

PROJECTED GRID FACIAL PHOTOGRAPHY

John P. Fricker B.D.S.,
(University of Sydney)

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TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	iv
AESTHETICS	1
: Definition	1
FACIAL HARMONