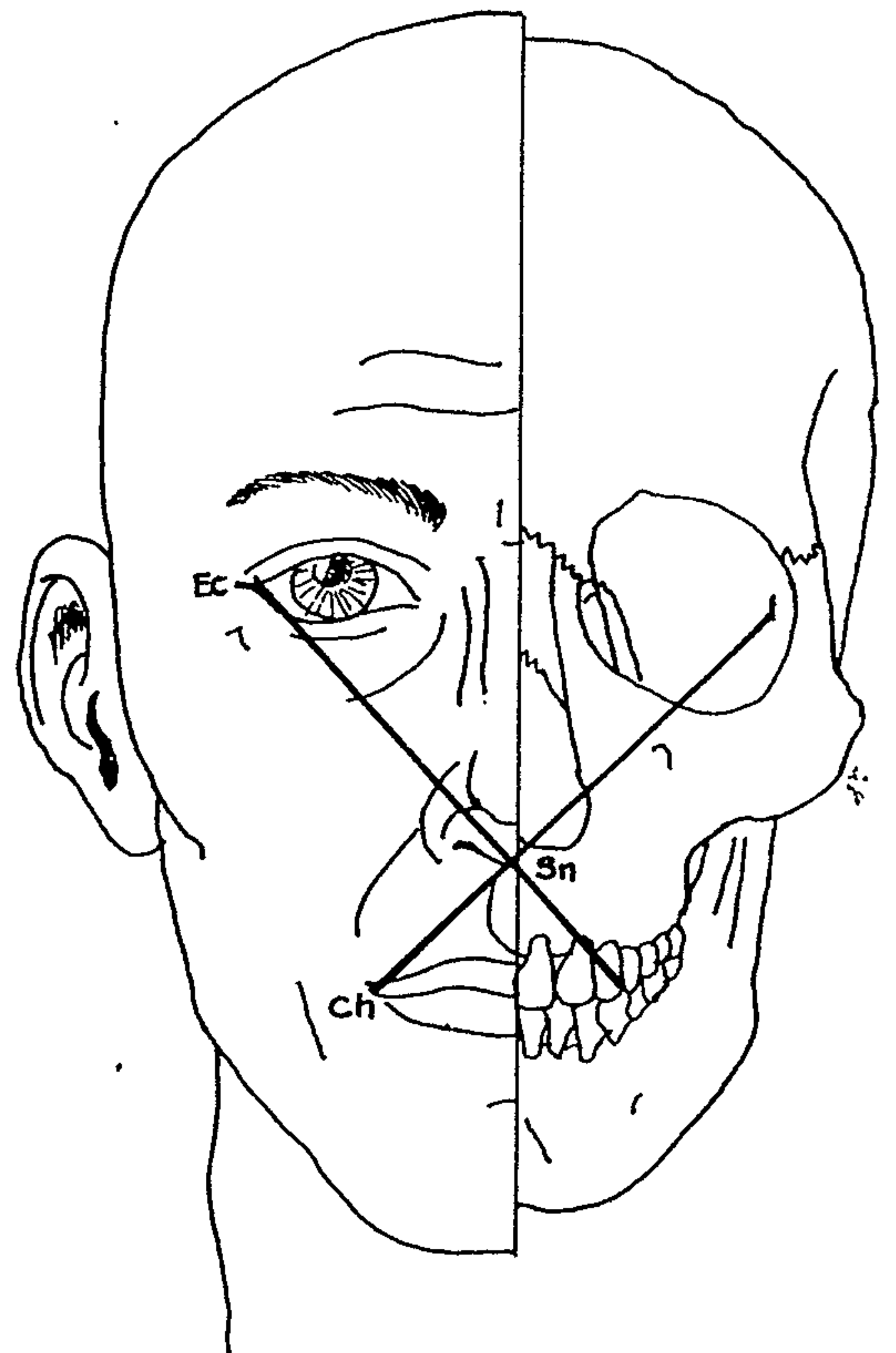


Fig 5d Facial X

Source George (1993)

The diagrammatic representations condensed from "Anatomical and Artistic Guidelines for Forensic Facial Construction" by **George (1993)** are given in **Fig 5**.

Fedosyutkin and Nainys (1993) have established 33 inter-relationships of the skull and the face, which are summarized below. A pictorial presentation is given in **Fig 6 to Fig 12** condensed to three pages for easy reference.

- 1 **The shape of the upper head** depends on the width of the forehead, the height of the transverse arc, the protrusion of the sincipital tubercle, and is divided into four: hemisphere, pentagonoid, oval and rectangular. **Fig 6a**
- 2 **The hairline** is the transition of the smooth surface of the forehead bone into smooth rough tubercles above the forehead.
- 3 **The hairstyle** depends on the available information, in the absence of which it is preferable to presume a short haircut.
- 4 **The shape of the temporal lines** gives an indication of the slope of the forehead, protrusion of the bridge of the nose, and the upper part of the brow ridge.
- 5 **The lower part of the face** contours the mandible. **Fig 6b**
- 6 **Angle of the mandible** If the gonial angle is >125 and the coronoid process is high, the lower part of the face would be oval or triangular, angles less < 125 and with low coronoid process will suggest a rounded or a rectangular face. **Fig 6c**
- 7 **The presence of convexities** in the lower margins of the mandibular body warrants suitable projections during retouching. **Fig 6d**
- 8 **The degree of elevation** in the frontal part of the mandible, and the widths of its base define the width of the chin. **Fig 6e**
- 9 **The decrease of the height** of the mandibular body, from the chin triangle to the side of the rami will produce a high chin. **Fig 7a**
- 10 **Averted gonial regions** of the mandible are associated with the wide variants of the lower face **Fig 7b**

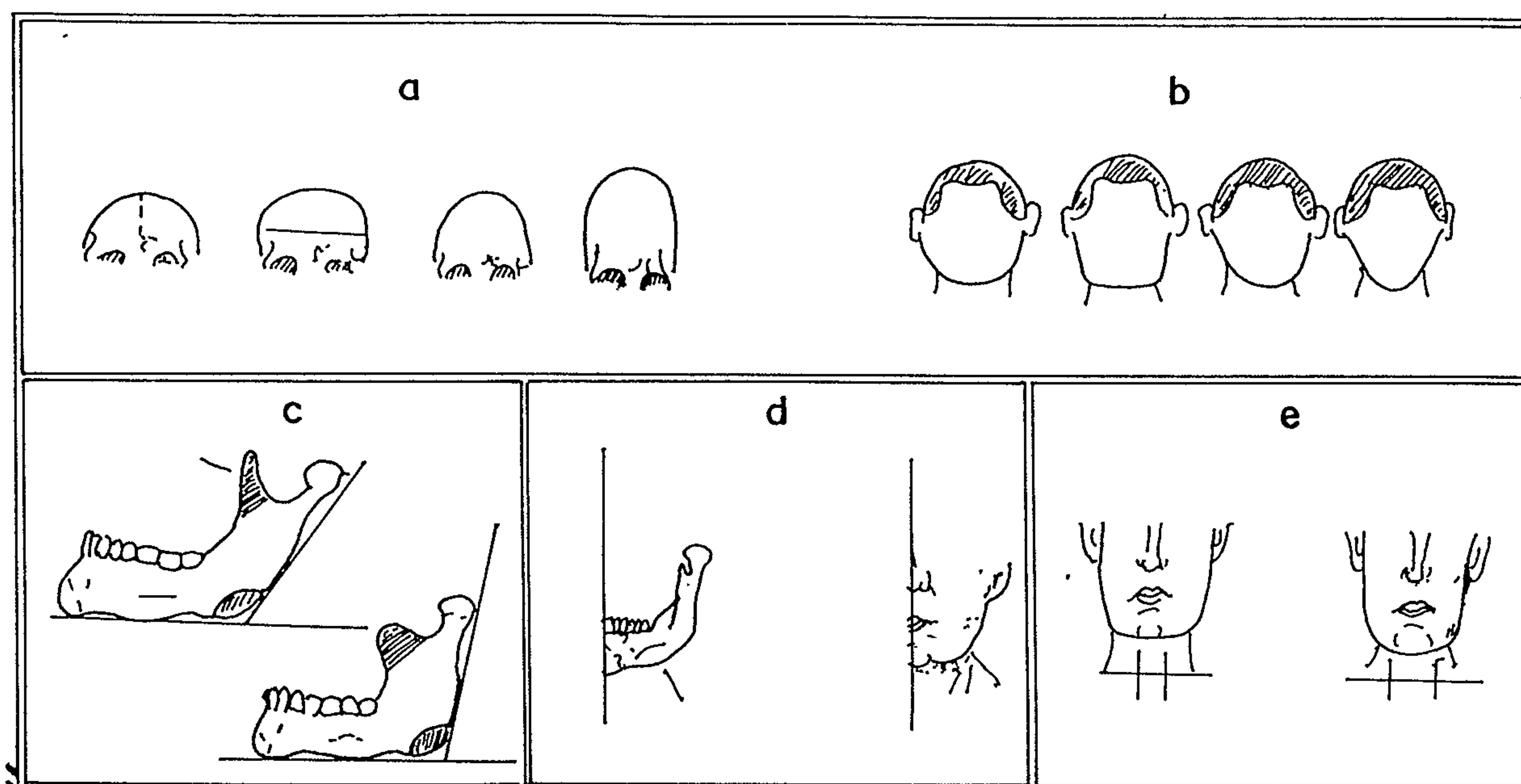


Fig 6 a-shapes of transverse arc, b-basic face shapes rounded square oval and triangular, c-mandibular structure narrow (left) and wide (right), d-convexities of the lower lateral margin of the mandibular bone and their appearance in the face, 6e-the width of the base of the chin triangle narrow chin (left) wide chin (right)

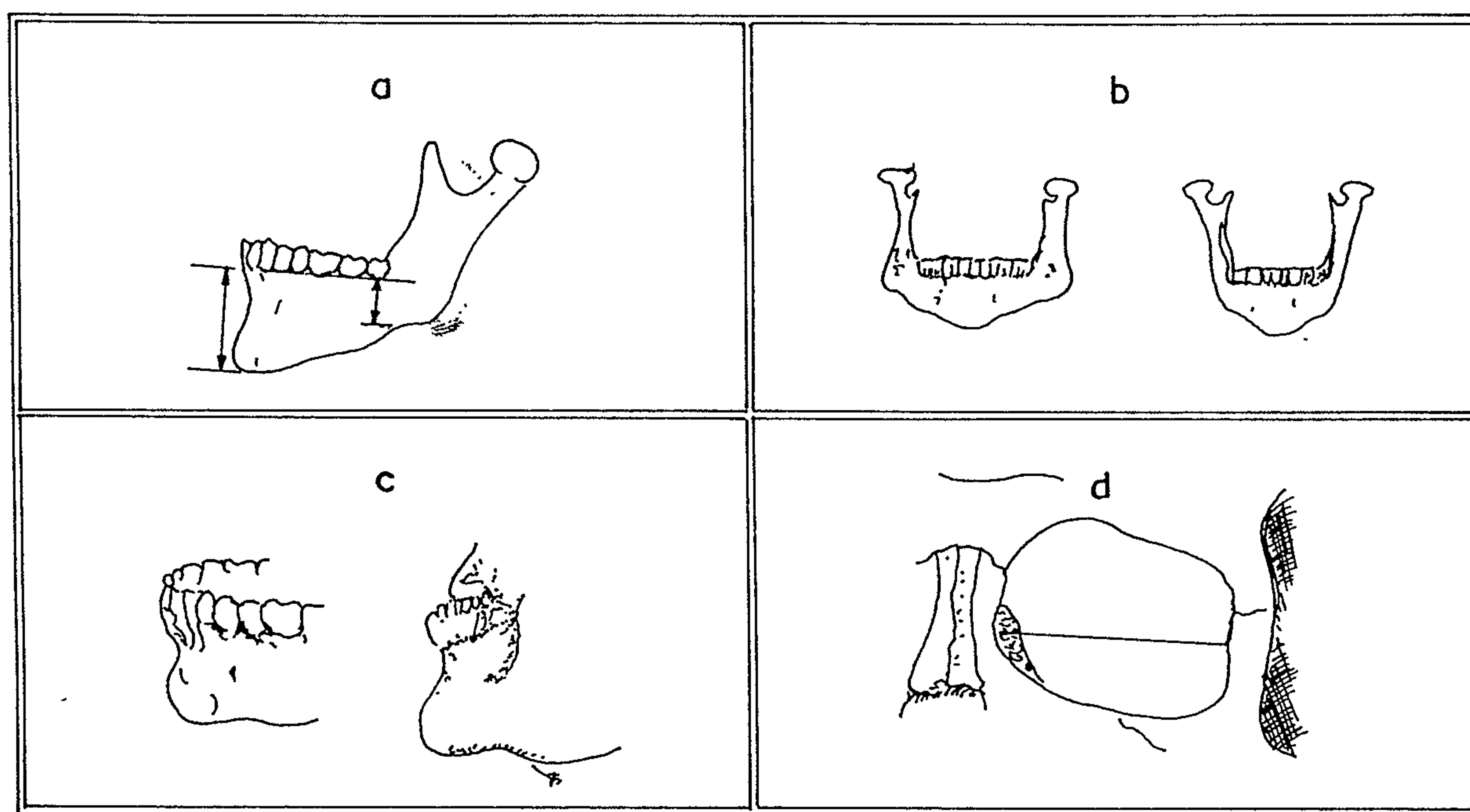


Fig 7 a-narrow face characterised by decrease in the height of the mandibular body from front to back, b-the degree of gonial eversion of the mandible, c-pronounced development of the alveolar edge of the mandible, d-location of the eye slit

Source : Fedosyutkin and Nainys(1993)

- 11 **Frontal edge of the alveolar arc** if well developed will give an estimated projection of the lower lip. **Fig 7c**
- 12 **The location of the eye** is generally on the straight line that connects the malar tubercle with the base of the anterior lacrimal crest. **Fig 7d**
- 13 **The length of the eye** is 60 - 80 % of the width of the orbit.
- 14 **The protrusion of the eyeballs** depends on the depth of the orbital cavity, vertical inclination of the orbit, and the thickness and the degree of the overhang. **Fig 8a to Fig 8c**
- 15 **Deepest eye impressions** are produced by well-developed brow ridge and bridges of the nose.
- 16 Wide opening eye slit with protruding eyeballs, by weak orbital profile, coupled with a smooth thickened outer rim.
- 17 **The nature of the fold of the fixed part of the upper eyelid.** The direction of the upper rim of the orbit. **Fig 9a to Fig 9d**
- 18 **Over hanging eyebrows,** are produced by strong developed supra orbital margin **Fig 9a and 9b**
- 19 **The brow ridge and the bridge of the nose, which also defines the arrangements, determine the arrangements and the variations of the eyebrows.** **Fig 9c**
- 20 **The arrangement of the eyebrow** over the supra orbital rim is decided by the thickening of the supra orbital rim and a strong brow ridge **Fig 9d**
- 21 **The tragus of the ear** corresponds to the upper rim of the external auditory meatus. **Fig 10a to Fig 10d**
- 22 **The height of the ear** equals the height of the nose. The protrusion of the ear can be upper lower or total. When it is upper the supramastoid crest on the temporal bone is strongly developed, and protrudes. With lower protrusion the outer surface of the mastoid process is rough. If all are present then there is total protrusion.

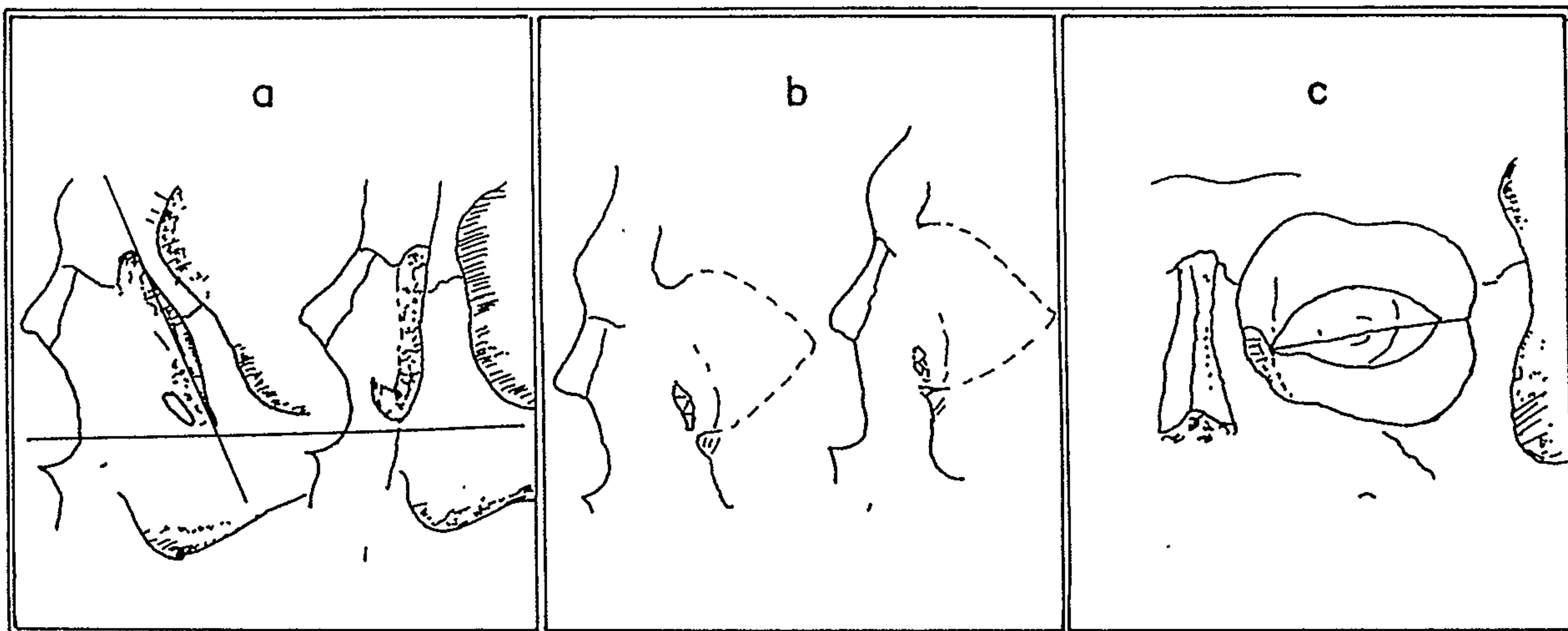


Fig 8a - vertical profiling of the orbit strongly angled (left) and weakly angled (right) **8b**- characteristics of the upper margins of the orbit thickened over hanging rim (left) and narrow rim (right) **8c**-placement of the eye in the orbit

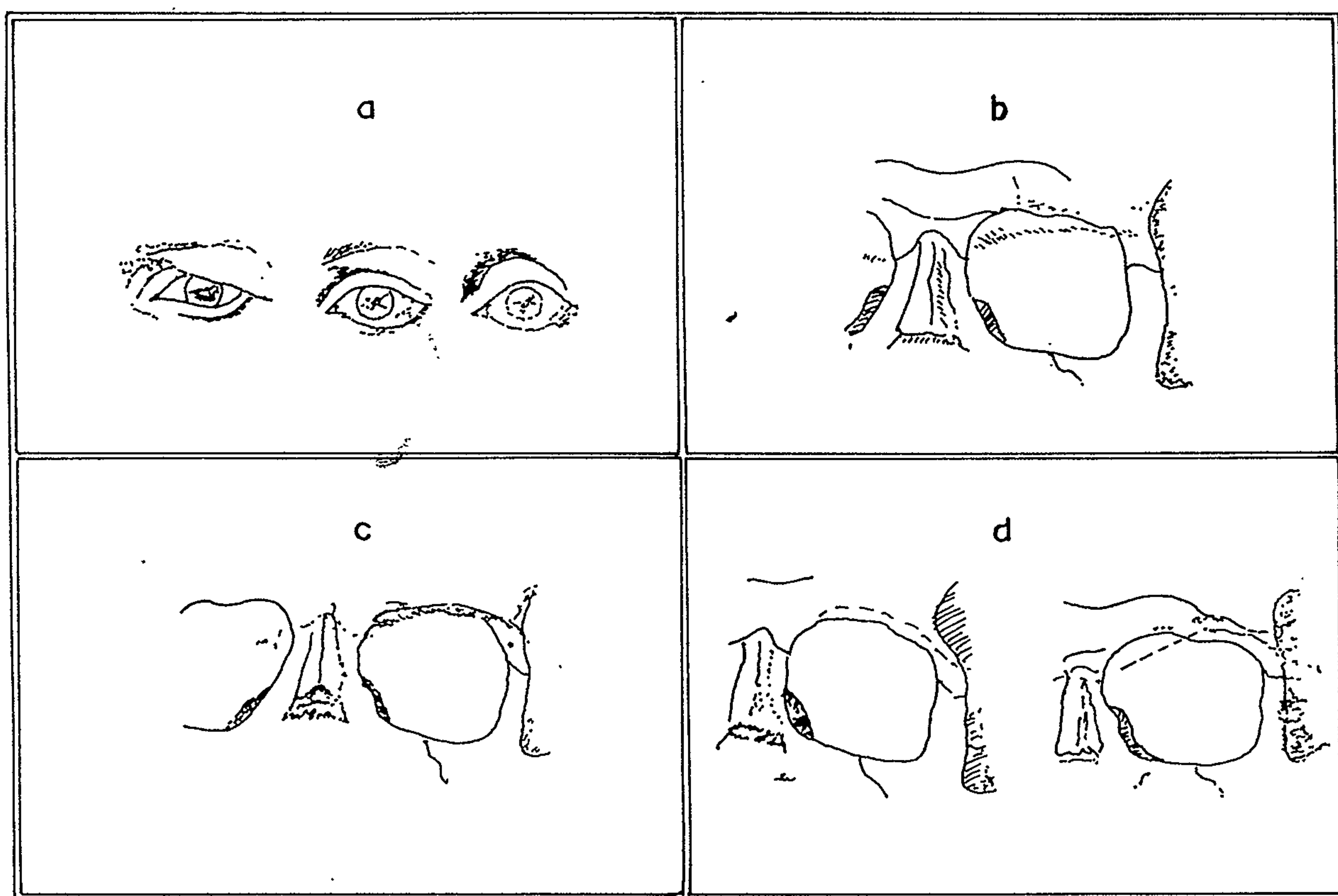


Fig 9a - direction of the overhang fold of the upper eyelid, arrangement of the eyebrow with strongly, **9b** and weakly **9c** pronounced superior orbital margin **9d** - form of the upper rim of the eye brow: arced (left) and triangular (right)

Source : Fedosyutkin and Nainys(1993)

- 23 **The lobe of the ear** is attached if the mastoid process is directed downwards, and is free if the mastoids point forward. **Fig 10b and Fig 10c**
- 24 **The width and the height of the curvatures of the cheekbones** define the width and the profile of the face. **Fig 10d**
- 25 **The nose-cheek fold** extends from the upper end of the nostril towards the first molar. The variables are depth of the canine fossa, the degree of horizontal face profiling, and the projection of the frontal surface of the cheekbones and the presence or the absence of teeth.
- 26 **The height of the nose** equals the distance from the Nasion to 1 -2 mm below the nasal spine. The width is defined as the midpoints of the canines, or alveoli, **Fig 11a**. The width of the nasal ridge is 1 -2 mm more than the width of the nasal bones.
- 27 **The shape of the bony ridge** could be straight, prominent, concave or wavy. The base of the nose could be horizontal, elevated or prolapsed. **Fig 11b and Fig 11c** The position of the base of the nose follows the direction of the central part of the nasal spine.
- 28 **The tip of the nose** is at the point where the imaginary lines extended from the ridge of the nasal bones and the spines cross. A wide tip correlates with a short wide and groovy nasal spine and low wide nasal foramen. A narrow tip is when the nasal spine is long narrow and pronounced, and when the nasal foramen is long and narrow. **Fig 12a**
- 29 **The wing of the nose** begins at the lateral edge of the piriform foramen at the level of the nasal spine. An exposed nasal septum is characteristic of a crest shaped base of the nose. **Fig 12b**
- 30 **The closed mouth** is at the level of the upper edge of the anterior teeth. The width equals to the distance between the mandibular second molars.
- 31 **The width of the philtrum** corresponds to the distance between the midpoints of the upper central incisors. **Fig 12c**
- 32 **The muzzle area** protrudes forwards in prognathism, the upper lip protrudes than the lower lip in maxillary prognathism, and the lower lip protrudes past the upper one in a reverse situation or in a underbite or an edge to edge occlusion.

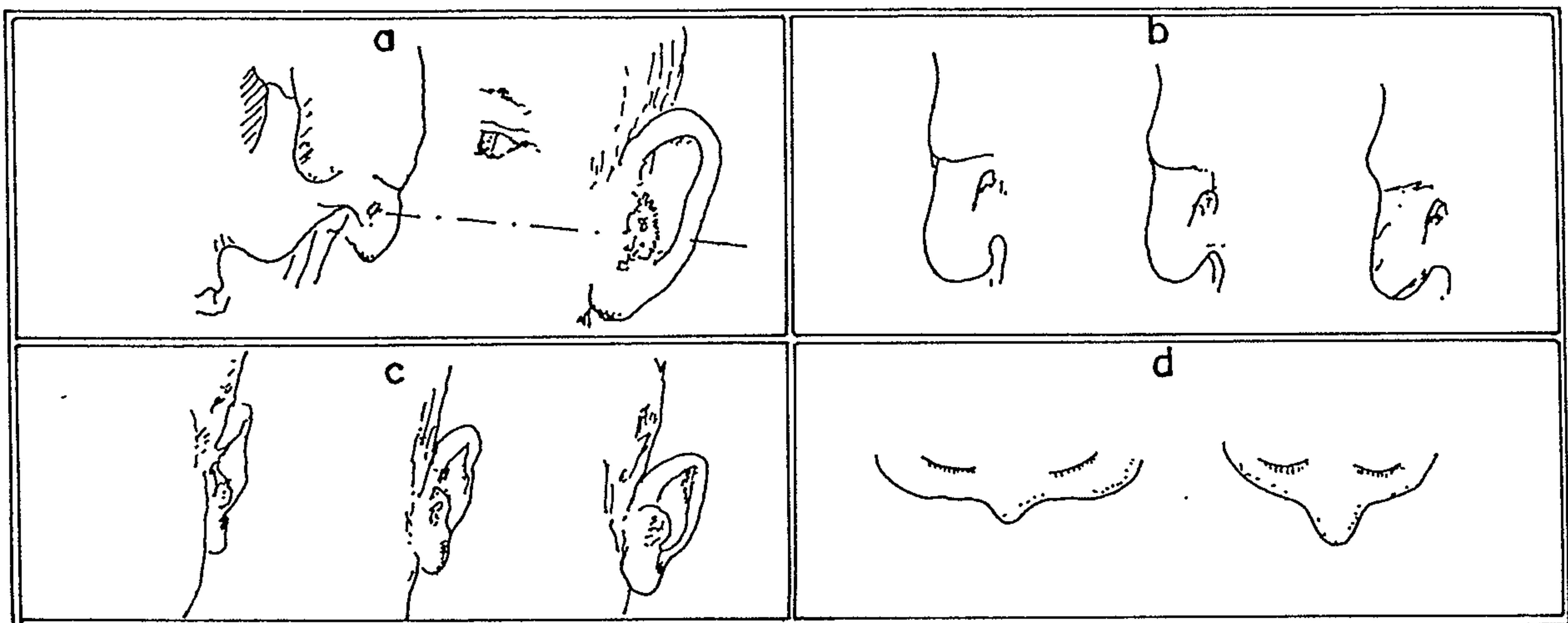


Fig 10a - placement of the ear in relation to the external auditory meatus, b - different degrees of protrusion of the supra mastoid crest, the outer surfaces of the mastoid crest weak (left) moderate (middle) and strong (right), c - protrusion of the ears; weak (left) moderate (middle) and strong (right) d - horizontal profile of the face : weak (left) strong (right)

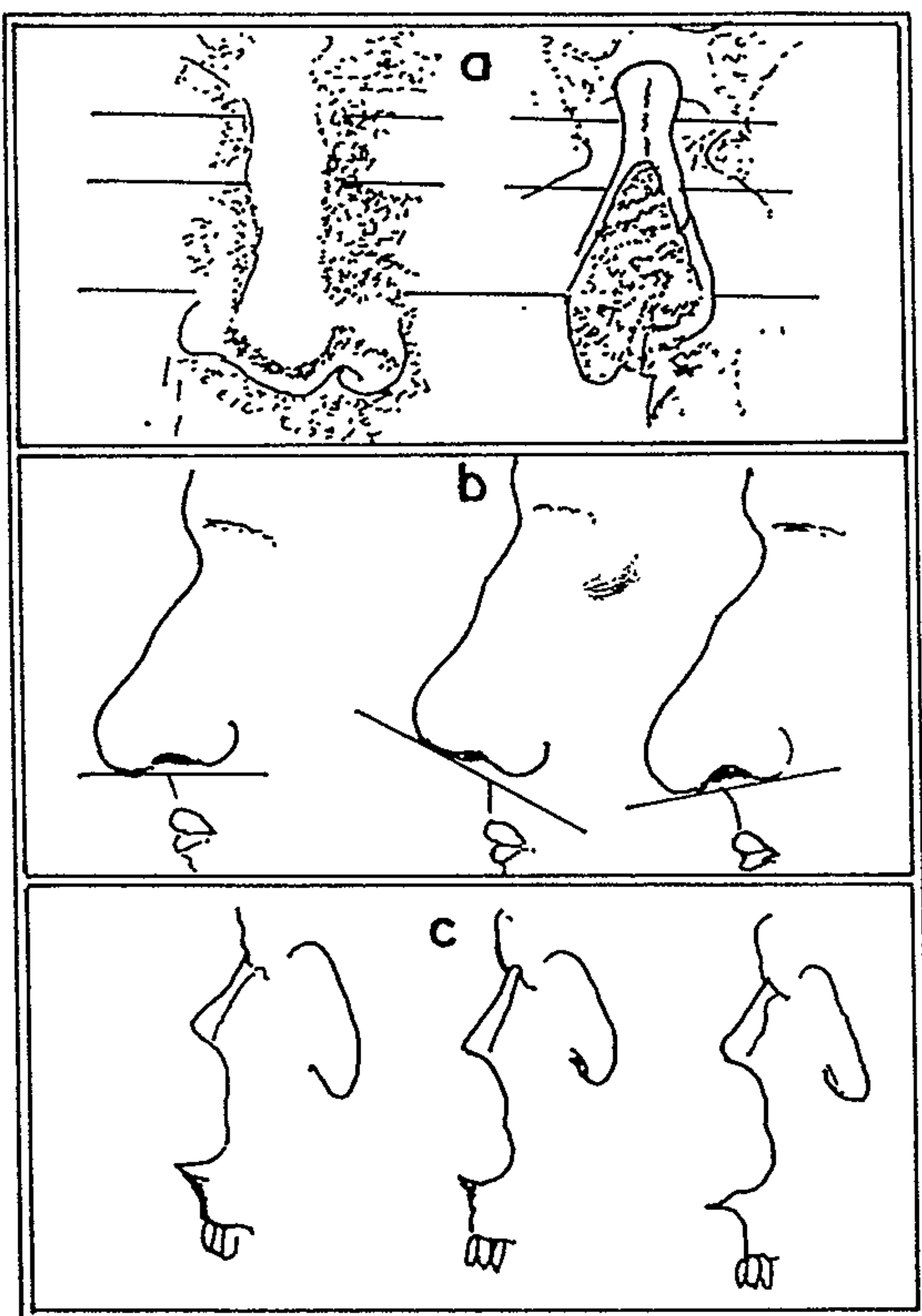


Fig 11a- the width of the nose b- position of the base of the nose: horizontal (left), elevated (middle) and prolapsed (right), c- shapes and the direction of the nasal spine: horizontal (left) elevated (middle) and prolapsed (right)

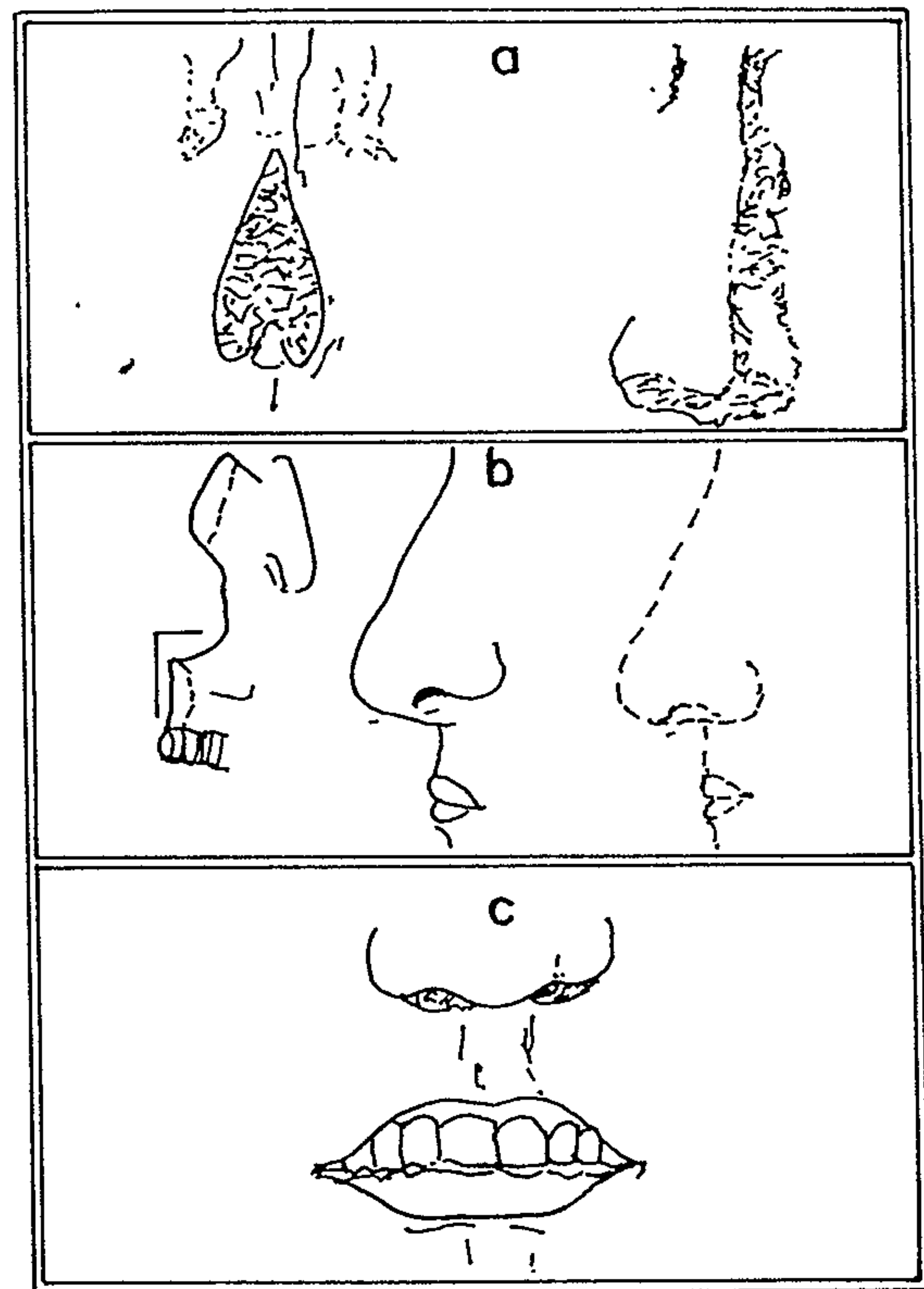


Fig 12a- shape of the piriform foramen and corresponding nose form b- exposed nasal septum and form of columella: crest shaped (solid line) straight (double line) c- mouth width, lip height the relationship of the philtrum and the central incisors

Source : Fedosyutkin and Nainys(1993)

- 33 **The direction of the line between closed lips** generally take the direction of the line formed when the teeth are closed.

Three-dimensional facial construction from a skull is a method that could produce a likeness of an individual, which may enable a relative or an acquaintance of a deceased to provide a clue for a final identification. After the reconstruction of a face, the introduction of hairstyles with reference to colour and length is best achieved by computer software, on the scanned image of the reconstructed face.

The first step suggested is the determination of the race, sex, age and stature by a careful examination of the skeletal remains. The next step suggested is a thorough skull examination based on the guidelines suggested by **George (1993)** which were shown previously in **Fig 5** with particular emphasis on the prominence and the texture of muscle attachments. Most workers suggest that a duplication of the skull should be done to avoid damage to the skull, to make it available for reference during construction, to make multiple models and to enable the skull to be returned if there is a requirement to do so. There are different methods of duplication of skulls and the method of choice is the split cast technique to obtain an accurate working model.

The mandible is secured, with or without teeth, in the approximated position of occlusion. (which is crucial in the determination of the facial height). All the undercuts and apertures are blocked out using modeling clay. The prosthetic or plaster eyes are fixed based on the concept that the centre of the pupil is in line between the midpoints of the superior and inferior orbital rims. The basis of the reconstruction is the use of average thickness for given anatomical landmarks. Stainless steel wires are fixed onto these landmarks and cut to size depending on the appropriate thickness. Some sculptors suggest the use of matchsticks, with the coloured end pointing out, as these could be seen through a thin layer of clay. By using this as the starting point and using the 34 guidelines and the seven facial canons of relationships, individual muscles are placed in a systemic order. Most sculptors prefer to start with the temporalis, masseter, buccinator and the occipito frontalis, followed by orbicularis oculi and orbicularis oris. The construction of the lips, nose and the ears is best done purely in a non-artistic fashion using only the scientifically accepted relationships.

4.2 PHOTOGRAPHIC SUPERIMPOSITION

Superimposition means the placing of one image on another. The starting point for photographic superimposition is the availability of a photograph of known magnification to be compared with a skull. Basically a living person could only tilt his head, side ways, forwards or backwards or could rotate his head round a central axis. But when photographs are taken these changes in posture will result in different somatometric measurements.

The somatometric measurements that one could obtain from the photograph vary depending on the degree of rotation, extension or flexion and the tilt of the head at the time the photograph was taken. Though there are limitations in the rotation of the head, and the degrees to which a head could be tilted, it is still not an easy task to match an unknown three dimensional head with an available two dimensional photograph. If the photograph obtained is one without a tilt or a rotation or a flexion or an extension as it is taken in most studios for passports or portraits, the task of matching is easier than when there are tilts and rotations or other deviations.

Comparison of skulls and photographs can lead to identification of missing persons. The first attempts to identify skulls were by comparison with portraits, sculptured busts and death masks. **Welker (1867)** made comparisons of skull measurements of Dante, Shiller, and Kant. The first photographic comparison ending in a negative conclusion was carried out by **Lander in 1918** where by comparison she over ruled the possibility of a skull being that of a particular individual. The basic concept of superimposition was by making outline drawings of the skull and the portrait, to assess the coincidence of the outlines. One of the earliest superimposition was by **Pearson (1926)**, who matched the skull of George Buchanan with his portrait.

Pearson and Morant (1934) were the pioneers in photographic superimposition and their original work was on Oliver Cromwell's head. Using the head of the executed criminal a superimposition was made between the photographic portrait and the photograph of the skull to certify the accuracy of the method.

Glaister and Brash (1937) were of the opinion that it would have been easy to compare if the photograph of the skull was taken from the same distance as that of the original portrait. They used photographic superimposition techniques to corroborate existing evidence presented in the first documented case. Their method was by producing a positive image of the portrait and a negative image of the skull and then superimposing them on radiographic films, and producing prints from them. The negative of the portrait on the back of the camera was used as a focusing screen to determine the orientation and to get the correct size of the skull.

Magnification or reduction of photographs to life size needed mathematical precision. Known objects in the photograph were used initially for this purpose. **Simpson (1943)** used the inter-pupillary distance and the inter-orbital width as guidelines for photographic superimposition.

Gruner and Reinhard (1959) went a step further where cephalometric points were marked on both the skull and the ante-mortem photograph. A system of grid lines was drawn firstly from the points of the portrait on to a transparent acrylic sheet, and secondly from the skull to the second transparent acrylic sheet. By using the first acrylic sheet the exact pattern of the grid lines of the portrait were reproduced on to a sighting device. By using the sighting device and the acrylic sheet, the skull was oriented at the end of a suitably constructed optical bench. A double exposure photograph was then taken to record the superimposition first with the portrait attached to the acrylic sheet and the second with that of the correctly oriented skull minus the sighting device and the acrylic sheet.

Cocks in 1970 used anthropometric landmarks by marking them on both the photographs of the skull and the portrait, and subsequent by joining the points to produce a series of triangles. The pattern of triangles of the skull photograph was then compared with those of the portrait and it was found that a positive matching could be achieved.

Klonaris and Furare (1980) used similar superimposition techniques to compare the maxillary fragment, where an enlarged reverse contrast transparent radiograph produced from an ante mortem peri-apical radiograph was compared with the photograph of the maxillary fragment.

Thomas, Nortje and Van Ieperen (1986) projected a transparent image of the skull onto a life size enlargement of a photograph by placing the projector at the right distance for the projection of the identical size of the skull.

The recognition of the importance of the perspective was further strengthened by the work of **Iten (1987)** by his statement that the three dimensional objects appear differently on two-dimensional photographs, depending on the distance involved when pictures are taken.

The split beam technique of **Hashimoto (1991)** in Japan has been described in the thesis of **Taylor (1991)** who has had personal communication with Professor Hashimoto. The method is described next.

The skull to be identified was mounted on an adjustable stand and placed in front of a backdrop sheet of coloured cardboard at the end of a bench. A 9.0 mm square fine wire mesh screen mounted in a clear plexiglass sheet was positioned in front of the skull. A modified 35mm SLR camera was set at the opposite end of the bench.

The modification of the camera involved the replacement of the standard split image glass-focusing screen with an aerial image-focusing screen. Two mirrors, an optical mirror and a half mirror, were placed to the left and diagonal to the camera respectively. To the right of the camera a life-sized enlargement of the ante-mortem photograph was placed directly behind a 10-mm square fine wire mesh grid mounted in clear plexi glass.

The light source, which consisted of two 200-watt lamps, was positioned between the skull and the camera. The image of the ante-mortem photograph was reflected from the optical mirror and through the half mirror so that the image of both skull, and the portrait, could be seen through the viewfinder of the camera. Each image could be intensified or reduced by alteration of the light source.

The distances between the skull grids, mirrors, photograph and camera were determined according to the distance at which the ante-mortem photograph was taken. When these distances were correct the two grids appeared superimposed indicating the appropriate degree of magnification and an exact reproduction of the perspective incorporated in the ante mortem photograph.

This system enables the skull to be aligned against the photograph before an image is recorded and also takes into account the perspective incorporated in the ante-mortem photograph. After correct alignment was obtained, an image of the skull was recorded, subsequent to the removal of the half mirror. A negative transparency of the ante-mortem portrait was then overlaid onto a positive print of the skull. A sheet of white film was moved between the transparency and the print to highlight the comparison.

There was a doubt as to whether the distances between the skull grids, mirrors, photograph and camera determined according to the distance at which the ante-mortem photograph was taken made any appreciable difference in the comparisons. A diagrammatic arrangement of the mirrors is shown in **Fig 13 . (Hashimoto 1996)**

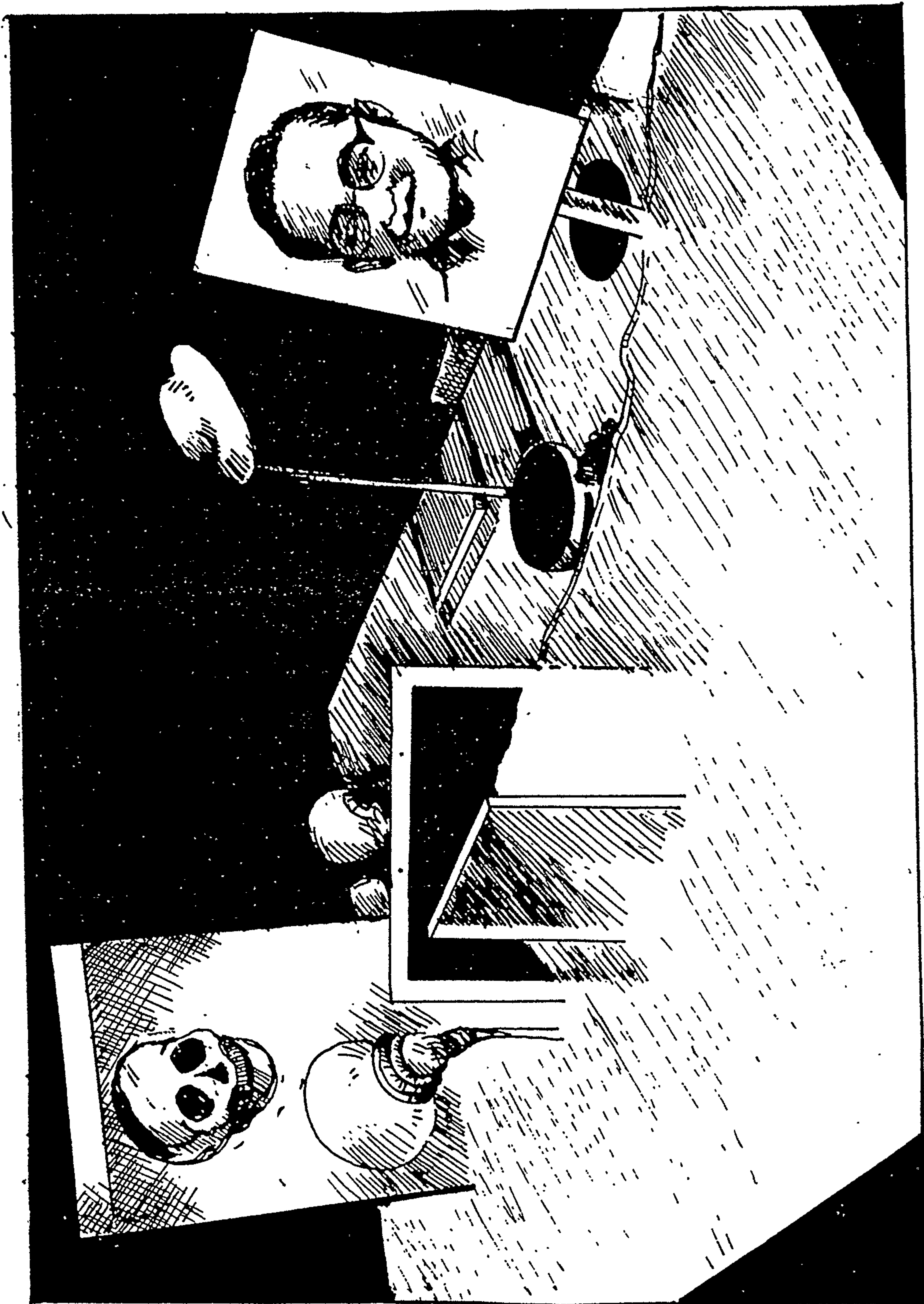


Fig 13 Diagrammatic representation of the lay out of mirrors

Hashimoto (1996)

4.3 VIDEO-SUPERIMPOSITION

Helmer and Gruner (1977a) pioneered the development of video-superimposition and promoted its use in the identification of skulls. They reproduced images of skulls and photographs on two monitors using two video cameras and electronically mixed them in overall and partial views. The two video cameras were adjusted to each other simultaneously to take pictures of the skull and a suitable picture of any size. The picture signals through the animation compositor were projected on a monitor screen. Video-animation compositor allows any degree of intensity in the pictures of either skull or the portrait but also makes it possible for the precise control of the skull and the soft tissues.

Helmer and Gruner (1977b) used a modified version of the video technique by incorporating charts showing the tissue thickness charts obtained by ultrasound techniques. Superimposition on the skull with gauge markers placed at the anatomical landmarks to correspond to the relative tissue thickness was carried out using a sighting device, with the facial outline of the photograph.

Brown (1983) advocated the technique of using two video-cameras, one on the skull and the other on the photograph. A special effects generator was used to feed the two images independently to two monitors and the combination of the images to a third monitor. The special effects generator could produce a series of combinations by mixing and fading. The entire process could be taped for future study or presentation in a court of law.

The lay out of equipment of the present method advocated by the NSW Forensic Dental Unit is shown in **Fig 14** with photographic images of the different stages of vertical and horizontal fading. The skull is fixed to a device which could rotate it to any position on the three possible planes, which in turn is fixed on to a horizontally movable railing. The photograph too is fixed to a stand, which can also move into a position on the three possible planes. The two video cameras are focused one on the photograph and the skull. By manually adjusting the distances between camera, skull and the photograph it is possible to superimpose the image of the skull on the photograph.

The advantage of having two videos are: the possibility of producing two positive images to be put on one another the ability to change the sizes, and the possibility of freezing of a particular frame. Video-superimposition could be more acceptable in courts when comparisons are done with a photograph and a skull, rather than between a photograph and an already taped video film.

Koelmeyer (1982) used a third video-camera to include the radiographs, and a simpler version was suggested by **Dorion (1983)** where he superimposed a life size radiograph onto a life size photograph.

A simpler method using one video-camera and a transparency of the photograph placed in front of a television screen was used by **Loh and Chao (1989)** where the image of the skull produced by the camera on the television screen was compared with the transparency.

An improvement of this process was postulated by **Lan, Tao and Wang (1990)** who used a computer to control all movements of the skull and the photograph. The method proved to be devoid of human error as selected anatomical lines were used for the alignment of the skull without reference to the ante-mortem photograph. The analysis for similarities or discrepancies was also by the computer, thus eradicating the human error component.

Kamijo and Sakai (1970) designed a remote controlled device for the mounting and adjustment of the skull, where the movement during the orientation was viewed on a ground glass screen upon which an ante-mortem photograph was simultaneously projected.

A significant turning point was the invention of the goniometer where the camera was fixed on a vertical arm, which could move around the permanently fixed skull. A permanent reference point like the midpoint of the upper central incisor could represent the centre of rotation of the camera, which enabled the camera to traverse 360 degrees horizontally and 200 degrees vertically around the skull.

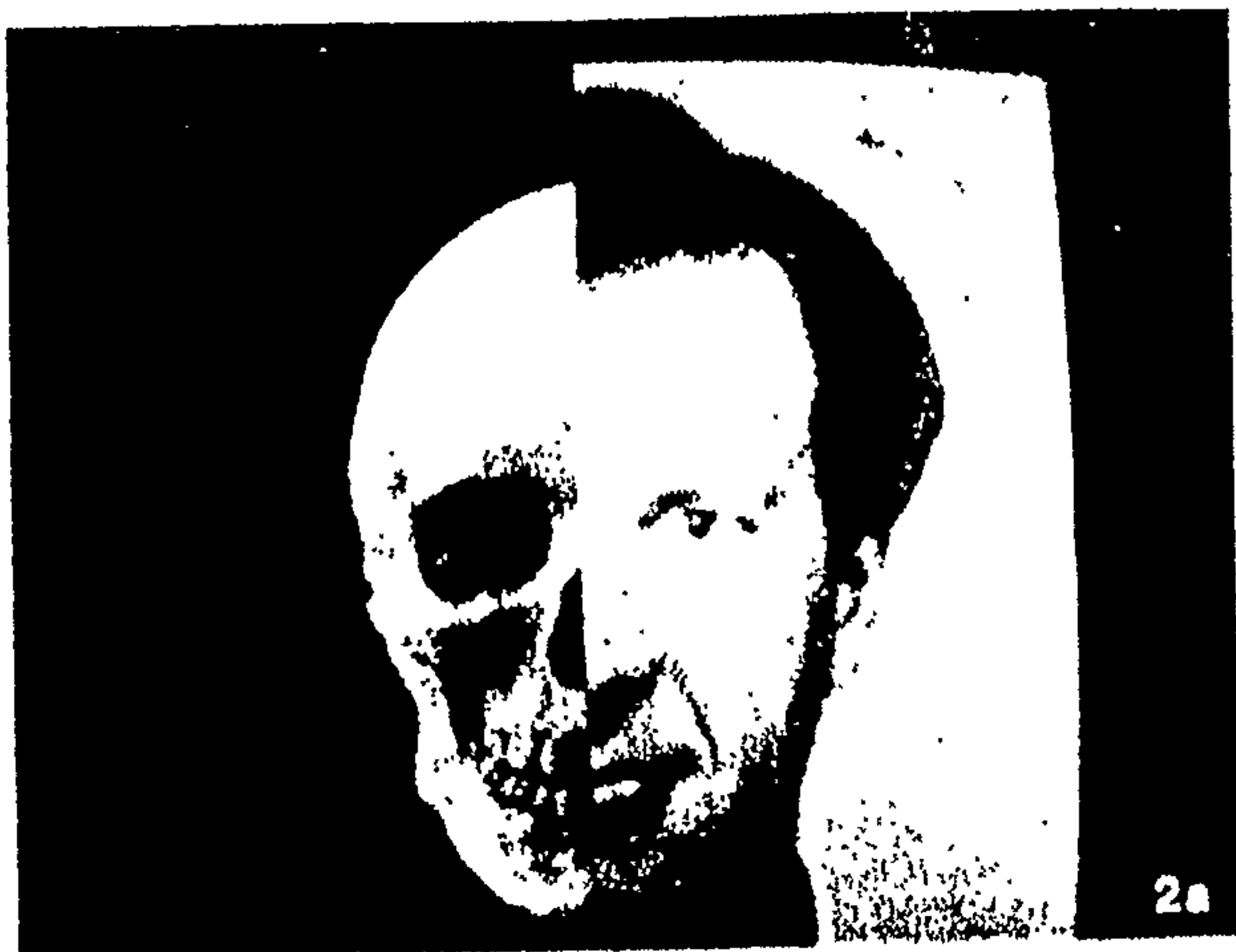


Fig 14a Vertical fade



Fig 14b Horizontal fade



Fig 14c Vertical/Horizontal fade

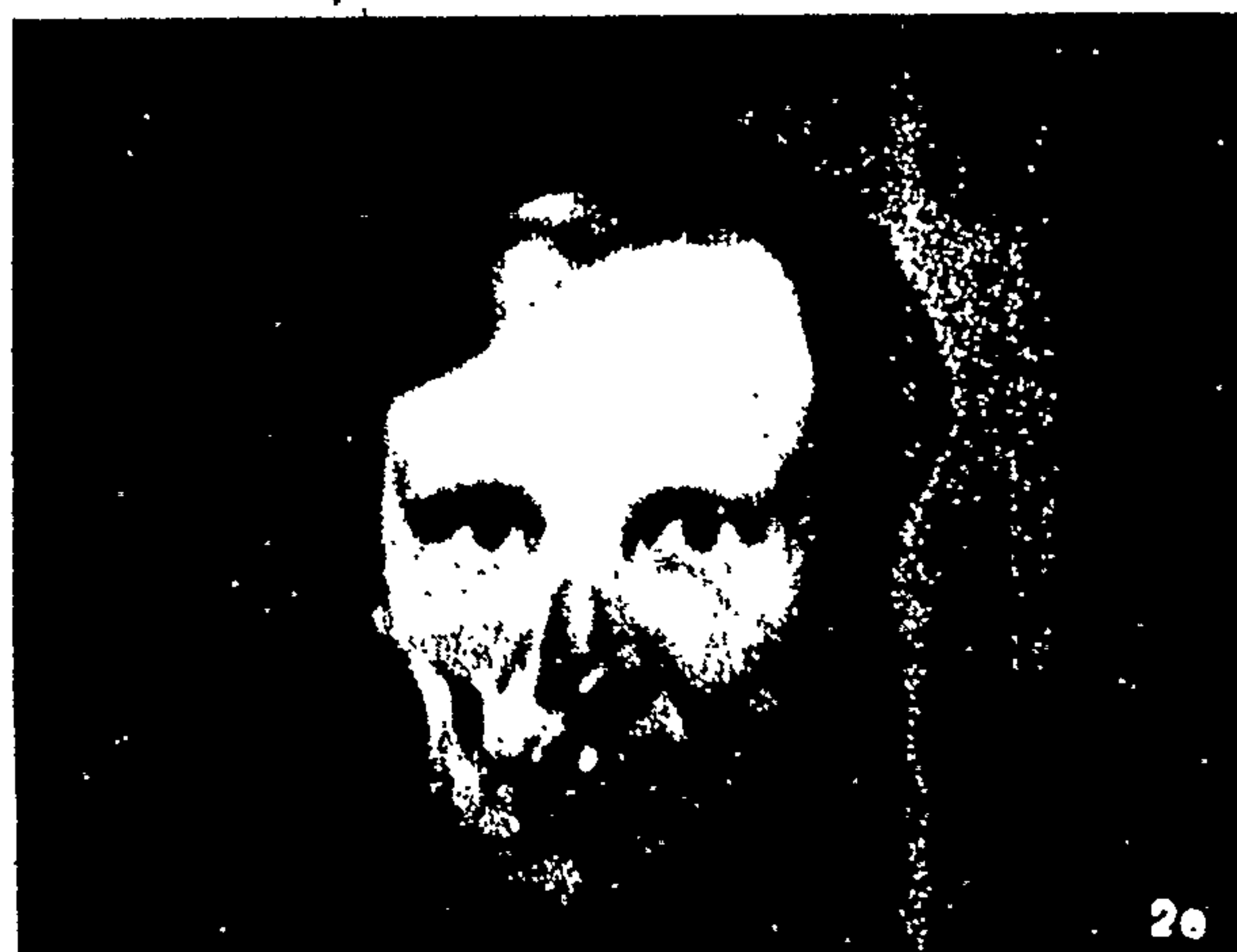


Fig 14d fade

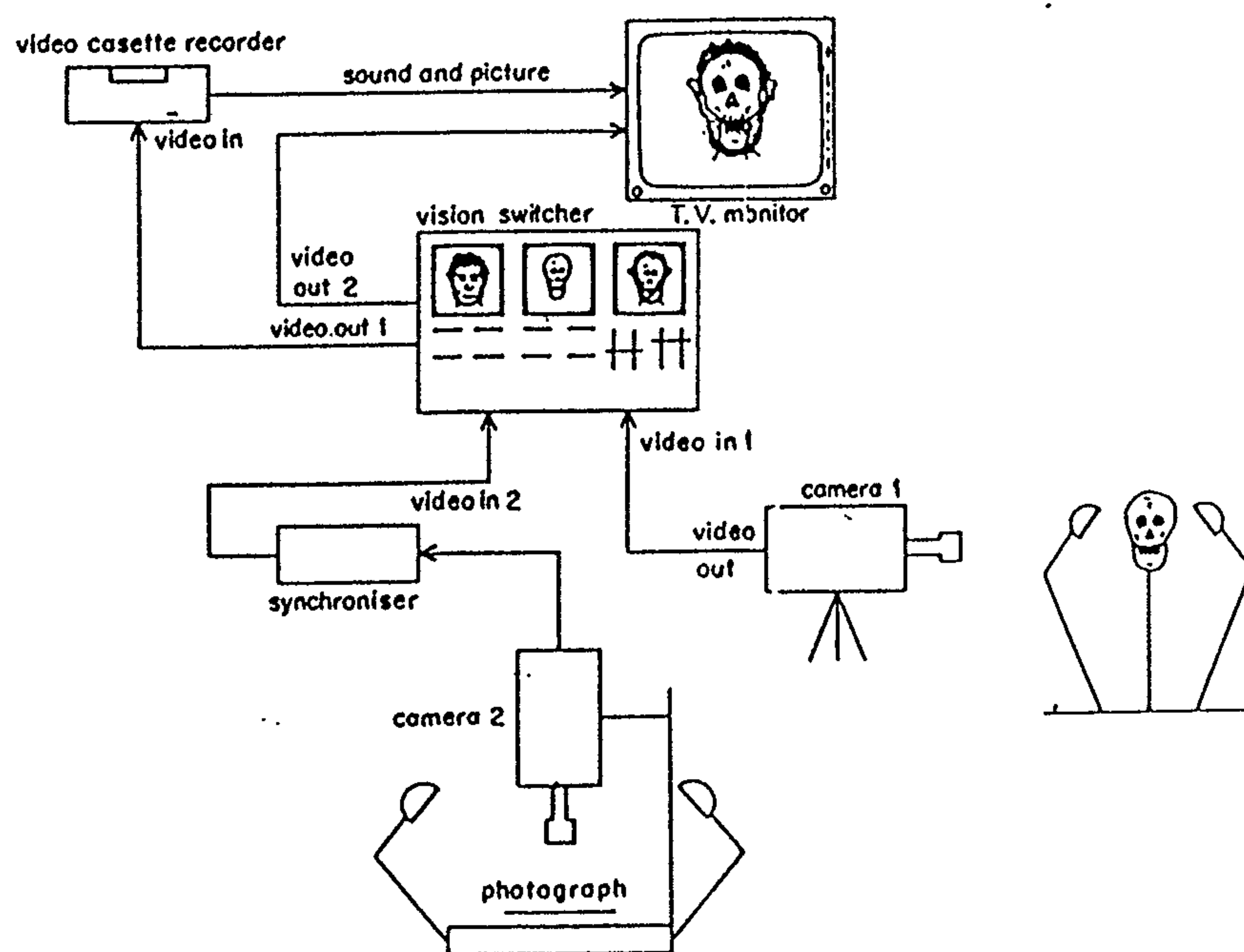


Fig 14 Scheme for facial video superimposition
Source: Brown; Journal of Forensic Odonto Stomatology (1983)

Brocklebank and Holmgren (1989) introduced a method for the support and orientation of the skull. It was possible to rotate the skull, and move it in two vertical planes. The skull was connected to vertical threaded connecting rods, by screwing with horizontal fixing pins. The rods were fitted onto a height adjustable, circular plate of aluminum. This structure was made to sit on a pan and tilt device, which enabled the desired movements. The entire device and the camera were attached to two parallel rails, which made movements and rotations possible.

Most of the authors who have undertaken work in the field of identification of skulls have classified their own methods in different ways, as useful, as powerful, as very successful , as a method that appears to provide a much higher measure of reliability, and lastly as a valid method of identification if performed with utmost accuracy.

5 INVESTIGATION OF FACIAL RATIOS

5.1 STANDARD AND NON - STANDARD FACIAL RELATIONSHIPS

The basic guidelines accepted in the reconstruction of a face from an unknown skull are the tissue thickness tables of **Krogman and Iscan (1986)**, facial canons put forward by **Fedosyutkin and Nainys (1993)** and the skull to face craniometric and cephalometric relationships suggested by **George (1993)**

The relationships between certain horizontal and vertical measurements are accepted as standards for facial proportions. If one could reconstruct a face from an unknown skull, using these relationships and the relative measurements from the standard tissue thickness table, then the skull on which the face was constructed would have had some unique features. For the link between these unique features of the skull and the face to exist there has to be a relationship of common parameters between these two.

The aim of the research was to identify non-standard proportions which fall outside the already documented facial proportions, with the view to using them for matching unknown skulls with known faces.

A face is recognised by its features, ie eyes, nose, mouth and ears, and their anatomical placing. The vast variations of the individual components in size shape and colour play a significant role in defining the individuality of a living person for recognition purposes. The individuality of a person basically depends on the positioning of the eyes, the nose and the mouth in the face from a vertical and a horizontal perspective.

A statue or a photograph retains its individuality irrespective of its size, it should be the ratios or the proportion of facial measurements, and not the individual measurements, that are responsible for the final image produced.

Since the ratios finally make a face specific, it could be inferred that the vertical and the horizontal proportions that are not already accepted as standard ratios could well be used for comparison purposes to identify a photograph to match an unknown skull. ie mathematically finding, on a theory of probability, how many of the total selected ratios match.

The hypothesis put forward is to find the degree of uniqueness and specificity of non-standard vertical and horizontal relationships. Based on these relationships percentages between vertical, horizontal, and a combination of these two measurements could be calculated. This hypothesis has its own limitations, as a set of ratios cannot be calculated with mathematical precision to positively identify an unknown skull.

Irrespective of the method used for the matching of known photographs with unknown skulls, one of the biggest problems encountered is the posing position of the photographs. In the mathematical method suggested, there are two advantages the first one being the measurements could be calculated by using simple formulae provided the pose does not include a combination of rotations, flexion and a tilt; and two, it does not have to depend on the size of the photograph for comparison.

The main principle underlying this hypothesis is the theory of probability: it depends on the likelihood of the pre-selected specific ratios for an unknown skull, statistically and/or graphically follow the trend of a known face. This initially will be helpful for the elimination process for identification of an unknown skull.

5.2 SELECTED RATIOS

In practice when unknown skulls and faces are given to be identified, it becomes a tedious task to individually go through video- and/or optical methods of superimposition, which are the currently available and acceptable methods. The method put forward by the writer could well be used with minimum time and cost for the initial elimination process, where the probabilities could be limited to a few possible matches for further investigations.

The aim of this research was to determine the inter and intra-personal variation of different standard and non-standard ratios. To achieve this individual variations, collective variations, inter and intra-personal variations of both standard and non-standard facial ratios were analysed using different statistical methods ideally suited for the respective samples.

In this research project, the thrust has been an in depth study of facial ratios. Some of these facial ratios were documented as standard ratios irrespective of racial differences, even though they lacked hundred percent uniformity.

From these facial ratios eleven landmarks were chosen, of which five are paired for the measurement of horizontal distances, and six are unpaired on the Median Sagittal Plane for measurement of vertical distances.

Ten non-standard ratios were individually calculated using the thirteen distances measured between these established landmarks. Of the six samples investigated, non-standard facial ratios were calculated in four, the standard facial ratios in one, and the ratios involving the circumoral region in the other sample.

To minimise the discrepancies between the corresponding landmarks in the skull and face, the measurements were taken on the following basis for the skull and face separately in each individual case.

1 Right Cheilion to Left Cheilion

Face The distance between the right and the left points of the labial commissures.

Skull The distance between the cuspal tips of the right and left maxillary canines.

2 Right Ectocanthion to Left Ecanthion

Face The distance between the right and the left outer commissures of the palpebral fissures.

Skull Distance between the most lateral right and left points of the orbit.

3 Right Alare to Left Alare

Face The distance between the most lateral point of the nasal contour.

Skull The most lateral point on the nasal aperture.

4 Right Gonion to left Gonion

Face The distance between the right and the left most lateral points of the jawline in the mandibular angle.

Skull The midpoint of the angle of the mandible between the body and the ramus.

5 The distance between the Right Zygon to left Zygon

Face The most lateral point of the cheek.

Skull The most lateral point of the zygomatic arch.

As the terminology differs in some landmarks of the unpaired, the distances are described separately for the face and the skull, for easy reference.

6 The distance between the Nasion to Subnasale (face)

The distance between the Nasion and the Naso Spinale (skull)

Face The distance between the point of maximum convexity between the nose and the forehead to the midpoint of the columella base at the angle where the lower border of the nasal septum meets the upper lip.

Skull The distance between the midpoint of the suture between the frontal and the two nasal ones, to the point where a line drawn between the right and the left nasal apertures is intersected by the MSP.

- 7 The distance between Subnasale to Labiale Superius (face)**
The distance between Nasospinale to Supra Dentale (skull)
 Face The distance between the midpoint of the columella base at the angle where the lower border of the nasal septum meets the upper lip to the midpoint of the vermillion of the upper lip.
 Skull The distance between the point where the line drawn between the lower margin of the right and left nasal apertures is intersected by the MSP to the apex of the alveolus in the midline between the maxillary central incisors.
- 8 The distance between the Nasion to the Menton**
 Face The distance between the point of maximum convexity between the nose and the forehead to the lowest point on the MSP of the soft tissue chin.
 Skull The distance between the midpoint of the suture between the frontal and the two nasal bones to the lowest point on the mandible.
- 9 The distance between the Subnasale to Stomion (face)**
The distance between the Nasospinale to Incisor Superius (skull)
 Face The distance between the columella base at the angle where the lower border of the nasal septum meets the upper lip to the where the MSP crosses the horizontal labial fissure.
 Skull The distance between the point where the line drawn between the lower margins of the right and left nasal apertures is intersected by the MSP to the tip of the crown of the most anterior central maxillary incisor.
- 10 The distance between the Subnasale to Menton (face)**
The distance between the Nasospinale to Menton (skull)
 Face The distance between the columella base at the angle where the lower border of the nasal septum meets the upper lip to the lowest point on the MSP of the soft tissue chin.
 Skull The distance between the point where the line drawn between the lower margins of the right and left nasal apertures is intersected by the MSP to the lowest point of the mandible.
- 11 The distance between the Labiale Superius to Labiale Inferius (face)**
The distance between the Supra Dentale to Infra Dentale (skull)
 Face The distance between the midpoint of the vermillion of the upper lip to the midpoint of the vermillion of the lower lip.
 Skull The distance between the apex of the alveolus in the midline between the maxillary central incisors, to the apex of the alveolus in the midline between the mandibular central incisors.

- 12 The distance between the Stomion to Menton (face)**
The distance between the Incisor Superius to Menton (skull)
 Face The distance between the point where the MSP crosses the horizontal labial fissure to the lowest point on the MSP of the soft tissue chin.
 Skull The distance between the tip of the crown of the most anterior central maxillary incisor, to the lowest point on the mandible.
- 13 The distance between the Nasion to Stomion (face)**
The distance between the Nasion to Incisor Superius (skull)
 Face The distance between the point of maximum convexity between the nose and the forehead to the point where the MSP and the horizontal labial fissure meets.
 Skull The distance between the mid point of the suture between the frontal and the two nasal bones to the tip of the crown of the most anterior central maxillary incisor.

The ten non-standard ratios selected for analysis were:

Ch - Ch / Ec - Ec

Ch - Ch / Go - Go

Al - Al / Zy - Zy

Al - Al / Ch - Ch

N - Sn / Sn - Ls (Face) N - Ns / Ns - Sd (Skull)

N - Sn / N - Me (Face) N - Ns / N - Me (Skull)

Sn - So / Sn - Me (Face) Ns - Is / Ns - Me (Skull)

Ls - Li / So - Me (Face) Sd - Id / Is - Me (Skull)

N - Sn / Ch - Ch (Face) N - Ns / Ch - Ch (Skull)

Sn - Ls / N - So (Face) Ns - Sd / N - Is (Skull)

5.3 SAMPLES USED FOR THE INVESTIGATION

For the purpose of the research project six samples were used for investigating the uniqueness and a specificity of non standard vertical and horizontal facial ratios.

The *first sample* was that of facial newspaper photographs of twenty victims of the Tasmanian tragedy in 1995, and the skull of a known person not belonging to any of the victims. The thirteen distances between the landmarks suggested by the writer were measured, and the ten non-standard ratios were calculated. The results are shown in **Table 2**. This sample was used to investigate whether the relationship between the mean of the non-standard facial ratios, and the corresponding ratios of a known skull. A regression analysis method was employed for this purpose.

The *second sample* taken was that of facial newspaper photographs of the fifteen Australian airmen who died in a helicopter crash in 1995. The thirteen distances between the landmarks chosen were measured and the ten non-standard ratios were calculated. The results are shown in **Table 3**. The same ten non-standard ratios were calculated for the second sample, which was independent of the first sample. A statistical method called the "t - test" was used to investigate whether there was a significant difference between the means of the ratios. This was done mainly to measure the degree of sensitivity of a particular ratio for a sample with defined characteristics.

The *third sample* taken was that of facial photographs of five different poses of three known individuals. The ten ratios involving the circumoral region were calculated using the relevant landmarks. The results are shown in **Table 4**.

These first three sets of results were analysed to determine whether there was a significant difference between the averages, using the Analysis of Variance statistical method. In this method the sources of variation measured were of those between the samples and within the samples.

The *fourth sample* taken was that of facial photographs of the fifteen soldiers who died in the helicopter crash. The standard ratios were calculated. The results are shown in **Table 5**, The results were analysed to determine whether they follow **Furkas and Munro (1987)** study pattern using the goodness of fit Chi square statistical method.

The *fifth sample* taken was that of antero-postero radiographs of 55 skulls of Sri Lankan soldiers. The non-standard ratios were calculated. The results are shown in **Table 6**. A frequency distribution was constructed to illustrate the frequency of occurrence of specific combinations of ratios. This frequency distribution was then used for the statistical method called the Chi square (χ^2) analysis in order to determine whether there was any relationship between certain non-standard ratios.

The *sixth sample* taken was that of three hundred facial photographs of Sri Lankans taken randomly from magazines. The non-standard ratios were calculated. The results are shown in **Table 7**, using the already established thirteen landmarks. The results were analysed to determine the percentage frequency of occurrence of each ratio in an ascending order, to illustrate the degree of sensitivity of the mathematical method, based on the theory of probability, in matching a total of ten non-standard ratios.

5.4 RESULTS

The results and calculations of the non-standard ratios of the six samples described in Section 5.3 are given in **Tables 2 to 7**.

Table 2 Results and Calculations of Sample1

COMPARISON OF NON-STANDARD FACIAL RATIOS OF 20 KNOWN FACES WITH A KNOWN SKULL											
MEASUREMENT	SKULL	FACE 1	FACE 2	FACE 3	FACE 4	FACE 5	FACE 6	FACE 7	FACE 8	FACE 9	FACE 10
Ch - Ch	3.90	1.60	1.80	1.10	1.00	2.20	1.50	1.20	1.40	1.90	1.20
Ec - Ec	10.10	4.00	3.40	3.00	2.80	2.80	3.00	2.20	2.30	3.20	2.60
Ai - Ai	3.10	1.30	1.30	1.40	1.10	1.20	1.40	1.00	1.00	1.40	1.10
Go - Go	10.00	3.90	3.30	3.10	3.10	3.80	3.60	3.20	2.80	4.30	3.00
Zy - Zy	12.20	5.00	4.30	4.40	3.90	4.90	4.70	4.20	3.70	4.70	3.40
N-Ns(Sn)	4.60	2.00	1.80	1.40	1.60	1.70	1.50	2.00	1.50	1.80	1.50
Ns(Sn)-Sd(Ls)	2.30	0.70	0.50	0.40	0.30	0.50	0.60	0.40	0.30	0.40	0.60
N - Me	11.40	4.30	4.40	3.90	3.30	4.30	3.60	4.10	3.30	4.30	3.40
Ns(Sn)-Is(Sto)	3.00	1.00	0.60	0.90	0.40	0.80	0.70	0.50	0.60	0.70	0.80
Ns(Sn)-Me	7.00	3.00	2.40	2.40	1.90	2.70	1.90	2.20	1.90	2.40	2.10
Sd(Ls)-Id(Li)	2.00	0.50	0.60	0.70	0.50	0.40	0.30	0.40	0.20	0.50	0.40
Is(Sto)-Me	4.30	1.90	2.00	1.40	1.40	2.00	1.30	1.80	1.20	1.70	1.40
N -Is(Sto)	7.50	2.90	2.40	2.30	1.90	2.30	2.20	2.40	1.90	2.30	1.90
Ratios (100%)											
Ch-Ch/Ec-Ec	38.61	40.00	52.94	36.67	35.71	78.57	50.00	54.55	60.87	59.38	46.15
Ch-Ch/Go-Go	39.00	41.03	54.55	35.48	32.26	57.89	41.67	37.50	50.00	44.19	40.00
Al-AI / Zy-Zy	25.41	26.00	30.23	31.82	28.21	24.49	29.79	23.81	27.03	29.79	32.35
Al-AI/Ch-Ch	79.49	81.25	72.22	127.27	110.00	54.55	93.33	83.33	71.43	73.68	91.67
N-Ns(Sn)/Ns(Sn)-Sd(Ls)	200.00	285.71	360.00	350.00	533.33	340.00	250.00	500.00	500.00	450.00	250.00
N-Ns(Sn)/N-Me	40.35	46.51	40.91	35.90	48.48	39.53	41.67	48.78	45.45	41.86	44.12
Ns(Sn)-Is(Sto)/Ns(Sn)-Me	42.86	33.33	25.00	37.50	21.05	29.63	36.84	22.73	31.58	29.17	38.10
Sd(Ls)-Id(Li)/Is(Sto)-Me	46.51	26.32	30.00	50.00	35.71	20.00	23.08	22.22	16.67	29.41	28.57
N-Ns(Sn)/Ch-Ch	117.95	125.00	100.00	127.27	160.00	77.27	100.00	166.67	107.14	97.74	125.00
Ns(Sn)-Sd(Ls)/N-Is(Sto)	30.67	24.14	20.83	17.39	15.79	21.74	27.27	16.67	15.79	17.39	31.58

Table 2 (Contd) Results and Calculations of Sample1

COMPARISON OF NON-STANDARD FACIAL RATIOS OF 20 KNOWN FACES WITH A KNOWN SKULL											
MEASUREMENT	SKULL	FACE 11	FACE 12	FACE 13	FACE 14	FACE 15	FACE 16	FACE 17	FACE 18	FACE 19	FACE 20
Ch - Ch	3.90	1.40	1.40	1.30		1.30	2.00	1.80	1.50	1.80	1.40
Ec - Ec	10.10	2.90	2.90	2.90		3.00	3.60	3.30	3.80	3.00	2.80
Al - Al	3.10	0.90	0.80	1.30		0.50	1.40	1.60	1.00	0.90	0.80
Go - Go	10.00	3.50	4.20	3.10		3.30	4.60	3.20	3.20	3.80	3.40
Zy - Zy	12.20	4.60	4.40	5.00		4.30	5.30	5.00	4.30	4.60	4.00
N-Ns(Sn)	4.60	2.10	1.50	2.10	1.40	1.30	1.80	1.90	1.30	1.50	1.30
Ns(Sn)-Sd(Ls)	2.30	0.70	0.60	0.70	0.50	0.30	0.50	0.40	0.30	0.40	0.50
N - Me	11.40	4.30	4.40	4.60	3.30	3.30	4.60	5.20	3.20	3.60	3.80
Ns(Sn)-Is(Sto)	3.00	0.80	0.80	0.60	0.50	0.40	0.70	0.60	0.50	0.50	0.80
Ns(Sn)-Me	7.00	2.20	2.50	2.80	2.00	2.00	3.00	1.80	1.70	1.80	2.30
Sd(Ls)-Id(Li)	2.00	0.30	0.30	0.60	0.40	0.50	0.60	0.30	0.40	0.40	0.30
Is(Sto)-Me	4.30	1.60	1.80	2.00	1.20	1.40	2.00	2.20	1.20	1.00	1.50
N -Is(Sto)	7.50	2.40	2.50	2.30	2.10	1.90	2.60	2.80	1.90	2.30	2.30
Ratios (100%)											
Ch-Ch/Ec-Ec	38.61	48.28	53.85	44.83		43.33	55.56	54.55	39.47	60.00	50.00
Ch-Ch/Go-Go	39.00	40.00	33.33	41.94		39.39	43.48	56.25	46.88	47.37	41.18
Al-Al / Zy-Zy	25.41	19.57	18.18	26.00		11.63	26.42	32.00	23.26	19.57	20.00
Al-Al/Ch-Ch	79.49	64.29	57.14	100.00		38.46	70.00	88.89	66.67	50.00	57.14
N-Ns(Sn)/Ns(Sn)-Sd(Ls)	200.00	300.00	250.00	300.00	280.00	433.33	360.00	475.00	433.33	375.00	260.00
N-Ns(Sn)/N-Me	40.35	48.84	34.09	45.65	42.42	39.39	39.13	36.54	40.63	41.67	34.21
Ns(Sn)-Is(Sto)/Ns(Sn)-Me	42.86	36.36	32.00	21.43	25.00	20.00	23.33	33.33	29.41	27.78	34.78
Sd(Ls)-Id(Li)/Is(Sto)-Me	46.51	18.75	16.67	30.00	33.33	35.71	30.00	13.64	33.33	40.00	20.00
N-Ns(Sn)/Ch-Ch	117.95	150.00	107.14	161.54		100.00	90.00	105.56	86.67	83.33	92.86
Ns(Sn)-Sd(Ls)/N-Is(Sto)	30.67	29.17	24.00	30.43	23.81	15.79	19.23	14.29	15.79	17.39	21.74

Table 3 Results and Calculations of Sample 2

COMPARISON OF NON - STANDARD FACIAL RATIOS OF 15 VICTIMS															
MEASUREMENT	VICTIM - 1	VICTIM - 2	VICTIM - 3	VICTIM - 4	VICTIM - 5	VICTIM - 6	VICTIM - 7	VICTIM - 8	VICTIM - 9	VICTIM - 10	VICTIM - 11	VICTIM - 12	VICTIM - 13	VICTIM - 14	VICTIM - 15
(A) Ch - Ch	7.10	11.2	12.20	13.20	7.40	10.90	10.40	8.00	10.00	12.20	10.20	12.00	11.40	12.20	9.50
(B) Ec - Ec	17.50	20.00	21.50	20.90	18.90	20.00	19.20	18.50	18.00	19.00	21.20	18.70	19.00	20.50	19.20
(C) Al - Al	7.50	6.60	7.90	7.90	8.10	8.00	7.00	5.90	6.20	17.90	7.10	8.50	8.10	9.00	5.70
(D) Go - Go	19.90	21.50	25.90	21.50	21.90	21.00	20.80	21.00	20.00	24.10	25.00	24.00	21.50	21.80	17.00
(E) Zy - Zy	24.90	26.50	31.00	30.00	26.10	29.80	25.90	24.10	23.90	29.50	30.50	28.10	27.90	29.20	23.90
(F) B - Sn	8.80	8.00	10.80	9.70	10.50	8.90	9.50	10.50	9.80	9.90	9.00	10.20	9.90	7.80	7.50
(G) Sn - Ls	3.50	3.10	4.00	2.20	3.80	4.50	3.90	4.10	2.50	4.20	5.10	4.10	3.20	3.20	2.10
(H) N - Me	13.90	20.00	25.50	22.00	25.00	23.00	22.10	24.90	22.20	24.90	23.80	24.90	26.00	23.50	19.50
(I) Sn - Sto	5.10	4.00	5.00	3.90	5.50	5.20	4.20	5.10	3.20	4.60	6.00	5.10	4.20	4.20	4.00
(J) Sn - Me	15.00	12.00	14.90	13.90	14.90	14.20	13.10	14.20	12.50	14.90	15.20	14.20	16.10	15.00	10.90
(K) Ls - Li	3.00	3.50	3.10	4.00	4.20	3.50	3.50	3.00	4.00	4.20	3.00	3.90	3.50	3.00	4.00
(L) Sto - Me	10.00	8.50	10.10	10.20	10.40	10.00	8.90	9.50	11.20	9.90	10.20	10.00	10.90	10.90	8.50
(M) N - Sto	14.00	12.20	15.50	12.20	15.50	13.80	13.80	15.00	12.80	13.50	14.90	15.00	14.20	12.80	12.50
Ratios (100%)															
Ch-Ch/Ec-Ec	40.57	56.00	56.74	63.16	39.15	54.50	54.17	43.24	55.56	64.21	48.11	64.17	60.00	59.51	49.48
Ch-Ch/Go-Go	35.68	52.09	47.10	61.40	33.79	51.90	50.00	38.10	50.00	50.62	40.80	50.00	53.02	55.96	55.88
Al-Al/Zy-Zy	30.12	24.91	25.48	26.33	31.03	26.85	27.03	24.48	25.94	60.68	23.28	30.25	29.03	30.82	23.85
Al-Al/Ch-Ch	105.63	58.93	64.75	59.85	109.46	73.39	67.31	73.75	62.00	146.72	69.61	70.83	71.05	73.77	60.00
N-Sn/Sn-Ls	251.43	258.06	270.00	440.91	276.32	197.78	243.59	256.10	392.00	235.71	176.47	248.78	309.38	243.75	357.14
N-Sn/N-Me	63.31	40.00	42.35	44.09	42.00	38.70	42.99	42.17	44.14	39.76	37.82	40.96	38.08	33.19	38.46
Sn-Sto/Sn-Me	34.00	33.33	33.56	28.06	36.91	36.62	32.06	35.92	25.60	30.87	39.47	35.92	26.09	28.00	36.70
Ls-Li/Sto-Me	30.00	41.18	30.69	39.22	40.38	35.00	39.33	31.58	35.71	42.42	29.41	39.00	32.11	27.52	47.06
N-Sn/Ch-Ch	123.94	71.43	88.52	73.48	141.89	81.65	91.35	131.25	98.00	81.15	88.24	85.00	86.84	63.93	78.95
Sn-Ls/N-Sto	25.00	25.41	25.81	18.03	24.52	32.61	28.26	27.33	19.53	31.11	34.23	27.33	22.54	25.00	16.80

Table 4 Results and Calculations of Sample 3

COMPARISON OF FACIAL RATIOS INVOLVING THE CIRCUMORAL REGION IN 5 POSES OF 3 PEOPLE																
	FACE 1					FACE 2					FACE 3					
	Pose 1	Pose 2	Pose 3	Pose 4	Pose 5	Pose 1	Pose 2	Pose 3	Pose 4	Pose 5	Pose 1	Pose 2	Pose 3	Pose 4	Pose 5	
	Al-Al Ec-Ec N-Sn Sn-Me Sn-Sto Sto-Me Ch-Ch I-I Go-Go Sn-Ls Ls-Li N-Sto	1.2 2.5 1.2 2 0.7 1.3 1.6 1.3 3.5 0.2 0.2 1.6	1.1 2.5 1.2 1.8 0.5 1.3 1.7 1.4 3.4 0.2 0.1 1.5	1.1 2.4 1.2 1.9 0.5 1.4 1.6 1.3 3.3 0.2 0.2 1.6	1.1 2.4 1.2 1.8 0.5 1.3 1.7 1.3 3.6 0.1 0.3 1.6	1.1 2.6 1.2 1.5 0.4 1.1 1.5 1.4 3.3 0.2 0.2 1.6	1 2.8 1.5 2.2 0.8 1.4 1.1 1.5 3.5 0.3 0.3 2.1	1 2.8 1.5 2.2 0.8 1.4 1.1 1.5 3.5 0.3 0.3 2.1	1 2.9 1.5 2.1 0.7 1.4 1.1 1.5 3.5 0.5 0.2 2.2	1.1 2.8 1.5 2.1 0.7 1.4 1.4 1.5 3.5 0.5 0.2 2.2	1.1 2.8 1.5 2.2 0.7 1.5 1.4 1.5 3.6 0.5 0.2 2.2	1.1 2.5 1.3 2.1 0.6 1.5 1.4 1.5 3.6 0.4 0.1 0.5	1 2.5 1.3 2.1 0.6 1.5 1.4 1.5 3.6 0.4 0.1 0.5	1.1 2.5 1.2 1.9 0.7 1.2 2 1.4 3.6 0.3 0.2 0.5	1.1 2.6 1.3 1.9 0.6 1.3 1.9 1.5 3.5 0.4 0.2 0.6	
Ch- ch/Ec-Ec Ch-Ch/Go-Go Al-Al/Ch-Ch Sn-Sto/Sn-Me Ls-Li/Sto-Me N-Sn/Ch-Ch Sn-Ls/N-Sto Sn-Sto/Sto-Me Sto-Me/Ch-Ch Ch-Ch/I-I	0.64 0.46 0.75 0.35 0.15 0.75 0.13 0.54 0.81 1.23	0.68 0.50 0.65 0.28 0.08 0.71 0.13 0.38 0.76 1.21	0.67 0.48 0.69 0.26 0.14 0.75 0.13 0.36 0.88 1.23	0.71 0.47 0.65 0.28 0.23 0.71 0.06 0.38 0.76 1.31	0.58 0.45 0.73 0.27 0.18 0.80 0.13 0.36 0.73 1.07	0.46 0.37 0.77 0.33 0.14 1.15 0.23 0.50 1.08 0.87	0.39 0.31 0.91 0.36 0.21 1.36 0.14 0.57 1.27 0.73	0.38 0.31 0.91 0.33 0.14 1.36 0.23 0.50 1.27 0.73	0.50 0.40 0.79 0.33 0.14 1.07 0.23 0.50 1.00 0.93	0.50 0.39 0.79 0.32 0.13 1.07 0.23 0.47 1.07 0.93	0.60 0.41 0.73 0.30 0.14 0.87 0.67 0.43 0.93 1.00	0.56 0.39 0.71 0.29 0.07 0.93 0.80 0.40 1.07 0.93	0.80 0.56 0.55 0.37 0.17 0.60 0.60 0.58 0.60 1.43	0.73 0.54 0.58 0.32 0.15 0.68 0.67 0.46 0.68 1.27	0.65 0.49 0.59 0.32 0.15 0.71 0.67 0.46 0.76 1.21	

Table 5 Results and Calculation of Sample 4

COMPARISON OF THE INDIVIDUAL STANDARD RATIOS OF 15 VICTIMS															
	Vic 1	Vic 2	Vic 3	Vic 4	Vic 5	Vic 6	Vic 7	Vic 8	Vic 9	Vic 10	Vic 11	Vic 12	Vic 13	Vic 14	Vic 15
En-En	5	6.5	9	7	7	11.7	13	8.5	6.5	7	5	6	6	8	8
Al - Al	7.5	9.5	9	6.5	6.5	11	8	8	8.5	7	8	8.5	8	8.5	6
En-Ec	7	8	8	5	6	6.5	6.5	7	7.5	8	7	6	8	8.5	6
Ec-Ec	18	19	22.5	11.5	18.5	19	21	20.5	20	21	19	18.5	21	22	18
V-N	22.5	22	22	23	25.5	21	22	19.5	25	23	24	24.5	21.5	24	23
N-Me	24.5	22	27.5	28	23	22	26	26	26	27	24	27.5	29	24	22
N-Sn	10	11	15.5	13.5	10	12	11.5	15	11	11.5	11	12	12	9	11
Sn-Me	16	12	15	16	13.5	16	16	13	15.5	15	14	16	17	15	12
Sn -Sto	4.5	4	6	5.5	4	5	6	4	3.5	3.5	5	4	5	4	4
Sto-Me	11	8	12	11	11	11.5	10	11	11	10	8	11	14	12	8
Ch-Ch	12.5	13	12.5	9.5	11	10	10	13	11	10.5	10	13	11	13	10
I - I	11		11.5	8.5	10	10	11	12	11	11.5	10	11.5	11	11.5	
En-En / Al-Al	66.67	68.42	100.00	107.69	107.69	100.00	162.50	106.25	76.47	100.00	62.50	70.59	75.00	94.12	133.33
En-En / En-Ec	71.43	81.25	112.50	140.00	116.67	169.23	200.00	121.43	86.67	87.50	71.43	100.00	75.00	94.12	133.33
En-Ec / Ec-Ec	38.89	42.11	35.56	43.48	32.43	34.21	30.95	34.15	37.50	38.10	36.84	32.43	38.10	38.64	33.33
V-N / N-Me	91.84	100.00	80.00	82.14	110.87	95.45	84.62	75.00	96.15	85.19	100.00	89.09	74.14	100.00	104.55
N-Sn / Sn-Me	62.50	91.67	103.33	84.38	74.07	75.00	71.88	115.38	70.97	76.67	78.57	75.00	70.59	60.00	91.67
Sn-Sto / Sto-Me	40.91	50.00	50.00	50.00	36.36	43.48	60.00	36.36	31.82	35.00	62.50	36.36	35.71	33.33	50.00
Sto-Me / Ch-Ch	88.00	61.54	96.00	115.79	100.00	115.00	100.00	84.62	100.00	95.24	80.00	84.62	127.27	92.31	80.00
Ch-Ch / I-I	114		108.70	111.76	110.00	100.00	90.91	108.33	100.00	91.30	100.00	113.04	100.00	113.04	

Table 6 Results and Calculations of Sample 5

Radiographic measurements of 55 skulls

	Ch-Ch	Ec-Ec	Al- Al	Go-Go	Zy-Zy	N-Ns	Ns-Sd	N-Me	Ns-Is	Ns-Me	Sd-Id	Is-Me	N-Is
1	3.8	11.3	3.0	12.6	16.1	4.9	2.8	13.2	3.2	8.3	0.7	5.2	8.3
2	3.4	9.8	3.0	9.6	14.7	4.8	2.5	11.0	2.8	6.4	0.7	3.5	7.6
3	3.4	10.8	3.1	10.9	16.5	4.6	3.6	13.2	4.1	8.8	1.4	4.8	9.2
4	3.4	10.2	3.4	10.9	15.2	5.2	4.4	13.5	4.3	7.9	0.6	3.5	9.7
5	3.5	10.8	2.6	8.2	13.9	3.8	4.2	12.3	4.2	7.6	1.3	4.2	8.8
6	3.3	11.4	3.2	12.1	16.8	5.0	3.5	13.3	3.7	7.7	0.8	4.1	9.5
7	3.2	9.0	2.5	9.1	14.1	3.8	2.3	5.8	2.4	6.0	0.7	3.0	9.3
8	3.2	11.2	3.4	9.3	15.1	4.5	2.8	12.4	3.1	7.2	0.8	4.3	9.2
9	2.9	8.8	2.8	8.5	12.3	3.8	1.8	9.2	2.8	5.2	1.5	2.3	6.8
10	3.2	11.4	3.5	11.3	15.4	4.9	3.5	13.2	3.5	6.9	0.7	3.8	9.5
11	3.3	8.7	3.5	11.2	15.3	4.9	3.0	12.3	3.7	7.9	1.3	4.7	8.3
12	4.4	11.2	3.0	11.8	16.2	4.9	3.0	13.3	3.9	8.0	1.0	4.7	8.7
13	3.7	10.3	3.0	11.0	15.2	5.0	3.8	13.5	3.5	8.0	1.0	4.2	8.6
14	4.0	11.3	3.2	11.4	16.8	4.5	2.8	13.2	3.5	8.2	0.8	4.5	13.5
15	3.2	10.3	3.5	11.7	15.3	4.4	3.0	12.5	3.4	7.5	0.7	4.0	8.5
16	3.0	10.5	3.2	11.3	15.2	5.0	4.1	14.2	4.6	8.9	0.8	4.3	9.9
17	4.3	10.6	3.3	11.9	16.3	5.0	3.9	14.2	4.2	9.1	1.2	5.1	9.2
18	3.3	11.2	3.3	11.3	16.3	4.8	3.0	12.1	3.4	7.2	0.7	4.1	7.7
19	4.0	9.8	3.7	10.8	14.1	4.3	2.8	12.1	3.7	6.3	1.0	3.6	8.7
20	3.7	11.2	3.3	11.9	15.1	4.8	3.1	13.9	3.1	8.0	1.1	4.9	8.3
21	4.2	11.6	3.4	11.8	17.2	4.9	3.3	14.2	4.2	9.3	1.0	5.7	9.3
22	4.2	9.9	2.7	9.4	14.2	4.8	3.3	12.7	3.3	7.5	0.8	4.6	9.5
23	4.8	11.2	3.5	10.8	16.9	4.5	4.0	13.2	4.2	8.2	0.9	3.9	9.1
24	3.3	9.3	2.2	7.5	12.3	3.3	2.5	11.1	4.3	7.4	—	4.1	0.4
25	3.9	11.3	3.8	11.3	17.3	5.0	3.5	14.6	3.4	8.3	1.0	5.3	8.8
26	3.7	10.7	3.9	11.0	14.9	5.5	3.2	13.0	3.7	7.0	1.0	3.3	9.6
27	3.5	10.2	3.9	11.0	14.7	6.0	2.7	12.9	3.7	7.7	1.3	4.0	9.2
28	3.9	10.7	3.5	12.0	14.9	5.4	3.9	13.9	3.2	7.9	1.0	4.7	9.7
29	3.2	10.4	3.2	11.2	15.3	4.2	3.5	12.8	4.8	8.0	1.0	3.3	9.3
30	3.8	9.5	2.9	9.3	13.8	4.0	2.8	10.4	3.4	6.0	1.2	2.7	7.6
31	3.5	10.3	3.4	11.1	15.7	5.0	2.3	12.2	3.2	7.3	0.9	4.3	7.3
32	3.9	10.7	3.8	10.7	15.7	3.3	2.7	10.5	3.3	7.3	0.6	4.3	6.4
33	3.8	10.2	2.5	11.2	15.3	3.8	2.6	11.8	3.3	7.8	1.2	4.7	7.4
34	3.8	11.0	4.0	11.0	15.5	5.4	3.2	13.0	3.2	8.1	1.2	4.4	9.0
35	3.8	10.7	4.1	11.8	15.3	5.7	2.3	12.5	3.0	7.3	1.5	4.2	8.5
36	5.5	11.7	3.8	12.3	17.6	5.0	2.5	13.2	4.2	8.5	1.8	4.0	10.3
37	6.0	12.4	3.8	12.0	15.9	4.9	3.5	12.7	3.7	7.9	1.1	4.0	9.3
38	4.5	12.3	4.5	12.2	16.9	4.9	2.7	12.6	2.9	7.4	0.7	4.4	12.3
39	4.8	10.9	3.4	10.3	15.2	4.7	3.6	11.4	3.7	8.5	0.8	3.8	8.3
40	3.4	10.5	2.7	11.2	14.3	4.1	4.2	13.3	4.2	7.7	1.2	4.2	9.2
41	3.5	10.8	3.0	9.5	14.4	4.5	2.8	12.5	3.2	7.5	2.0	4.5	12.2
42	4.0	13.5	4.0	13.0	16.0	5.0	4.0	16.0	5.0	11.0	1.8	6.0	10.0
43	4.5	10.8	4.0	11.0	16.5	5.0	3.0	13.8	4.0	8.5	1.3	5.0	8.6
44	4.2	10.2	3.0	10.0	15.0	5.2	3.3	13.0	4.5	8.5	1.5	4.5	8.5
45	4.0	10.2	4.1	11.0	14.0	4.5	3.4	2.4	3.8	8.0	1.0	4.3	8.3
46	3.9	10.6	3.9	10.0	15.2	5.0	2.7	12.0	3.2	7.0	1.3	3.7	8.0
47	3.8	10.3	3.2	9.9	15.0	4.2	3.5	12.0	4.0	8.0	1.1	4.0	12.3
48	3.8	10.7	3.7	10.9	14.8	4.3	3.0	12.3	3.7	7.6	1.1	3.7	8.3
49	4.3	10.3	3.1	10.5	15.2	5.0	2.7	12.3	3.2	7.3	0.6	4.2	8.8
50	3.6	10.2	3.3	11.5	15.0	4.5	3.7	12.5	3.7	8.3	0.5	4.3	8.0
51	3.5	8.3	3.4	11.9	16.3	4.9	3.2	12.9	3.8	8.0	0.8	4.5	8.6
52	3.5	10.9	3.2	10.7	15.3	4.9	2.8	13.7	3.7	8.0	1.0	4.2	13.8
53	3.4	9.9	3.0	10.8	15.1	4.0	3.5	12.6	4.1	8.0	0.8	3.8	12.5
54	3.1	10.4	3.2	11.3	14.8	4.2	3.0	12.4	3.5	7.0	0.8	4.9	8.7
55	4.0	10.9	3.8	12.0	16.1	4.9	3.0	13.3	3.7	8.0	1.3	4.3	8.3

Table 6 (Contd) Results and Calculations of Sample 5

NON -STANDARD RATIOS IN SKULL RADIOGRAPHS										
	Ch-Ch Ec-Ec	Ch-Ch Go-Go	Al-Al Zy-Zy	Al-Al Ch-Ch	N-Ns Ns-Sd	N-Ns N-Me	Ns-Is Ns-Me	Sd-Id Is-Me	N-Ns Ch-Ch	Ns-Sd N-Is
1	0.3	0.3	0.2	0.8	1.8	0.4	0.4	0.1	1.3	0.3
2	0.3	0.4	0.2	0.9	1.9	0.4	0.4	0.2	1.4	0.3
3	0.3	0.3	0.2	0.9	1.3	0.3	0.5	0.3	1.4	0.4
4	0.3	0.3	0.2	1.0	1.2	0.4	0.5	0.2	1.5	0.5
5	0.3	0.4	0.2	0.7	0.9	0.3	0.6	0.3	1.1	0.5
6	0.3	0.3	0.2	1.0	1.4	0.4	0.5	0.2	1.5	0.4
7	0.4	0.4	0.2	0.8	1.7	0.7	0.4	0.2	1.2	0.2
8	0.3	0.3	0.2	1.1	1.6	0.4	0.4	0.2	1.4	0.3
9	0.3	0.3	0.2	1.0	2.1	0.4	0.5	0.7	1.3	0.3
10	0.3	0.3	0.2	1.1	1.4	0.4	0.5	0.2	1.5	0.4
11	0.4	0.3	0.2	1.1	1.6	0.4	0.5	0.3	1.5	0.4
12	0.4	0.4	0.2	0.7	1.6	0.4	0.5	0.2	1.1	0.3
13	0.4	0.3	0.2	0.8	1.3	0.4	0.4	0.2	1.4	0.4
14	0.4	0.4	0.2	0.8	1.6	0.3	0.4	0.2	1.1	0.2
15	0.3	0.3	0.2	1.1	1.5	0.4	0.5	0.2	1.4	0.4
16	0.3	0.3	0.2	1.1	1.2	0.4	0.5	0.2	1.7	0.4
17	0.4	0.4	0.2	0.8	1.3	0.4	0.5	0.2	1.2	0.4
18	0.3	0.3	0.2	1.0	1.6	0.4	0.5	0.2	1.5	0.4
19	0.4	0.4	0.3	0.9	1.5	0.4	0.6	0.3	1.1	0.3
20	0.3	0.3	0.2	0.9	1.5	0.3	0.4	0.2	1.3	0.4
21	0.4	0.4	0.2	0.8	1.5	0.3	0.5	0.2	1.2	0.4
22	0.4	0.4	0.2	0.6	1.5	0.4	0.4	0.2	1.1	0.3
23	0.4	0.4	0.2	0.7	1.1	0.3	0.5	0.2	0.9	0.4
24	0.4	0.4	0.2	0.7	1.3	0.3	0.6	0.0	1.0	6.3
25	0.3	0.3	0.2	1.0	1.4	0.3	0.4	0.2	1.3	0.4
26	0.3	0.3	0.3	1.1	1.7	0.4	0.5	0.3	1.5	0.3
27	0.3	0.3	0.3	1.1	2.2	0.5	0.5	0.3	1.7	0.3
28	0.4	0.3	0.2	0.9	1.4	0.4	0.4	0.2	1.4	0.4
29	0.3	0.3	0.2	1.0	1.2	0.3	0.6	0.3	1.3	0.4
30	0.4	0.4	0.2	0.8	1.4	0.4	0.6	0.4	1.1	0.4
31	0.3	0.3	0.2	1.0	2.2	0.4	0.4	0.2	1.4	0.3
32	0.4	0.4	0.2	1.0	1.2	0.3	0.5	0.1	0.8	0.4
33	0.4	0.3	0.2	0.7	1.5	0.3	0.4	0.3	1.0	0.4
34	0.3	0.3	0.3	1.1	1.7	0.4	0.4	0.3	1.4	0.4
35	0.4	0.3	0.3	1.1	2.5	0.5	0.4	0.4	1.5	0.3
36	0.5	0.4	0.2	0.7	2.0	0.4	0.5	0.5	0.9	0.2
37	0.5	0.5	0.2	0.6	1.4	0.4	0.5	0.3	0.8	0.4
38	0.4	0.4	0.3	1.0	1.8	0.4	0.4	0.2	1.1	0.2
39	0.4	0.5	0.2	0.7	1.3	0.4	0.4	0.2	1.0	0.4
40	0.3	0.3	0.2	0.8	1.0	0.3	0.5	0.3	1.2	0.5
41	0.3	0.4	0.2	0.9	1.6	0.4	0.4	0.4	1.3	0.2
42	0.3	0.3	0.3	1.0	1.3	0.3	0.5	0.3	1.3	0.4
43	0.4	0.4	0.2	0.9	1.7	0.4	0.5	0.3	1.1	0.3
44	0.4	0.4	0.2	0.7	1.6	0.4	0.5	0.3	1.2	0.4
45	0.4	0.4	0.3	1.0	1.3	1.9	0.5	0.2	1.1	0.4
46	0.4	0.4	0.3	1.0	1.9	0.4	0.5	0.4	1.3	0.3
47	0.4	0.4	0.2	0.8	1.2	0.4	0.5	0.3	1.1	0.3
48	0.4	0.3	0.3	1.0	1.4	0.3	0.5	0.3	1.1	0.4
49	0.4	0.4	0.2	0.7	1.9	0.4	0.4	0.1	1.2	0.3
50	0.4	0.3	0.2	0.9	1.2	0.4	0.4	0.1	1.3	0.5
51	0.4	0.3	0.2	1.0	1.5	0.4	0.5	0.2	1.4	0.4
52	0.3	0.3	0.2	0.9	1.8	0.4	0.5	0.2	1.4	0.2
53	0.3	0.3	0.2	0.9	1.1	0.3	0.5	0.2	1.2	0.3
54	0.3	0.3	0.2	1.0	1.4	0.3	0.5	0.2	1.4	0.3
55	0.4	0.3	0.2	1.0	1.6	0.4	0.5	0.3	1.2	0.4

Table 7 (Contd) Results and Calculations of Sample 6

NON - STANDARD RATIOS FOR 299 FACIAL PHOTOGRAPHS										
	Ch - Ch Ec - Ec	Ch - Ch Go - Go	Al - Al Zy - Zy	Al - Al Ch - Ch	N - Sn Sn - Ls	N - Sn N - Me	Sn - Sto Sn - Ls	Ls - Li Sto - Me	N - Sn Ch - Ch	Sn - Ls N - Sto
1	0.61	0.55	0.30	0.55	1.50	0.33	1.25	0.33	0.55	0.40
2	0.70	0.64	0.29	0.57	1.33	0.36	1.00	0.75	0.57	0.50
3	0.59	0.53	0.38	0.90	3.00	0.45	1.33	0.33	0.90	0.27
4	0.62	0.67	0.27	0.50	2.50	0.24	0.50	0.40	0.63	0.17
5	0.80	0.73	0.23	0.38	2.00	0.33	1.50	0.60	0.50	0.33
6	0.75	0.60	0.44	0.78	1.33	0.33	1.00	0.60	0.44	0.38
7	0.59	0.63	0.30	0.70	1.75	0.39	1.50	0.29	0.70	0.33
8	0.54	0.50	0.27	0.57	1.67	0.42	1.00	0.60	0.71	0.38
9	0.45	0.42	0.20	0.60	2.00	0.40	1.50	0.50	0.80	0.40
10	0.65	0.48	0.28	0.64	1.75	0.35	1.50	0.63	0.64	0.33
11	0.55	0.38	0.33	0.83	1.60	0.33	1.60	0.60	0.67	0.36
12	0.63	0.56	0.27	0.60	1.75	0.37	1.25	0.43	0.70	0.33
13	0.72	0.62	0.33	0.62	4.50	0.47	2.00	0.50	0.69	0.20
14	0.64	0.60	0.26	0.56	2.00	0.53	1.00	0.60	0.89	0.36
15	0.61	0.61	0.35	0.73	2.67	0.47	1.00	0.50	0.73	0.27
16	0.65	0.50	0.33	0.73	1.75	0.37	12.50	0.33	0.64	0.36
17	0.64	0.60	0.32	0.67	3.50	0.44	2.00	0.67	0.78	0.22
18	0.56	0.48	0.32	0.80	2.00	0.40	1.25	0.44	0.80	0.31
19	0.53	0.48	0.33	0.80	1.60	0.38	1.20	0.33	0.80	0.21
20	0.60	0.55	0.32	0.67	1.40	0.39	1.40	0.33	0.58	0.42
21	0.53	0.51	0.27	0.61	1.88	0.39	1.50	1.00	0.83	0.36
22	0.55	0.57	0.36	0.75	2.00	0.33	1.60	0.50	0.63	0.28
23	0.59	0.51	0.31	0.74	2.14	0.39	1.71	0.47	0.79	0.28
24	0.53	0.63	0.32	0.80	2.25	0.47	1.25	0.43	0.90	0.33
25	0.73	0.57	0.19	0.38	1.67	0.23	1.33	0.40	0.63	0.43
26	0.52	0.52	0.31	0.73	2.25	0.45	1.25	0.50	0.82	0.31
27	0.63	0.60	0.20	0.39	2.67	0.32	2.33	0.40	0.67	0.23
28	0.89	0.73	0.21	0.38	1.33	2.00	1.00	0.75	0.50	0.50
29	0.56	0.60	0.32	0.67	2.00	0.38	1.67	0.50	0.67	0.33
30	0.56	0.50	0.27	0.60	2.00	0.50	1.50	0.40	0.80	0.40
31	0.47	0.36	0.36	0.93	2.17	0.37	1.33	0.24	0.87	0.30
32	0.57	0.60	0.36	0.75	2.00	0.40	1.75	0.50	0.67	0.31
33	0.54	0.54	0.31	0.77	2.00	0.48	1.00	0.56	0.92	0.38
34	0.63	0.63	0.35	0.67	1.60	0.42	1.00	0.43	0.67	0.42
35	0.59	0.54	0.22	0.54	2.00	0.42	1.40	0.40	0.77	0.33
36	0.64	0.60	0.22	0.44	2.00	0.33	2.00	0.50	0.44	0.25
37	0.53	0.44	0.32	0.75	1.67	0.36	1.33	0.50	0.63	0.33
38	0.64	0.53	0.33	0.67	1.67	0.33	1.33	0.50	0.56	0.38
39	0.50	0.50	0.32	0.75	2.00	0.35	1.67	0.57	0.75	0.30
40	0.58	0.58	0.19	0.43	3.00	0.46	1.50	0.38	0.86	0.25
41	0.45	0.38	0.36	1.00	1.33	0.33	1.33	0.40	0.80	0.43
42	0.58	0.50	0.35	0.64	2.00	0.40	1.25	0.50	0.73	0.33
43	0.71	0.59	0.26	0.50	2.50	0.31	2.50	0.50	0.50	0.25
44	0.47	0.50	0.32	0.67	1.67	0.29	0.67	0.25	0.56	0.38
45	0.44	0.57	0.36	0.63	8.00	0.67	2.00	0.60	1.00	0.14
46	1.00	0.47	0.36	0.71	6.00	0.55	4.00	0.60	0.86	0.14
47	0.27	0.33	0.25	0.75	2.50	0.36	1.50	0.33	1.25	0.33
48	0.60	0.60	0.23	0.50	4.00	0.36	2.00	0.50	0.67	0.14
49	0.67	0.50	0.25	0.50	5.00	0.22	3.00	0.50	0.83	0.17
50	0.37	0.50	0.20	0.43	2.50	0.36	1.50	0.40	0.71	0.29

Table 7 (Contd) Results and Calculations of Sample 6

NON-STANDARD RATIOS FOR 299 FACIAL PHOTOGRAPHS										
	<u>Ch - Ch</u> Ec - Ec	<u>Ch - Ch</u> Go - Go	<u>Al - Al</u> Zy - Zy	<u>Al - Al</u> Ch - Ch	<u>N - Sn</u> Sn - Ls	<u>N - Sn</u> N - Me	<u>Sn-Sto</u> Sn - Ls	<u>Ls - Li</u> Sto - Me	<u>N - Sn</u> Ch - Ch	<u>Sn - Ls</u> N - Sto
51	0.60	0.60	0.29	0.67	4.00	0.40	2.00	0.75	0.67	0.17
52	0.50	0.75	0.33	0.56	1.67	0.42	1.00	0.75	0.56	0.38
53	0.80	0.62	0.33	0.63	1.67	0.42	1.00	0.40	0.63	0.43
54	0.75	0.60	0.38	0.67	3.00	0.50	1.00	0.60	0.67	0.25
55	0.80	0.53	0.20	0.38	1.50	0.50	0.75	0.60	0.75	0.57
56	0.64	0.50	0.25	0.57	1.50	0.46	0.75	0.33	0.86	0.57
57	0.90	0.75	0.21	0.33	2.00	0.33	1.50	0.33	0.44	0.33
58	0.90	0.64	0.20	0.33	5.00	0.36	3.00	0.43	0.56	0.14
59	0.57	0.67	0.38	0.75	4.00	0.67	2.00	0.50	1.00	0.25
60	1.00	0.80	0.23	0.38	0.50	0.30	0.50	0.67	0.38	1.00
61	0.87	0.68	0.29	0.46	2.00	0.33	2.67	0.57	0.46	0.29
62	1.26	0.92	0.30	0.33	1.60	0.32	1.40	0.45	0.33	0.38
63	0.62	0.53	0.33	0.75	2.00	0.40	1.33	0.67	0.75	0.38
64	0.50	0.50	0.38	1.00	1.50	0.60	2.00	0.67	1.00	0.50
65	0.50	0.50	0.29	0.80	1.67	0.50	1.00	0.50	1.00	0.43
66	0.25	0.25	0.21	1.00	2.50	1.00	1.50	0.40	1.67	0.25
67	0.64	0.47	0.53	1.29	2.50	1.00	1.50	0.60	0.71	0.25
68	0.56	0.50	0.25	0.60	2.00	1.00	1.50	0.50	0.80	0.29
69	0.55	0.46	0.31	0.67	2.00	1.00	1.50	0.50	0.67	0.29
70	0.50	0.41	0.22	0.57	2.00	1.20	1.00	0.50	0.86	0.33
71	0.69	0.64	0.29	0.56	0.63	0.38	0.38	0.33	0.56	1.00
72	0.42	0.38	0.18	0.60	0.71	0.42	0.29	0.25	1.00	1.00
73	0.54	0.42	0.24	0.69	0.59	0.33	0.29	0.40	0.77	1.13
74	0.69	0.60	0.29	0.56	0.71	0.42	0.29	0.25	0.56	1.00
75	0.60	0.60	0.29	0.56	0.71	0.42	0.43	1.00	0.56	0.88
76	0.69	0.60	0.35	0.67	0.63	0.36	0.25	1.50	0.56	1.14
77	0.77	0.67	0.32	0.60	0.57	0.29	0.29	0.50	0.40	1.17
78	0.67	0.57	0.35	0.75	0.57	0.31	0.14	1.00	0.50	1.40
79	0.75	0.53	0.30	0.67	0.83	0.63	0.17	0.40	0.56	1.00
80	0.71	0.63	0.33	0.60	0.71	0.42	0.29	1.50	0.50	1.00
81	0.60	0.54	0.35	0.73	2.25	0.56	1.25	0.36	0.60	0.33
82	0.60	0.55	0.29	0.75	1.80	0.53	1.40	0.33	0.75	0.38
83	0.54	0.58	0.31	0.71	2.50	0.71	1.50	0.29	0.71	0.18
84	0.58	0.58	0.29	0.57	1.33	0.50	1.33	0.40	0.57	0.43
85	0.62	0.53	0.29	0.63	1.25	0.56	1.25	0.33	0.63	0.44
86	0.58	0.50	0.25	0.57	2.50	0.63	1.50	0.40	0.71	0.33
87	0.70	0.64	0.23	0.43	3.50	1.17	1.50	0.50	1.00	0.33
88	0.71	0.63	0.33	0.60	2.33	0.70	1.00	0.50	0.70	0.33
89	0.60	0.69	0.29	0.44	1.67	0.56	1.00	0.40	0.56	0.33
90	0.64	0.60	0.25	0.44	2.00	0.86	1.00	0.40	0.67	0.38
91	0.67	0.67	0.27	0.50	2.00	0.50	1.50	0.25	0.67	0.40
92	0.67	0.55	0.20	0.50	1.50	0.38	2.00	0.25	0.50	0.40
93	0.57	0.53	0.22	0.50	3.00	0.46	2.00	0.50	0.75	0.25
94	0.60	0.55	0.14	0.33	2.50	0.50	1.50	0.50	0.83	0.29
95	0.50	0.50	0.29	0.67	2.00	0.40	1.50	0.40	0.67	0.33
96	0.56	0.56	0.25	0.60	1.50	0.38	1.50	0.50	0.60	0.40
97	0.53	0.57	0.28	0.63	2.67	0.57	1.33	0.60	1.00	0.30
98	0.63	0.67	0.33	0.60	2.33	0.47	1.67	0.50	0.70	0.30
99	0.60	0.53	0.26	0.56	2.00	0.47	1.25	0.57	0.89	0.40
100	0.50	0.53	0.24	0.50	2.00	0.29	2.00	0.33	0.50	0.25

Table 7 (Contd) Results and Calculations of Sample 6

NON-STANDARD RATIOS FOR 299 FACIAL PHOTOGRAPHS										
	$\frac{\text{Ch} - \text{Ch}}{\text{Ec} - \text{Ec}}$	$\frac{\text{Ch} - \text{Ch}}{\text{Go} - \text{Go}}$	$\frac{\text{Al} - \text{Al}}{\text{Zy} - \text{Zy}}$	$\frac{\text{Al} - \text{Al}}{\text{Ch} - \text{Ch}}$	$\frac{\text{N} - \text{Sn}}{\text{Sn} - \text{Ls}}$	$\frac{\text{N} - \text{Sn}}{\text{N} - \text{Me}}$	$\frac{\text{Sn} - \text{Sto}}{\text{Sn} - \text{Ls}}$	$\frac{\text{Ls} - \text{Li}}{\text{Sto} - \text{Me}}$	$\frac{\text{N} - \text{Sn}}{\text{Ch} - \text{Ch}}$	$\frac{\text{Sn} - \text{Ls}}{\text{N} - \text{Sto}}$
101	0.80	0.62	0.29	0.50	2.50	0.42	1.50	0.60	0.63	0.25
102	0.50	0.43	0.21	0.50	1.67	0.45	1.33	0.50	0.83	0.43
103	0.60	0.60	0.23	0.50	2.00	0.40	2.50	0.50	0.67	0.29
104	0.64	0.53	0.28	0.56	1.00	0.24	1.25	0.50	0.44	0.44
105	0.67	0.67	0.33	0.50	1.00	0.25	1.50	0.50	0.33	0.50
106	0.43	0.46	0.27	0.67	3.00	0.50	1.50	0.40	1.00	0.29
107	0.64	0.64	0.26	0.56	2.50	0.36	1.50	0.60	0.56	0.25
108	0.63	0.56	0.30	0.60	1.50	0.43	1.50	0.67	0.60	0.40
109	0.58	0.54	0.36	0.71	1.33	0.36	1.00	0.60	0.57	0.43
110	0.50	0.42	0.29	0.80	1.33	0.40	1.33	0.50	0.80	0.60
111	0.75	0.46	0.18	0.33	1.50	0.43	1.50	0.67	0.50	0.40
112	0.69	0.75	0.28	0.56	1.67	0.38	1.33	0.33	0.56	0.33
113	0.54	0.70	0.23	0.43	1.33	0.44	1.33	0.40	0.57	0.50
114	0.42	0.56	0.30	0.60	2.00	0.57	1.50	0.50	0.80	0.50
115	0.55	0.43	0.36	0.67	1.33	0.36	1.33	0.75	0.67	0.43
116	0.50	0.58	0.25	0.57	2.00	0.46	1.33	0.60	0.86	0.38
117	0.62	0.50	0.33	0.75	2.00	0.46	1.33	0.80	0.75	0.33
118	0.82	0.64	0.36	0.56	1.33	0.33	1.33	1.00	0.44	0.50
119	0.80	0.67	0.38	0.63	2.00	0.33	1.50	0.60	0.50	0.40
120	0.78	0.64	0.23	0.43	2.00	0.36	1.50	0.75	0.57	0.40
121	0.75	0.53	0.28	0.56	1.67	0.38	1.67	0.57	0.56	0.38
122	0.80	0.57	0.25	0.50	1.33	0.36	1.33	0.75	0.50	0.43
123	0.90	0.69	0.29	0.44	1.33	0.40	1.33	0.60	0.44	0.43
124	0.55	0.50	0.23	0.50	1.67	0.50	1.33	0.60	0.83	0.38
125	0.54	0.54	0.27	0.57	1.67	0.36	1.33	0.80	0.71	0.33
126	0.53	0.44	0.43	0.75	1.67	0.38	1.33	0.60	0.63	0.43
127	0.43	0.46	0.23	0.50	2.00	0.44	1.50	0.50	0.67	0.40
128	0.63	0.63	0.33	0.60	1.50	0.43	1.50	0.67	0.60	0.40
129	0.64	0.64	0.25	0.43	1.33	0.50	1.33	0.75	0.57	0.60
130	0.67	0.86	0.25	0.33	1.50	0.43	1.50	0.67	0.50	0.50
131	0.40	0.40	0.25	0.75	2.00	0.44	1.50	0.50	1.00	0.40
132	0.36	0.36	0.23	0.75	2.50	0.38	1.50	0.40	1.25	0.29
133	0.69	0.69	0.29	0.56	1.33	0.31	1.33	0.40	0.44	0.38
134	0.60	0.60	0.29	0.67	1.25	0.36	1.00	0.60	0.56	1.00
135	0.67	0.57	0.29	0.63	1.67	0.38	1.33	0.50	0.63	0.38
136	0.50	0.36	0.27	0.75	1.00	0.44	1.00	0.33	1.00	0.67
137	0.45	0.45	0.21	0.60	1.00	0.40	1.25	0.50	0.80	0.80
138	0.58	0.58	0.27	0.57	1.67	0.42	1.33	0.50	0.71	0.38
139	0.60	0.55	0.29	0.67	1.67	0.45	1.33	0.40	0.83	0.50
140	0.67	0.60	0.33	0.67	2.00	0.36	1.50	0.50	0.67	0.33
141	1.33	1.14	0.25	0.25	2.00	0.40	1.50	0.25	0.25	0.29
142	0.50	0.56	0.25	0.60	1.50	0.33	1.50	0.50	0.60	0.40
143	0.64	0.56	0.33	0.67	1.67	0.33	1.33	0.33	0.56	0.33
144	0.45	0.42	0.20	0.60	1.50	0.30	1.50	0.75	0.60	0.33
145	0.64	0.50	0.27	0.57	2.00	0.40	1.50	0.25	0.57	0.33
146	0.63	0.56	0.27	0.60	1.50	0.38	1.50	0.75	0.60	0.67
147	0.58	0.54	0.36	0.71	1.67	0.38	1.00	0.40	0.71	0.50
148	0.70	0.50	0.25	0.57	1.67	0.38	1.33	0.40	0.71	0.43
149	0.63	0.63	0.33	0.60	1.50	0.33	1.50	0.67	0.60	0.67
150	0.67	0.57	0.50	0.75	1.50	0.43	1.50	0.67	0.75	0.67

Table 7 (Contd) Results and Calculations of Sample 6

NON - STANDARD RATIOS FOR 299 FACIAL PHOTOGRAPHS										
	$\frac{Ch - Ch}{Ec - Ec}$	$\frac{Ch - Ch}{Go - Go}$	$\frac{Al - Al}{Zy - Zy}$	$\frac{Al - Al}{Ch - Ch}$	$\frac{N - Sn}{Sn - Ls}$	$\frac{N - Sn}{N - Me}$	$\frac{Sn - Sto}{Sn - Ls}$	$\frac{Ls - Li}{Sto - Me}$	$\frac{N - Sn}{Ch - Ch}$	$\frac{Sn - Ls}{N - Sto}$
151	0.64	0.60	0.35	0.67	2.50	0.38	2.00	0.40	0.56	0.25
152	0.56	0.50	0.18	0.60	1.50	0.30	1.50	0.50	0.60	0.33
153	0.78	0.54	0.25	0.57	2.50	0.38	1.50	0.40	0.71	0.22
154	0.47	0.50	0.31	0.71	2.50	0.36	1.50	0.40	0.71	0.22
155	0.54	0.54	0.33	0.71	2.50	0.45	1.50	0.60	0.71	0.25
156	0.67	0.62	0.33	0.63	1.33	0.33	1.33	0.60	0.50	0.50
157	0.60	0.67	0.40	0.67	2.00	0.44	1.50	0.50	0.67	0.40
158	0.64	0.60	0.28	0.56	1.67	0.33	1.33	0.43	0.56	0.38
159	0.54	0.70	0.32	0.86	1.67	0.38	1.33	0.50	0.71	0.43
160	0.56	0.50	0.36	0.80	2.00	0.40	1.50	0.67	0.80	0.33
161	0.42	0.36	0.31	1.00	2.00	0.40	2.00	0.50	0.80	0.29
162	0.45	0.50	0.45	1.00	2.50	0.50	1.50	0.50	1.00	0.29
163	0.63	0.71	0.33	0.60	2.00	0.57	1.50	0.67	0.80	0.50
164	0.46	0.46	0.21	0.50	1.67	0.38	1.33	0.50	0.83	0.38
165	0.59	0.59	0.36	0.80	2.67	0.42	1.33	0.38	0.80	0.27
166	0.47	0.50	0.32	0.86	2.67	0.47	1.33	0.38	1.14	0.30
167	0.57	0.67	0.29	0.50	3.00	0.43	2.00	0.33	0.75	0.25
168	0.29	0.28	0.38	0.60	1.67	0.36	1.33	0.33	1.00	0.38
169	0.57	0.67	0.29	0.50	1.50	0.38	1.50	0.20	0.75	0.50
170	0.67	0.67	0.29	0.50	1.50	0.38	1.50	0.20	0.75	0.50
171	0.71	0.71	0.22	0.40	2.00	0.57	1.50	0.33	0.80	0.50
172	0.50	0.50	0.25	0.67	1.50	0.60	1.50	0.33	1.00	0.50
173	0.71	0.71	0.33	0.60	2.00	0.50	1.50	0.50	0.80	0.40
174	0.56	0.56	0.30	0.60	2.00	0.50	2.00	0.50	0.80	0.40
175	0.67	0.67	0.25	0.50	1.50	0.75	1.50	0.33	0.75	0.67
176	0.67	0.57	0.43	0.75	1.50	1.00	1.50	0.33	0.75	0.50
177	0.67	0.50	0.38	0.75	1.50	0.50	2.00	0.33	0.75	0.50
178	0.71	0.63	0.33	0.60	1.50	0.30	1.50	0.17	0.60	0.40
179	0.40	0.33	0.38	1.25	2.00	0.40	1.50	0.67	1.00	0.40
180	0.44	0.44	0.33	1.00	2.00	0.40	1.50	0.50	1.00	0.33
181	0.45	0.36	0.42	1.00	2.33	0.50	1.33	0.40	1.40	0.30
182	0.71	0.42	2.00	0.80	3.00	0.67	1.50	0.50	1.20	0.22
183	0.50	0.42	0.57	0.80	2.67	0.62	1.33	0.40	1.60	0.30
184	0.45	0.38	0.38	0.60	3.50	0.78	1.00	0.50	1.40	0.25
185	0.50	0.36	0.33	0.75	1.50	0.75	0.75	0.33	1.50	0.57
186	0.44	0.36	0.25	0.75	1.50	0.67	0.50	0.25	1.50	0.67
187	0.43	0.33	0.38	1.00	1.67	0.71	1.00	1.00	1.67	0.60
188	0.45	0.42	0.33	0.80	2.00	0.50	1.00	0.67	1.20	0.43
189	0.63	0.50	0.27	0.60	1.67	0.56	1.00	0.50	1.00	0.43
190	0.40	0.33	0.44	1.00	1.25	0.50	0.50	0.50	1.25	0.57
191	0.43	0.50	0.27	0.67	1.50	0.40	1.00	0.43	1.00	0.44
192	0.50	0.45	0.29	0.80	2.50	0.45	1.50	0.75	1.00	0.33
193	0.67	0.50	0.20	0.50	1.67	0.38	1.00	0.40	0.83	0.38
194	0.42	0.31	0.31	0.80	1.50	0.43	1.00	0.60	1.20	0.40
195	0.44	0.31	0.36	1.25	1.67	0.33	1.33	0.43	1.25	0.38
196	0.43	0.40	0.17	0.67	1.50	0.43	1.00	0.50	1.00	0.33
197	0.36	0.31	0.23	0.75	1.67	0.33	1.00	0.50	1.25	0.43
198	0.36	0.33	0.27	0.75	1.67	0.38	1.00	0.33	1.25	0.43
199	0.56	0.50	0.20	0.40	2.00	0.44	1.50	0.50	0.80	0.40
200	0.30	0.27	0.23	1.00	1.33	0.36	1.00	0.60	1.33	0.38

Table 7 (Contd) Results and Calculations of Sample 6

NON - STANDARD RATIOS FOR 299 FACIAL PHOTOGRAPHS										
	$\frac{\text{Ch} - \text{Ch}}{\text{Ec} - \text{Ec}}$	$\frac{\text{Ch} - \text{Ch}}{\text{Go} - \text{Go}}$	$\frac{\text{Al} - \text{Al}}{\text{Zy} - \text{Zy}}$	$\frac{\text{Al} - \text{Al}}{\text{Ch} - \text{Ch}}$	$\frac{\text{N} - \text{Sn}}{\text{Sn} - \text{Ls}}$	$\frac{\text{N} - \text{Sn}}{\text{N} - \text{Me}}$	$\frac{\text{Sn} - \text{Sto}}{\text{Sn} - \text{Ls}}$	$\frac{\text{Ls} - \text{Li}}{\text{Sto} - \text{Me}}$	$\frac{\text{N} - \text{Sn}}{\text{Ch} - \text{Ch}}$	$\frac{\text{Sn} - \text{Ls}}{\text{N} - \text{Sto}}$
201	0.67	0.60	0.17	0.33	2.00	0.44	1.00	0.40	0.67	0.40
202	0.63	0.56	0.18	0.40	1.50	0.43	1.50	0.67	0.60	0.40
203	0.71	0.56	0.30	0.60	2.00	0.44	1.50	0.50	0.80	0.40
204	0.42	0.42	0.20	0.60	2.00	0.36	1.50	0.60	0.80	0.33
205	0.59	0.46	0.28	0.71	2.25	0.38	1.00	0.40	0.75	0.30
206	0.89	0.53	0.33	0.75	2.50	0.36	2.00	0.60	0.63	0.25
207	0.61	0.58	0.30	0.64	1.67	0.31	1.33	0.43	0.45	0.33
208	0.50	0.38	0.21	0.60	0.80	0.33	0.80	0.50	0.80	0.71
209	0.69	0.56	0.39	0.78	1.67	0.33	4.67	0.67	0.56	0.33
210	0.78	0.70	0.25	0.43	1.50	0.30	1.00	0.40	0.43	0.29
211	0.67	5.33	0.44	0.69	2.40	0.41	1.20	0.33	0.75	0.26
212	0.59	0.50	0.31	0.71	1.11	0.31	0.89	0.28	0.59	0.45
213	0.52	0.42	0.27	0.73	1.71	0.34	0.86	1.14	0.80	0.33
214	0.53	0.64	0.35	0.67	2.50	0.36	2.00	0.50	0.56	0.25
215	0.53	0.42	0.36	0.90	1.33	0.35	1.33	0.50	0.80	0.46
216	0.63	0.55	0.36	0.75	2.00	0.38	1.25	0.33	0.67	0.33
217	0.58	0.50	0.38	0.82	2.25	0.47	1.25	0.50	0.82	0.57
218	0.70	0.73	0.37	0.63	2.20	0.48	1.40	0.57	0.69	0.31
219	0.67	0.53	0.30	0.70	3.00	0.50	1.33	0.50	0.90	0.33
220	0.10	0.10	0.33	4.00	2.00	0.27	1.00	0.40	4.00	0.40
221	0.67	0.53	0.30	0.70	1.75	0.41	0.75	0.57	0.70	0.40
222	0.43	0.38	0.20	0.67	1.50	0.40	1.25	0.67	1.00	0.40
223	0.85	0.85	0.35	0.47	2.25	0.39	1.75	0.33	0.53	0.29
224	0.50	0.64	0.28	0.56	0.50	0.17	1.17	0.89	0.33	0.55
225	0.60	0.50	0.31	0.56	2.67	0.57	1.33	0.71	0.89	0.38
226	0.57	0.42	2.00	0.77	1.33	0.32	1.17	0.60	0.62	0.25
227	0.53	0.40	0.37	0.88	1.57	0.35	1.43	1.50	0.69	0.39
228	0.62	0.51	0.33	0.71	1.63	0.37	1.25	0.33	0.62	0.38
229	0.58	0.46	0.29	0.91	1.43	0.37	1.14	0.70	0.91	0.44
230	0.90	0.64	0.25	0.44	2.50	0.36	1.50	0.50	0.56	0.25
231	0.52	0.50	0.30	0.83	4.33	0.46	1.33	0.50	1.08	0.18
232	0.50	0.45	0.33	0.90	1.75	0.27	1.50	0.23	0.70	0.31
233	0.63	0.53	0.33	0.71	2.00	0.39	1.17	0.17	0.71	0.32
234	0.64	0.47	0.27	0.57	1.33	0.44	1.33	0.60	0.57	0.38
235	1.13	1.00	0.36	0.44	1.67	0.38	1.00	0.40	0.56	0.38
236	0.64	0.60	0.41	0.67	6.60	1.10	1.60	0.33	1.83	0.28
237	0.26	0.26	0.41	1.80	1.25	0.28	1.50	0.50	1.00	0.44
238	0.50	0.60	0.36	0.67	1.67	0.63	1.33	0.67	0.83	0.43
239	0.56	0.50	0.25	0.60	1.33	0.44	1.67	0.40	0.80	0.60
240	0.56	0.42	0.36	0.80	1.33	0.40	1.33	0.40	0.80	0.60
241	0.47	0.38	0.29	0.93	1.88	0.42	1.50	0.57	1.00	0.33
242	0.50	0.44	0.27	0.73	2.00	0.42	1.20	0.50	0.91	0.33
243	0.60	0.60	0.31	0.67	2.75	0.44	2.00	0.63	0.73	0.27
244	0.52	0.52	0.32	0.75	1.40	0.39	1.60	0.40	0.58	0.33
245	0.66	0.61	0.31	0.63	3.50	0.70	1.75	0.31	0.74	0.24
246	0.69	0.55	0.29	0.55	1.67	0.42	2.33	0.57	0.45	0.30
247	0.61	0.55	0.33	0.73	1.00	0.28	1.20	0.43	0.45	0.45
248	0.53	0.56	0.36	0.80	2.33	0.41	1.33	0.38	0.70	0.30
249	0.50	0.53	0.42	0.80	2.00	0.42	1.25	0.57	0.80	0.33
250	0.59	0.56	0.35	0.70	1.67	0.38	1.33	0.80	0.50	0.33

Table 7 (Contd) Results and Calculations of Sample 6

NON - STANDARD RATIOS FOR 299 FACIAL PHOTOGRAPHS										
	$\frac{Ch - Ch}{Ec - Ec}$	$\frac{Ch - Ch}{Go - Go}$	$\frac{Al - Al}{Zy - Zy}$	$\frac{Al - Al}{Ch - Ch}$	$\frac{N - Sn}{Sn - Ls}$	$\frac{N - Sn}{N - Me}$	$\frac{Sn - Sto}{Sn - Ls}$	$\frac{Ls - Li}{Sto - Me}$	$\frac{N - Sn}{Ch - Ch}$	$\frac{Sn - Ls}{N - Sto}$
251	0.59	0.53	0.33	0.70	1.50	0.25	1.00	0.50	0.60	0.40
252	0.75	0.60	0.35	0.58	1.50	0.38	1.00	0.43	0.50	0.36
253	0.56	0.50	0.27	0.60	1.50	0.30	1.50	0.33	0.60	0.40
254	0.45	0.38	0.29	0.80	1.33	0.33	1.00	0.50	0.80	0.50
255	0.44	0.67	0.27	0.50	1.67	0.42	1.00	0.80	0.63	0.43
256	0.64	0.70	0.38	0.71	2.50	0.42	1.00	0.75	0.71	0.29
257	0.58	0.58	0.29	0.57	2.50	0.38	2.00	0.60	0.71	0.25
258	0.75	0.67	0.44	0.67	4.00	0.50	2.00	0.50	0.67	0.20
259	1.00	0.54	0.19	0.57	1.33	0.29	1.33	0.75	0.57	0.38
260	0.50	0.45	0.31	0.80	1.33	0.31	1.00	0.75	0.80	0.38
261	0.63	0.48	0.35	0.75	1.40	0.28	1.00	0.42	0.58	0.38
262	0.80	0.63	0.36	0.67	3.50	0.44	4.00	0.67	0.58	0.18
263	0.42	0.50	0.29	0.80	1.67	0.36	1.00	0.50	1.00	0.38
264	0.62	0.62	0.44	0.88	3.50	0.58	1.50	0.60	0.88	0.25
265	0.56	0.56	0.24	0.67	1.60	0.42	1.00	0.67	0.89	0.42
266	0.64	0.58	0.28	0.71	3.00	0.46	1.50	0.50	0.86	0.25
267	0.55	0.43	0.28	0.83	2.00	0.43	1.33	0.60	1.00	0.43
268	0.36	0.29	0.25	1.00	2.50	0.36	1.00	0.50	1.25	0.29
269	0.50	0.50	0.30	0.75	3.00	0.38	1.00	0.33	0.75	0.20
270	0.63	0.56	0.30	0.60	4.00	0.50	1.00	0.67	0.80	0.20
271	0.56	0.50	0.35	0.78	2.00	0.40	1.00	0.50	0.89	0.33
272	0.57	0.54	0.30	0.69	0.50	0.33	0.50	0.60	0.62	1.14
273	0.59	0.50	0.35	0.74	2.25	0.47	1.25	0.38	0.95	0.29
274	0.37	0.39	0.25	0.73	2.00	0.43	1.00	0.50	1.09	0.38
275	6.00	0.86	0.25	0.67	1.67	0.42	1.00	0.50	0.83	0.38
276	0.54	0.44	0.32	0.86	2.00	0.40	1.33	0.50	0.86	0.33
277	0.44	0.44	0.23	0.71	1.50	0.38	1.50	0.50	0.86	0.40
278	0.56	0.42	0.27	0.70	0.80	0.44	1.20	0.50	0.80	0.83
279	0.50	0.47	0.43	0.86	2.00	0.40	1.33	0.05	0.86	0.33
280	0.59	0.54	0.29	0.62	1.33	0.33	1.00	0.50	0.62	0.43
281	0.53	0.42	0.31	0.80	5.00	0.50	2.00	0.50	1.00	0.17
282	0.45	0.38	0.42	1.10	1.67	0.42	1.00	0.40	1.00	0.43
283	0.57	0.50	0.28	0.63	2.00	0.50	1.50	0.67	1.00	0.40
284	0.61	0.50	0.25	0.55	2.00	0.40	1.50	0.60	0.73	0.33
285	0.43	0.43	0.26	0.83	1.50	0.38	1.00	0.50	1.00	0.40
286	0.54	0.44	0.32	0.80	3.50	0.44	2.00	0.50	0.93	0.22
287	0.54	0.47	0.36	0.93	3.00	0.46	2.50	0.29	0.86	0.25
288	0.00	0.00	0.18	0.67	1.50	0.38	1.50	0.50	0.85	0.40
289	0.56	0.47	0.23	0.78	2.00	0.50	1.50	0.75	0.89	0.40
290	0.50	0.44	0.33	0.81	2.00	0.47	1.25	0.67	1.00	0.40
291	0.60	0.52	0.33	0.75	2.25	0.43	1.25	0.44	0.75	0.29
292	0.47	0.42	0.31	0.81	1.25	0.26	1.25	0.33	0.63	0.44
293	0.54	0.47	0.32	0.79	2.00	0.46	1.33	0.60	0.86	0.33
294	0.59	0.42	0.33	0.80	2.25	0.38	1.25	0.40	0.90	0.33
295	0.47	0.50	0.29	0.71	2.33	0.50	1.33	0.50	1.00	0.33
296	0.56	0.56	0.30	0.70	2.67	0.44	1.33	0.43	0.80	0.25
297	0.45	0.43	0.31	0.80	2.50	0.36	1.50	0.50	1.00	0.25
298	0.64	0.58	0.25	0.50	2.50	0.38	1.50	0.60	0.71	0.29
299	0.58	0.58	0.25	0.50	1.50	0.43	1.25	0.50	0.86	0.44

5.5 STATISTICAL ANALYSIS

5.5.1 Relationship between the Skull Ratio and its corresponding Facial Ratio

With reference to the first sample as shown in Table 2, in order to investigate the relationship between the *facial ratio* and its corresponding *skull ratio*, a correlation coefficient was calculated between the *mean facial ratio* and the corresponding *skull ratio* for the 10 non-standard ratios. A regression analysis was then performed between the mean facial ratio and its corresponding skull ratio in order to determine the form of the relationship. The results of the analysis are given below.

Table 8 Skull ratio and the corresponding Mean Facial ratios of 20 known faces

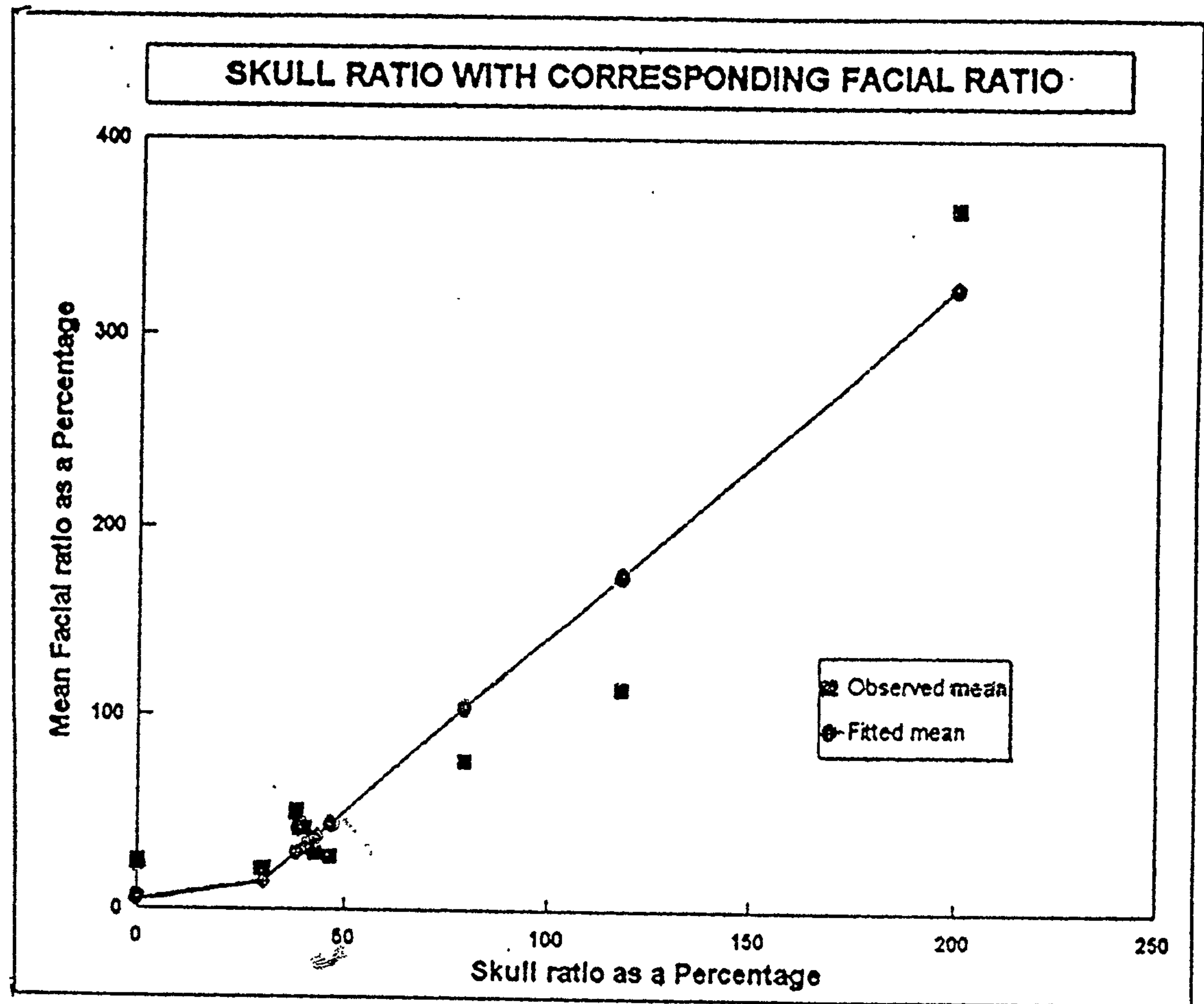
Ratio	Skull Ratio (X) %	Mean Facial Ratio (Y) %	Fitted Facial Ratio (y) %
Al - Al / Zy - Zy	25.41	25.27	4.85
Ns - Sd / N - Is	30.67	21.01	14.49
Ch - Ch / Ec - Ec	38.61	50.77	29.04
Ch - Ch / Go - Go	39.00	43.39	29.75
N - Ns / N - Me	40.35	41.79	32.23
Ns - Is / Ns - Me	42.86	29.42	36.83
Sd - Id / Is - Me	46.51	27.67	43.51
Al - Al / Ch - Ch	79.49	76.39	103.94
N - Ns / Ch - Ch	117.95	113.69	174.40
N - Ns / Ns - Sd	200.00	364.29	324.74

The calculated correlation coefficient was obtained as $r = + 0.96$.

The Regression Analysis showed that the **Mean Facial Ratio** was found to have a linear relationship with its corresponding **Skull Ratio X** of the form

$$y = 1.8 X - 42$$

Fig 15 - Scatter diagram of Skull Ratios and Corresponding Mean Facial Ratios with the fitted Regression line.



5.5.2 Significant differences between the Mean Facial Ratios of Two Independent Samples

The same 10 Non-Standard facial ratios calculated for the first sample, were calculated for an independent sample of 15 victims given as the second sample in Table 3. A Statistical "t" - test was carried out for each of the 10 Non-Standard Facial ratios between the first sample of 20 known faces and the second sample of 15 victims.

The results are presented in Tables 9 to 18.

Table 9 The First Non-Standard Facial Ratio: Ch - Ch / Ec - Ec

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	40.00	40.57		11	48.28	48.11
2	52.94	56.00		12	53.85	64.17
3	36.67	56.74		13	44.83	60.00
4	35.71	63.16		14	43.33	59.51
5	78.57	39.15		15	55.56	49.48
6	50.00	54.50		16	54.55	
7	54.55	54.17		17	39.47	
8	60.87	43.24		18	60.00	
9	59.38	55.56		19	50.00	
10	46.15	64.21		20		
				Total	964.63	808.57
				Mean	50.77	53.91
Coefficient of variation	20.2%	15.23%		Std. Deviation	10.24	8.21

Results of the t - test at 5% level of significance.
 $t = (53.91 - 50.77) / \sqrt{\{(8.21)^2/15 + (10.24)^2/19\}} = 0.991$ for 32 degrees of freedom.

As the calculated value of 0.991 is less than the critical value of 2.04 for 32 degrees of freedom, we conclude that there is no significant difference in the mean facial ratio of Ch-Ch/Ec-Ec between the two samples.

Table 10 The Second Non-Standard Facial Ratio: Ch-Ch / Go-Go

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	41.03	35.68		11	40.00	40.80
2	54.55	52.09		12	33.33	50.00
3	35.48	47.10		13	41.94	53.02
4	32.26	61.40		14	39.39	55.96
5	57.89	33.79		15	43.48	55.88
6	41.67	51.90		16	56.25	
7	37.50	50.00		17	46.88	
8	50.00	38.10		18	47.37	
9	44.19	50.00		19	41.18	
10	40.00	50.62		20		
				Total	824.39	726.34
				Mean	43.39	48.42
Coefficient of Variation	16.74%	16.40%		Std. Deviation	7.26	7.94

Results of the t - test at 5% level of significance.
 $t = (48.42 - 43.39) / \sqrt{\{(7.94)^2/15 + (7.26)^2/19\}} = 1.91$ for 32 degrees of freedom.

As the calculated value of 1.91 is less than the critical value of 2.04 for 32 degrees of freedom, we conclude that there is no significant difference in the mean facial ratio of Ch-Ch / Go-Go between the two samples.

Table 11 The Third Non-standard Facial Ratio: Al - Al / Zy -Zy

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	26.00	30.12		11	19.57	23.28
2	30.23	24.91		12	18.18	30.25
3	31.82	25.48		13	26.00	29.03
4	28.21	26.33		14	11.63	30.82
5	24.49	31.03		15	26.42	23.85
6	29.79	26.85		16	32.00	
7	23.81	27.03		17	23.26	
8	27.03	24.48		18	19.57	
9	29.79	25.94		19	20.00	
10	32.35	60.68		20		
				Total	480.15	440.08
				Mean	25.27	29.34
Coefficient of Variation				Std. Deviation	5.55	9.05
	21.95%	30.84%				

Results of the t - test at 5% level of significance.
 $t = (29.34 - 25.27) / \sqrt{\{(9.05)^2/15 + (5.55)^2/19\}} = 1.53$ for 32 degrees of freedom.

As the calculated value of 1.53 is less than the critical value of 2.04 for 32 degrees of freedom, we conclude that there is no significant difference in the mean facial ratio of Al - Al / Zy - Zy between the two samples.

Table 12 The Fourth Non-Standard Facial Ratio:- Al - Al / Ch -Ch

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	81.25	105.63		11	64.29	69.61
2	72.22	58.93		12	57.14	70.83
3	127.27	64.75		13	100.00	71.05
4	110.00	59.85		14	38.46	73.77
5	54.55	109.46		15	70.00	60.00
6	93.33	73.39		16	88.89	
7	83.33	67.31		17	66.67	
8	71.43	73.75		18	50.00	
9	73.68	62.00		19	57.14	
10	91.67	146.72		20		
				Total	1451.32	1167.05
				Mean	76.39	77.80
Coefficient of Variation				Std. Deviation	21.996	24.298
	28.80%	31.23%				

Results of the t - test at 5% level of significance.
 $t = (77.80 - 76.39) / \sqrt{\{(24.298)^2/15 + (21.996)^2/19\}} = 0.18$ for 32 degrees of freedom.

As the calculated value of 0.18 is less than the critical value of 2.04 for 32 degrees of freedom, we conclude that there is no significant difference in the mean facial ratio of Al - Al / Ch - Ch between the two samples.

Table 13 The Fifth Non-Standard Facial Ratio:- N - Sn / Sn -Ls

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	285.71	251.43		11	300.00	176.47
2	360.00	258.06		12	250.00	248.78
3	350.00	270.00		13	300.00	309.38
4	533.33	440.91		14	280.00	243.75
5	340.00	276.32		15	433.33	357.14
6	250.00	197.78		16	360.00	
7	500.00	243.59		17	475.00	
8	500.00	256.10		18	433.33	
9	450.00	392.00		19	375.00	
10	250.00	235.71		20	260.00	
				Total	7285.71	4157.42
				Mean	364.29	277.16
Coefficient of Variation	25.74%	25.54%		Std. Deviation	93.78	71.79

Results of the t - test at 5% level of significance.
 $t = (364.29 - 277.16) / \sqrt{\{(70.79)^2/15 + (93.78)^2/20\}} = 3.13$ for 33 degrees of freedom.

As the calculated value of 3.13 is greater than the critical value of 2.05 for 33 degrees of freedom, we conclude that there is a **significant difference** in the mean facial ratio of N - Sn / Sn - Ls between the two samples.

Table 14 The Sixth Non-Standard Facial Ratio:- N - Sn / N - Me

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	46.51	63.31		11	48.84	37.82
2	40.91	40.00		12	34.09	40.96
3	35.90	42.35		13	45.65	38.08
4	48.48	44.09		14	42.42	33.19
5	39.53	42.00		15	39.39	38.46
6	41.67	38.70		16	39.13	
7	48.78	42.99		17	36.54	
8	45.45	42.17		18	40.63	
9	41.86	41.14		19	41.67	
10	44.12	39.76		20	34.21	
				Total	835.78	628.02
				Mean	41.79	41.87
Coefficient of Variation	10.96%	15.74%		Std. Deviation	4.58	6.59

Results of the t - test at 5% level of significance.
 $t = (41.87 - 41.79) / \sqrt{\{(6.59)^2/15 + (4.58)^2/20\}} = 0.04$ for 33 degrees of freedom.

As the calculated value of 0.04 is less than the critical value of 2.05 for 33 degrees of freedom, we conclude that there is **no significant difference** in the mean facial ratio of N - Sn / N - Me between the two samples.

Table 15 The Seventh Non-Standard Facial Ratio:- Sn - Sto / Sn - Me

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	33.33	34.00		11	36.36	39.47
2	25.00	33.33		12	32.00	35.92
3	37.50	33.56		13	21.43	26.09
4	21.05	28.06		14	25.00	28.00
5	29.63	36.91		15	20.00	36.70
6	36.84	36.62		16	23.33	
7	22.73	32.06		17	33.33	
8	31.58	35.92		18	29.41	
9	29.17	25.60		19	27.78	
10	38.10	30.87		20	34.78	
				Total	588.35	493.11
				Mean	29.42	32.87
Coefficient of Variation	20.05%	13.10%		Std. Deviation	5.90	4.31

Results of the t - test at 5% level of significance.

$$t = (32.87 - 29.42) / \sqrt{\{(4.31)^2/15 + (5.90)^2/20\}} = 2.00 \text{ for 33 degrees of freedom.}$$

As the calculated value of 2.00 is less than the critical value of 2.05 for 33 degrees of freedom, we conclude that there is no significant difference in the mean facial ratio of Sn - Sto / Sn - Me between the two samples.

Table 16 The Eighth Non-Standard Facial Ratio:- Ls - Li / Sto - Me

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	26.32	30.00		11	18.75	29.41
2	30.00	41.18		12	16.67	39.00
3	50.00	30.69		13	30.00	32.11
4	35.71	39.22		14	33.33	27.52
5	20.00	40.38		15	35.71	47.06
6	23.08	35.00		16	30.00	
7	22.22	39.33		17	13.64	
8	16.67	31.58		18	33.33	
9	29.41	35.71		19	40.00	
10	28.57	42.42		20	20.00	
				Total	553.41	540.61
				Mean	27.67	36.04
Coefficient of Variation	32.67%	15.82%		Std. Deviation	9.04	5.70

Results of the t - test at 5% level of significance.

$$t = (36.04 - 27.67) / \sqrt{\{(5.70)^2/15 + (9.04)^2/20\}} = 3.35 \text{ for 33 degrees of freedom.}$$

As the calculated value of 3.35 is greater than the critical value of 2.05 for 33 degrees of freedom, we conclude that there is a **significant difference** in the mean facial ratio of Ls - Li / Sto - Me between the two samples.

Table 17 The Ninth Non- Standard Facial Ratio:- N - Sn / Ch - Ch

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	125.00	123.94		11	150.00	88.24
2	100.00	71.43		12	107.14	85.00
3	127.27	88.52		13	161.54	86.84
4	160.00	73.48		14	100.00	63.93
5	77.27	141.89		15	90.00	78.95
6	100.00	81.65		16	105.56	
7	166.67	91.35		17	86.67	
8	107.14	131.25		18	83.33	
9	94.74	98.00		19	92.86	
10	125.00	81.15		20		
				Total	2160.19	1385.62
				Mean	113.69	92.37
Coefficient of Variation	24.57%	24.44%		Std. Deviation	27.94	22.58

Results of the t - test at 5% level of significance.
 $t = (113.69 - 92.37) / \sqrt{\{(22.58)^2/15 + (27.94)^2/19\}} = 2.46$ for 32 degrees of freedom.

As the calculated value of 2.46 is greater than the critical value of 2.04 for 32 degrees of freedom, we conclude that there is a **significant difference** in the mean facial ratio of N - Sn / Ch - Ch between the two samples.

Table 18 The Tenth Non-Standard Facial Ratio:- Sn - Ls / N - Sto

Number	First Sample	Second Sample		Number	First Sample	Second Sample
1	24.14	25.00		11	29.17	34.23
2	20.83	25.41		12	24.00	27.33
3	17.39	25.81		13	30.43	22.54
4	15.79	18.03		14	23.81	25.00
5	21.74	24.52		15	15.79	16.80
6	27.27	32.61		16	19.23	
7	16.67	28.26		17	14.29	
8	15.79	27.33		18	15.79	
9	17.39	19.53		19	17.39	
10	31.58	31.11		20	21.74	
				Total	420.23	383.51
				Mean	21.01	25.57
Coefficient of Variation	25.59%	19.55%		Std. Deviation	5.38	5.00

Results of the t - test at 5% level of significance.
 $t = (25.57 - 21.01) / \sqrt{\{(5.00)^2/15 + (5.38)^2/20\}} = 2.58$ for 33 degrees of freedom.

As the calculated value of 2.58 is greater than the critical value of 2.05 for 33 degrees of freedom, we conclude that there is a **significant difference** in the mean facial ratio of Sn - Ls / N - Sto between the two samples.

5.5.3 Significant differences between the mean ratio of five poses of three faces using the Third sample

The statistical calculations, including the Analysis of Variance (ANOVA) for each of the non-standard ratios are given in the Tables 19 - 28.

Table 19 Statistical calculations for the First Facial ratio Ch-Ch/Ec-Ec

	1st Face	2 nd Face	3rd Face	Total
Pose 1	0.64000	0.464286	0.60000	
Pose 2	0.68000	0.392857	0.56000	
Pose 3	0.66667	0.379310	0.80000	
Pose 4	0.70833	0.500000	0.730769	
Pose 5	0.57692	0.500000	0.653846	
Total T	3.27192	2.236453	3.344615	8.85299
Number N =	5	5	5	15
Mean Y	0.65438	0.447291	0.66892	0.590
Std deviation O	0.0498	0.05794	0.09727	
Σy ²	2.15102	1.01377	2.27514	5.43993
T ² /n	2.14109	1.00034	2.23729	5.37872

Analysis of Variance for Table 19

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3 - 1=2	5.3787-(8.853) ² /15=0.154	0.154/2=0.0768	
Within Faces	15-3=12	5.4399-5.3787=0.0612	0.0612/12=0.0051	0.0768/0.0051=15.06
Total	15-1=14	0.215		

As the calculated value of 15.06 is greater than the critical F value of 3.88 at 5% significant level, there is a significant difference between the mean ratio of Ch-Ch/Ec-Ec between the 3 faces.

Table 20 Statistical calculations for the Second Facial ratio Ch-Ch/Go-Go

	1st Face	2 nd Face	3rd Face	Total
Pose 1	0.457143	0.371429	0.405405	
Pose 2	0.500000	0.314286	0.388889	
Pose 3	0.484848	0.314286	0.555556	
Pose 4	0.472222	0.400000	0.542857	
Pose 5	0.454545	0.38889	0.485714	
Total T	2.368758	1.78889	2.378426	6.536
Number N =	5	5	5	15
Mean Y	0.473752	0.357778	0.475685	0.436
Std deviation O	0.019099	0.040988	0.07659	
Σy ²	1.123662	0.646746	1.154847	2.92525
T ² /n	1.122203	0.640000	1.131382	2.89359

Analysis of Variance for Table 20

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3-1=2	2.8936-(6.536) ² /15=0.045	0.045/2=0.0228	
Within Faces	15-3=12	2.9253-2.8936=0.0317	0.0317-12=0.0026	0.0228-0.0026=8.64
Total	15-1=14	0.0773		

As the calculated value of 8.64 is greater than the critical F value of 3.88 at 5% significant level, there is a significant difference between the mean ratio of Ch-Ch/Go-Go between the 3 faces.

Table 21 Statistical calculations for the Third Facial ratio Al-Al/Ch-Ch

	1 st Face	2 nd Face	3rd Face	Total
Pose 1	0.75000	0.76923	0.73333	
Pose 2	0.64706	0.90909	0.71429	
Pose 3	0.68750	0.90909	0.5500	
Pose 4	0.64706	0.78571	0.57895	
Pose 5	0.73333	0.78571	0.58824	
Total T	3.46495	4.15884	3.1648	10.7886
Number N =	5	5	5	15
Mean Y	0.69299	0.83177	0.63296	0.719
Std deviation O	0.04777	0.0709	0.08439	
Σy^2	2.4103	3.4793	2.03168	7.92128
T^2 /n	2.40117	3.4592	2.00319	7.86356

Analysis of Variance for Table 21

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3-1=2	$7.864-(10.789)^2/15=0.104$	$0.3104/2=0.052$	
Within Faces	15-3=12	$7.921-7.864=0.058$	$0.058/12=0.0048$	$0.052/0.0048=10.81$
Total	15-1=14	0.162		

As the calculated value of 10.81 is greater than the critical F value of 3.88 at 5% significant level, there is a significant difference between the mean ratio of Al-Al/Ch-Ch between the 3 faces.

Table 22 Statistical calculations for the Fourth Facial ratio Sn-Sto/Sn-Me

	1st Face	2 nd Face	3rd Face	Total
Pose 1	0.35000	0.33333	0.30000	
Pose 2	0.27778	0.36364	0.28571	
Pose 3	0.26316	0.33333	0.36842	
Pose 4	0.27778	0.33333	0.31579	
Pose 5	0.26667	0.31818	0.31579	
Total T	1.43538	1.68182	1.58571	4.703
Number N =	5	5	5	15
Mean Y	0.28708	0.3367	0.31715	0.3135
Std deviation O	0.03578	0.0166	0.03128	
Σy^2	0.41718	0.5668	0.50681	1.491
T^2 /n	0.41206	0.5657	0.5029	1.481

Analysis of Variance for Table 22

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3-1=2	$1.481-(4.703)^2/15=0.0062$	$0.0062/2=0.003$	
Within Faces	15-3=12	$1.491-1.481=0.0101$	$0.0101/12=0.0008$	$0.0031/0.0008= 3.65$
Total	15-1=14	0.0163		

As the calculated value of 3.65 is less than the critical F value of 3.88 at 5% significant level, there is no significant difference between the mean ratio of Sn-Sto/Sn-Me between the 3 faces.

Table 23 Statistical calculations for the Fifth Facial ratio Ls-Li/Sto-Me

	1st Face	2 nd Face	3rd Face	Total
Pose 1	0.153846	0.142857	0.142857	
Pose 2	0.076923	0.0214286	0.066667	
Pose 3	0.142857	0.142857	0.166667	
Pose 4	0.230769	0.142857	0.153846	
Pose 5	0.181818	0.133333	0.153846	
Total T	0.786213	0.77619	0.683883	2.2463
Number N =	5	5	5	15
Mean Y	0.1572426	0.15524	0.13678	0.1498
Std deviation O	0.0563	0.03326	0.04009	
Σy^2	0.1363	0.12492	0.09997	0.3612
T^2 / n	0.12363	0.12049	0.09354	0.3377

Analysis of Variance for Table 23

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3-1=2	$0.338(2.246)^2 / 15=0.0013$	$0.0013/2=0.0006$	
Within Faces	15-3=12	$0.3612-0.338=0.0235$	$0.0235/12=0.00196$	$0.0006/0.00196=0.324$
Total	15-1=14	0.0248		

As the calculated value of 0.324 is less than the critical F value of 3.88 at 5% significant level, there is **no** significant difference between the mean ratio of Ls-li/Sto-Me between the 3 faces.

Table 24 Statistical calculations for the Sixth Facial ratio N-Sn/Ch-Ch

	1st Face	2 nd Face	3rd Face	Total
Pose 1	0.7500	1.153846	0.866667	
Pose 2	0.705882	1.363636	0.928571	
Pose 3	0.75	1.363636	0.6000	
Pose 4	0.705882	1.071429	0.684211	
Pose 5	0.80	1.071429	0.705882	
Total T	3.71176	6.023976	3.785331	3.78533
Number N =	5	5	5	15
Mean Y	0.7424	1.204795	0.7571	0.25235
Std deviation	0.0391	0.14885	0.1360	
Σy^2	2.76154	7.3463	2.9398	2.9398
T^2 / n	2.7554	7.2577	2.8658	2.8658

Analysis of Variance for Table 24

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3-1=2	$2.8658-(3.785)^2/15=0.6909$	$0.6909/2=0.345$	
Within Faces	15-3=12	$2.9398-2.8658=0.1687$	$0.1687/12=0.0141$	$0.345/0.014=24.57$
Total	15-1=14	0.8596		

As the calculated value of 24.57 is greater than the critical F value of 3.88 at 5% significant level, there is a **significant** difference between the mean ratio of N-Sn/Ch-Ch between the 3 faces.

Table 25 Statistical calculations for the Seventh Facial ratio N-Ls/N-Sto

	1st Face	2 nd Face	3rd Face	Total
Pose 1	0.1250	0.227773	0.66667	
Pose 2	0.1333	0.142857	0.80000	
Pose 3	0.1250	0.227273	0.60000	
Pose 4	0.0625	0.227273	0.66667	
Pose 5	0.1250	0.227273	0.66667	
Total T	0.5708	0.051949	3.40000	5.023
Number N =	5	5	5	15
Mean Y	0.1142	0.2104	0.68	0.335
Std deviation O	0.0291	0.0378	0.073	
Σy^2	0.0686	0.2270	2.333	2.6289
T^2 /n	0.0652	0.2213	2.312	2.5985

Analysis of Variance for Table 25

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3-1=2	$2.5985-(5.023)^2/15=0.9166$	$0.9166/2=0.458$	
Within Faces	15-3=12	$2.629-2.599=0.0304$	$0.0304/12=0.0025$	$0.0025/0.458=180.79$
Total	15-1=14	0.947		

As the calculated value of 180.79 is greater than the critical F value of 3.88 at 5% significant level, there is a **significant difference** between the mean ratio of N-Ls/N-Sto between the 3 faces.

Table 26 Statistical calculations for the Eighth Facial ratio Sn-Sto/Sto-Me

	1st Face	2 nd Face	3rd Face	Total
Pose 1	0.538462	0.500000	0.428571	
Pose 2	0.384615	0.571429	0.40000	
Pose 3	0.357143	0.50000	0.58333	
Pose 4	0.384615	0.50000	0.461538	
Pose 5	0.363636	0.466667	0.461538	
Total T	0.028471	1.294309	1.109985	4.4328
Number N =	5	5	5	15
Mean Y	0.4057	0.5076	0.467	0.2955
Std deviation O	0.0752	0.0385	0.0699	
Σy^2	0.8456	1.2943	1.10999	3.2499
T^2 /n	0.8229	0.3351	0.2464	1.4044

Analysis of Variance for Table 26

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3-1=2	$1.4044-(4.4328)^2/15=0.0944$	$0.0944/2=0.0472$	
Within Faces	15-3=12	$3.2499-1.4044=1.8455$	$1.8455/12=0.1538$	$0.0472/0.1538=0.307$
Total	15-1=14	1.9399		

As the calculated value of 0.307 is less than the critical F value of 3.88 at 5% significant level, there is **no significant difference** between the mean ratio of Sn-Sto/Sto-Me. between the 3 faces.

Table 27 Statistical calculations for the Ninth Facial ratio Sto-Me/Ch-Ch

	1st Face	2 nd Face	3rd Face	Total
Pose 1	0.812500	1.076923	0.933333	
Pose 2	0.764706	1.272727	1.071429	
Pose 3	0.875000	1.272727	0.60000	
Pose 4	0.764706	1.00000	0.684211	
Pose 5	0.733333	1.071429	0.764706	
Total T	3.95025	5.69381	4.053679	13.6977
Number N =	5	5	5	15
Mean Y	0.7901	1.13876	0.81074	0.913
Std deviation O	0.0553	0.126	0.19074	
Σy^2	3.1331	6.5474	3.43199	13.11
T^2 / n	3.12089	6.48389	3.28646	12.891

Analysis of Variance for Table 27.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3-1=2	$12.891(13.6977)^2/15=$ 0.386	0.386/2=0.191	
Within Faces	15-3=12	$13.11-12.891=0.219$	$0.219/12=$ 0.0183	$0.191/0.0183$ = 10.47
Total	15-1=14	0.215		

As the calculated value of 10.47 is greater than the critical F value of 3.88 at 5% significant level, there is a **significant difference** between the mean ratio of Sto-Me/Ch-Ch. between the 3 faces.

Table 28 Statistical calculations for the Tenth Facial ratio Sto-Me/Ch-Ch

	1st Face	2 nd Face	3rd Face	Total
Pose 1	1.230769	0.866667	1.00000	
Pose 2	1.214286	0.733333	0.93333	
Pose 3	1.230769	0.733333	1.428571	
Pose 4	1.307692	0.933333	1.266667	
Pose 5	1.071429	0.933333	1.214286	
Total T	6.054945	4.199999	5.842557	16.0978
Number N =	5	5	5	15
Mean Y	1.211	0.839999	1.16857	1.0732
Std deviation O	0.086	0.1011	0.2019	
Σy^2	7.3621	3.5688	6.9909	17.9218
T^2 / n	7.3325	3.528	6.8278	17.6883

Analysis of Variance for Table 28

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F _{2,12} Value
Among Faces	3-1=2	$17.688-(16.098)^2/15=$ 0.412	0.412/2=0.206	
Within Faces	15-3=12	$17.922-17.688=0.234$	$0.234/12=0.019$	$0.206/0.019=$ 10.59
Total	15-1=14	0.646		

As the calculated value of 10.59 is greater than the critical F value of 3.88 at 5% significant level, there is a **significant difference** between the mean ratio of Ch-Ch/L-L. between the 3 faces.

5.5.4 Farkas Munro study pattern in the Fourth sample

The results and calculations of the Fourth sample given in Table 5 of Section 5.4 were analysed to investigate whether the standard ratios given in the Furkas Munro study pattern were followed. When possible a Chi-square value (χ^2) was calculated to observe whether the Observed pattern followed the Expected pattern.

Table 29 Pattern of the distance between eyes and the width of the nose

	En-En=AI-AI	En-En<AI-AI	En-En>AI-AI	Total
Observed Values	3	7	5	15
Observed Percentage	20.0%	46.7%	33.3%	100.0%
Expected Percentage	40.8%	37.9%	21.4%	100.1%

$\chi^2 = \{(20.0-40.8)^2/40.8\} + \{(46.7-37.9)^2/37.9\} + \{(33.3-21.4)^2/21.4\} = 19.26$ for 2 degrees of freedom.

As the Chi square value of 19.26 for 2 degrees of freedom is greater than the critical value of 5.99 at 5% level of significance we can conclude that the pattern of the distance between the eyes and the width of the nose, does not conform to the given pattern.

Table 30 Pattern of the distance between the eyes and the width of an eye

	En-En=Ec-En	En-En>Ec-En	En-En<Ec-En	Total
Observed Values	1	7	7	15
Observed Percentage	6.67%	46.67%	46.67%	100.01%
Expected Percentage	33.33%	51.50%	15.20%	100.03%

$\chi^2 = \{(6.67-33.33)^2/33.33\} + \{(46.67-51.50)^2/51.50\} + \{(46.67-15.20)^2/15.20\} = 86.93$ for 2 degrees of freedom

As the Chi square value of 86.93 for 2 degrees of freedom is greater than the critical value of 5.99 at 5% level of significance we can conclude that the pattern of the distance between the eyes and the width of an eye, does not conform to the given pattern.

Table 31 Pattern of the proportion between the Vertex to Nasion distance and the Nasion to the Menton distance

	V-N=N-Me	V-N>N-Me	V-N<N-Me	Total
Observed Values	3	2	10	15
Observed Percentage	20.0%	13.3%	66.7%	100%

The proportion Vertex to Nasion was equal to Nasion to Menton for only 20% of the cases.

Table 32 Pattern of the distance from the root of the nose to the bottom of the chin and the length of the nose

	N-Sn<Sn-Me	N-Sn>Sn-Me	Total
Observed Values	13	2	15
Observed Percentage	86.7%	13.3%	100%
Expected Percentage	43.0%	57.0%	100%

$\chi^2 = \{(86.7-43.0)^2/43.0\} + \{(13.3-57.0)^2/57.0\} = 76.14$ for one degree of freedom.

As the Chi square value is greater than the critical value of 3.84 for 1 degree of freedom at 5% level of significance we can conclude that it does not follow the given pattern.

Table 33 Pattern of the Sn-Sto distance with the Sto-Me distance

	Sn-Sto=Sto-Me	Sn-Sto>Sto-Me	Sn-Sto<Sto-Me	Total
Observed Values	4	2	9	15
Observed Percentage	27%	13%	60%	100%

We observe that there were only 27% of cases where the distance Sn-Sto was equal to the distance Sto-Me.

Table 34 Pattern of the Irido Oral proportion canon: Ch-Ch distance with the L-L distance

	Ch-Ch=L-L	Ch-Ch>L-L	Ch-Ch<L-L	Total
Observed Values	4	7	2	15
Observed Percentage	31%	54%	15.0%	100%

We observe that there were only 30.8% of cases where the distance Ch-Ch was equal to the distance L-L.

5.5.5 Pattern and relationships between Non-Standard Skull ratios using the Fifth sample

To illustrate the frequencies of occurrences of combinations of the non-standard skull ratios, a frequency table of the calculations was made from the observations of the 55 skull X-rays of Sri Lankans. This **Table 35** was used to investigate the independence of occurrences of certain combinations of non-standard ratios shown in **Tables 36 - 37**.

Table 35 - Frequency of Occurrence of Combination of Non- Standard Skull Ratios

Ch- Ch Ec-Ec				Ns-Sd/N-Me =0.3- 0.4				Ns-Sd/N-Me = 0.5 to 0.7 Ns-Is/Ns-Me Ns-Is/Ns-Me		TO	
	Ch-Ch Go-Go			Ns-Is/ Ns-Me = 0.4 Ns-Is/Ns-Me=0.5-0.6							
		Al-Al Zy-Zy						0.4	0.5 – 0.6		
			Al- Al Ch- Ch	Ns-Sd/N-Is 0.2 to 0.3	Ns-Sd/N-Is 0.4 to 0.5	Ns-Sd/N-Is 0.2 to 0.3	Ns-Sd/N-Is 0.4 to 0.5	Ns-Sd/N-Is 0.2 to 0.3	Ns-Sd/N-Is 0.2 to 0.3		
0.3	0.3	0.2	0.6-0.9	1	1	2	2	0	0	6	
			1.0-1.1	2	1	2	7	0	0	12	
		0.3	0.6-0.9	0	0	0	0	0	0	0	0
			1.0-1.1	0	1	1	1	0	1	0	4
		0.2	0.6-0.9	2	0	0	1	0	0	0	3
			1.0-1.1	0	0	0	0	0	0	0	0
	0.3	0.3	0.6-0.9	0	0	0	0	0	0	0	0
			1.0-1.1	0	0	0	0	0	0	0	0
		0.2	0.6-0.9	0	4	0	0	0	0	0	4
			1.0-1.1	0	0	0	3	0	0	0	3
0.4 – 0.5	0.3	0.3	0.6-0.9	0	0	0	0	0	0	0	0
			1.0-1.1	3	1	5	6	1	0	16	
	0.2	0.6-0.9	0	0	0	1	0	0	1	1	
		1.0-1.1	0	0	1	0	0	0	1	1	
	0.3	0.6-0.9	0	0	1	0	0	0	0	1	1
		1.0-1.1	1	0	1	1	0	0	0	3	55

Table 36 To investigate whether the ratios Ns-Is/Ns-Me and Ns-Sd/N-Is are independent of the ratio Ch-Ch/Ec.Ec for the given AI-AI ratios for Ns-Sd/N-Me ratio ranging from 0.3 to 0.7

OBSERVED VALUES

		Ns-Is/Ns-Me 0.4 Ns-Sd/N-is 0.2 to 0.5	Ns-Is/Ns-Me Ns-Sd/N-Is 0.2 to 0.3	0.5 to 0.6 Ns-Sd/N-Is 0.4 to 0.5	Total
Ch-Ch Ec-Ec	0.3	8	6	11	25
	0.4 to0.5	11	7	12	30
TOTAL		19	13	23	55

EXPECTED VALUES

		Ns-Is/Ns-Me 0.4 Ns-Sd/N-is 0.2 to 0.5	Ns-Is/Ns-Me Ns-Sd/N-Is 0.2 to 0.3	0.5 to 0.6 Ns-Sd/N-Is 0.4 to 0.5	Total
Ch-Ch Ec-Ec	0.3	8.6	5.9	10.5	25
	0.4 to 0.5	10.4	7.1	12.5	30
TOTAL		19	13	23	55

$$\chi^2 = \{(8-8.6)^2/8.6\} + \{(11-10.4)^2/10.4\} + \{(5.9-6)^2/5.9\} + \{(7-7.1)^2/7.1\} + \{(11-10.5)^2/10.5\} + \{(12-12.5)^2/12.5\} = 0.12 \text{ for 2 degrees of freedom}$$

As the Chi Square value is less than the critical value of 5.99 for 2 degrees equivalent at 5% level of significance we can conclude that for this sample of skulls the Ns-sd/N-Is ratios are independent of the Ch-Ch/Ec-.Ec ratio for the given AI-AI ratios where the Ns-Sd/N-Me ratio for the skull varies from 0.3 to 0.7

Table 37 To investigate whether the ratios Ns-Is/Ns-Me and Ns-Sd/N-Is are independent of the ratio Ch-Ch/Go-Go for the given AI-AI ratios for Ns-Sd/N-Me ratio ranging from 0.3 to 0.7

OBSERVED VALUES

		Ns-Is/Ns-Me 0.4 Ns-Sd/N-is 0.2 to 0.5	Ns-Is/Ns-Me Ns-Sd/N-Is 0.2 to 0.3	0.5 to 0.6 Ns-Sd/N-Is 0.4 to 0.5	Total
Ch-Ch Ec-Ec	0.3	11	6	14	31
	0.4 to 0.5	8	7	9	24
TOTAL		19	13	23	55

EXPECTED VALUES

		Ns-Is/Ns-Me 0.4 Ns-Sd/N-is 0.2 to 0.5	Ns-Is/Ns-Me Ns-Sd/N-Is 0.2 to 0.3	0.5 to 0.6 Ns-Sd/N-Is 0.4 to 0.5	Total
Ch-Ch Ec-Ec	0.3	10.7	7.3	13.0	31
	0.4 to 0.5	8.3	5.7	10.0	24
TOTAL		19	13	23	55

$$\chi^2 = \{(11-10.7)^2/10.7\} + \{(6-7.3)^2/7.3\} + \{(14-13)^2/13\} + \{(8-8.3)^2/8.3\} + \{(5.7-7)^2/5.7\} + \{(10-9)^2/10\} = 0.72 \text{ for 2 degrees of freedom}$$

As the Chi Square value is less than the critical value of 5.99 for 2 degrees equivalent at 5% level of significance we can conclude that for this sample of skulls the Ns-Is/Ns-Me and Ns-sd/N-Is ratios are independent of the Ch-Ch/Go-Go ratio for the given AI-AI ratios, where the Ns-Sd/N-Me ratio for the skull varies from 0.3 to 0.7

5.5.6 Frequency and Probability of occurrence of specific values of non-standard ratios using the Sixth sample

The results of the analysis of the data of the sixth sample of 299 photographs of Sri Lankans given in **Table 7** depicting the highest frequency and the probability of occurrences of values of the selected Non-Standard Ratios are given in **Table 38**.

Table 38 Highest frequency and the Probability of occurrence of the non-standard ratios.

Ratio	Ratio of highest frequency	Frequency of occurrence	Probability of occurrence
$\frac{Ch - Ch}{Ec - Ec}$	0.5	26	0.09
$\frac{Ch - Ch}{Go - Go}$	0.5	42	0.14
$\frac{Al - Al}{Zy - Zy}$	0.33	36	0.12
$\frac{Al - Al}{Ch - Ch}$	0.67	32	0.11
$\frac{N - Sn}{Sn - Ls}$	2	64	0.21
$\frac{N - Sn}{N - Me}$	0.38	33	0.12
$\frac{Sn - Sto}{Sn - Ls}$	1.33	56	0.19
$\frac{Ls - Li}{Sto - Me}$	0.5	85	0.28
$\frac{N - Sn}{Ch - Ch}$	1	31	0.1
$\frac{Sn - Ls}{N - Sto}$	0.33	48	0.16

For the data presented in Table 38:

In the first ratio it is observed that
 $Prob (Distance\ Ch - Ch = 1/2\ Distance\ Ec - Ec) = 0.09$
 Which means that the distance from right Ecanthion to Left Ecanthion is equal to twice the distance right Chilion to left Chilion for 9 % of the cases.

In the second ratio it is observed that
 $Prob (Distance\ Ch - Ch = 1/2\ Distance\ Go - Go) = 0.14$
 Which means that the distance from right Gonion to left Gonion is equal to twice the distance right Chilion to left Chilion for 14 % of the cases.

In the third ratio it is observed that

$$\text{Prob (Distance Al - Al = } 1/3 \text{ Distance Zy - Zy) = 0.12}$$

Which means that the distance from right Zygon to Left Zygon is equal to thrice the distance right Alare to left Alare for 12 % of the cases.

In the fourth ratio it is observed that

$$\text{Prob (Distance Al - Al = } 2/3 \text{ Distance Ch - Ch) = 0.11}$$

Which means that the three times distance from right Alare to left Alare is equal to twice the distance right Chilion to left Chilion for 11 % of the cases.

In the fifth ratio it is observed that

$$\text{Prob (Distance N - Sn = } 2 \text{ Distance Sn - Ls) = 0.21}$$

Which means that the distance from Nasion to Sub nasale is equal to twice the distance Sub nasale to Labiale supirius for 21 % of the cases.

In the sixth ratio it is observed that

$$\text{Prob (Distance N - Sn = } 2/5 \text{ Distance N - Me) = 0.12}$$

Which means that twice the distance Nasion to Mention is equal to five times the distance Nasion to Sub nasale for 12 % of the cases.

In the seventh ratio it is observed that

$$\text{Prob (Distance Sn - Sto = } 4/3 \text{ Distance Sn - Ls) = 0.19}$$

Which means that three times the distance Sub nasale to Stomium is equal to four times the distance Sub nasale to Labiale supirius for 19 % of the cases.

In the eighth ratio it is observed that

$$\text{Prob (Distance Ls - Li = } 1/2 \text{ Distance Sto - Me) = 0.28}$$

Which means that the distance Stomium to Mention is equal to twice the distance Labiale supirius to Labiale inferius for 28 % of the cases.

In the ninth ratio it is observed that

$$\text{Prob (Distance N - Sn = } 1/2 \text{ Distance Ch - Ch) = 0.1}$$

Which means that the distance from Nasion to sub nasale is equal to the distance right Chilion to left Chilion for 10 % of the cases.

In the tenth ratio it is observed that

$$\text{Prob (Distance Sn - Ls = } 1/3 \text{ Distance N - Sto) = 0.16}$$

Which means that the distance Nasion to Stomium is equal to three times the distance Sub nasale to Labiale Superius for 16 % of the cases.

5.6 SUMMARY OF FINDINGS

The Regression Analysis of the first sample, very clearly indicated that there was a linear relationship between the mean facial non-standard ratio and its corresponding skull ratio of the form $\text{Skull ratio} = 1.8 \cdot \text{Average Facial Ratio} - 41.7$.

The closeness of this linear relationship was indicated by the correlation coefficient which was + 0.96, depicting a positive correlation between the Non-standard facial ratio and its corresponding Skull Ratio.

The ten Non-standard facial ratios considered were:

- | | | |
|---------------------|---------------------|---------------------|
| (a) Ch-Ch / Ec-Ec. | (b) Ch-Ch / Go-Go | (c) Al-Al / Zy-Zy, |
| (d) Al-Al / Ch-Ch | (e) N - Sn / N - Me | (f) N - Sn / Sn-Ls, |
| (g) Sn-Sto / Sn-Me | (h) Ls-Li / Sto-Me | (i) N - Sn / Ch-Ch |
| (j) Sn-Ls / N - Sto | | |

The "t - test" carried out to investigate whether there were any significant differences in the mean non-standard ratios between the two independent samples, - the first sample and the second sample - as given in **Tables 9 to 18**, it was observed that the four non-standard ratios, namely N-Sn / Sn-Ls, Ls-Li / Sto-Me, N-Sn / Ch-Ch and Sn-Ls / N-Sto showed significant differences, suggesting that the position of the lips on the face in a vertical perspective contributed to increase specificity.

In the investigation whether there was a significant variation between the non-standard ratios of the five poses of the three faces using the Analysis of Variance in **Tables 19 to 28**, it was observed that while the F-ratio was significant for seven ratios, it was not significant for the ratios which involved the distances Sn - Sto and Ls -Li . This indicated that the different mouth positions had no significant effect when taken in combination with the other distances.

The "Goodness of fit" Chi - square method applied to the fourth sample to investigate whether the standard ratios followed the Farcas Munro pattern as given in **Tables 29 to 34**, it was observed that there was no significant fit in the given patterns, thus the indication was that even the accepted ratios differed in their respective degrees of uniformity.

The result of the analysis of the fifth sample given in **Tables 35 to 37**, indicate that the occurrences of specific combination of values for non standard ratios which is independent of each other and that there is a low frequency in the combination of specific values of Non-Standard ratios. The highest probability of occurrence of any one person having a particular combination of values of the given Non-Standard facial ratios is 0.13.

In the sixth sample the study was to investigate the probability of occurrence of specific values for selected Non-Standard ratios. **Table 38** indicated the highest frequency of occurrence and its corresponding probability, The highest probability of occurrence was for the distance Sto-Me being equal to twice the distance Ls-Li, which was only 0.28.

6 DISCUSSION

Perfection is a moving target. Professionals sometimes spend their whole lives trying to achieve it. It becomes therefore prudent to be satisfied with methods even with limitations, even without the expected refinement, particularly in areas governed by a large number of uncertainties that definitely fall beyond the control of man. This research substantiates the view that the identification of an unknown skull falls within these parameters and the methodology suggested would only make a task easier merely by a process of elimination, subsequently minimizing the number of probabilities.

The overall objective has been the identification of unknown human remains, when the state of the remains is skeletonised, decomposed or incinerated. The methodology of this particular study revolves round mathematical representation of a three dimensional object i.e. the skull and a two dimensional image i.e. a photograph by making use of a set of ratios. These ratios are based on the positions of the three main components of the face; i.e. where the eyes, nose and mouth are situated. The analysis of the results confirmed statistically the specificity and the uniqueness of these ratios.

When projected on a two dimensional perspective a face is basically a combination of lines, curves and angles of varying magnitudes which could be interpreted as a series of values. It should be possible for a face to be summarized as a series of data, which can be used for comparison purposes, as there is definitely a "visual difference between one face and another".

Facial differences seen racially as well as individually cannot be quantified. It is still possible to identify a person as being Indian or Sri Lankan, or if Sri Lankan it is also sometimes possible to make a fairly accurate guess as to whether Tamil or Sinhalese, the two predominant races in Sri Lanka. The question is how can one say this? It is on the overall picture, or the image that is presented to the observer.

This phenomenon is not limited to humans. Even zebras recognize not only their immediate family, but also their particular herd by the stripes. These stripes have been proved scientifically as specific though the human eye is not capable of identifying this particular specificity or the unique feature.

This itself is adequate to understand how difficult it is to develop a methodology with mathematical precision to identify an unknown skull. The findings of the researcher seek to quantify the measurements and thereby develop a group of data to describe the face. Though facial ratios have not yet been used for identification purposes, there is documented evidence that particular facial ratios are significant in identifying specific medical conditions. One such example is the narrow palpebral fissure width, high mid face, broad inter-alar distance, short back of the nose, prominent high chin, and broad low set ears, in Prader Willi syndrome.

(Levine, Le, Hall, Cassidy 1995)

Jantz and Meadows (1995) have also found differences of facial dimensions even between the same racial groups speaking different languages suggesting that even phonetics could effect the facial dimensions which are based finally on facial ratios.

The identification of the unknown skull or the identification of a decomposed body that is beyond recognition is a situation which occupies one extreme of a scale. The situation, where the dead person can be recognized as an individual, but not the identity occupies the other extreme. The second condition is common in mass disasters in away-from-home situations where there are no known people to identify the dead. The internationally accepted Disaster Victim Identification procedures become useful in such situations. It is important for third world countries to adopt a systematic method for the identification of disaster victims. It is essential for key people in disaster situations to have a thorough understanding of the importance of different areas and the mechanisms, which are relevant in the identification of unknown human remains.

None of the methods that are available today can be considered as foolproof methods of identification. From photographic superimposition methods where the size and the scale were the main drawbacks, video-superimposition has been evolved where the size and the scale could be

modified independently to find out whether or not the two images coincide with one another. Whilst initially the movements of the skull in the three different planes were done manually in the video superimposition techniques, there are remotely controlled devices now available for this purpose. These are used in the optical methods using the principle of the two-way or split beam mirror techniques.

Photographs have become the best method of remembering people and events all over the world irrespective of socio-economic differences. These readily available photographs serve as a source of valuable data for identification purposes. A photograph could be taken in a number of ways. With the vast number of possible variations, it becomes a Herculean task if one has to depend on an available photograph for the identification of an unknown skull. The success of any method therefore depends on the nature of the photograph available. This means the refinement of methods cannot be graded when there is a variable nature of the initial available data. There are specific positions and angulation used when radiographs are taken, either ante-mortem or post-mortem. A human error at any of these situations could result in a false identification or misidentification if one has to depend entirely on radiographic examinations. These are the limitations of this study.

A method used to identify criminals is to build a face from an available database of different parts of the face. In this method, once the basic facial features are selected according to available evidence of a witness who had seen the criminal, the experienced police officers claim that they can produce a face, which can produce a positive lead.

The general method used in this study was to identify a set of non-standard ratios and to find their uniqueness and specificities statistically. The results showed that the occurrence of frequency of combinations of these non-standard ratios could be considered as unique or specific when considered on a collective basis.

A digitized radiograph of the skull could be scanned into a computer in frontal or a lateral perspective. This could then be superimposed on an already scanned positive image of a photograph, provided they are of the same size.

The biggest problem encountered, in any type of superimposition methods is the non-availability of full frontal photographs of 1:1 scale. Therefore the recommendations are to instruct photographs to be taken of all new recruits from a specific distance using a specific camera, keeping the head in a specific position by using mirrors for the recruit to judge his own image on a 1:1 ratio. Its mandatory that the men should pose with a broad smile, so that individual variations of the teeth also could be made use of in comparison with post-mortem data. By this method any radiograph of a decomposed body could be easily compared with a frontal photograph of a known magnification. The comparison would be further simplified if the head for the photograph were placed in the same anatomical position as that used for an antero - posterior view of the skull.

A skull mounted on a remote control device could be filmed in slow motion and this could also be connected to a computer, which has a scanned image of the face for comparison. If the facilities are available, these methods could be less time consuming than the standard methods that are in vogue today.

With the advancement of modern technologies it will be possible for us to scan a three dimensional image of a skull to a computer and build a computer image of a face based on tissue thickness, and the data available.

The method suggested by the researcher has its own limitations, as it will not be possible to tell with mathematical precision the owner of an unknown skull. However it will be possible to minimise the number of possibilities by exclusion. Where one is confronted with a number of unknown skulls and a group of facial photographs, the mathematical approach which has been proposed will help to limit the number of possibilities of a particular skull. This mathematical approach would be cost effective as it could minimise the use of more expensive and tiresome procedures needed to establish positive identities individually. These are the strengths of this research study.

7 CONCLUSIONS

In most countries there is legislation to safeguard the birthrights of its people, regarding citizenship, right to own land and right to vote. All over the world we recognize another type of rights known as the last rites generally performed once a person is dead. To have last rites it's obligatory that one should have an identity. This has been the main theme of the research project, starting from the legal implications surrounding death, the identification of dead in disaster situations, the different tools available for such identifications and the important position that the dental data occupies.

It is mandatory that dependable medical and dental records should be available for the identification of the dead. Since it is impossible in third world countries to have proper medical and dental records up to the internationally accepted standards overnight, and disasters continue to occur with not much prior notice, it is prudent to look for cost effective simpler methods of identification of unknown human remains.

The proposing of the mathematical method based on the comparison of non-standard facial ratios, ideally suit the third world countries for the identification of dead bodies to be done at a lower cost without compromising the sensitivity and specificity of the method.

The recommendations of the mathematical approach based on the findings of this work, describing the protocol and the relevant methodology of the cost effective method suggested for the identification of unknown skeletal human remains is to make every potential high risk person to have a good facial photograph.

Relevant information on the different types of measurements used for teeth and skulls, and the different methods that are in current use for identification, is presented here.

The research component has been focussed on identifying a relationship between skulls and faces by quantifying them into a series of values in the form of ratios, which could be used for collective comparison with a view to limiting the probability by a simple process of exclusion.

Samples selected in this study to test the feasibility of the suggested methodology using mathematical calculations were from twenty photographs that appeared in the daily newspapers after the recent disasters in Hobart, the photographs of fifteen soldiers who died in the helicopter crash, different poses of facial expressions particularly involving the oral cavity of three living persons, fifty five skull radiographs of Sri Lankan soldiers, and two hundred and ninety nine facial photographs of Sri Lankans.

The studies for the determination of the practicality and the effectiveness of using ratios both standard and non-standard were done from different perspectives, and their results with a statistical analysis were given in Chapter Five.

The facial triangle made by the three points, Naso-spinale, Right and Left Ecanthion, which are considered as fixed landmarks, from an anthropometric view. It was found, though there were accepted variations of the position of the mouth depending on individual poses, it was the circum-oral region which decided the individuality of a face.

The findings showed a linear relationship between the mean facial ratio and its corresponding skull ratio and the closeness of the linear relationship was indicated by the correlation coefficient of $r = +0.96$.

The non-standard ratios, namely, Ls-Li / Sto-Me, N-Sn/ Sn-Ls, N-Sn / Ch-Ch, and Sn-Ls/N-Sto, showed sufficient differences suggesting that the position of the lips on the face in a vertical perspective contributed to increase the specificity, but the different mouth positions had no significant effect when taken in combination with other distances.

The findings also showed there was no significant fit with the given patterns thus proving that even the accepted standard ratios differed in their respective degrees of uniformity.

The highest probability of occurrence of a combination of any one person having a particular combination of the selected non-standard ratios was 0.13, whilst maximum probability of occurrences were all below 0.3 which substantiates the postulated hypothesis.

Therefore the collective results of the ten different ratios could be analyzed using the theory of probability to find out how many out of ten would match with one unknown skull to make the initial exclusion by an elimination process.

Based on these findings it is the opinion of the writer, that it is worthwhile to pursue this mathematical approach, as it could be possible to use this to ensure that dependable initial basic photographic data could be made available for an unforeseen eventuality to identify an unknown skull. Therefore it is the intention of the writer to make recommendations to adopt modified methodologies with the objective of obtaining maximum validity of the proposed hypothesis initially in the armed services on a specific protocol for the identification of unknown skeletal human remains.

This research study has established that there is sufficient reason to believe that the facial ratios have a significant impact on determining the identity of a person, by a method based on statistical probability.

Further research based on mathematical calculations of facial and skull ratios, are recommended. Furthermore the sample size could be expanded to provide great representations in terms of race, age and sex of the total population.

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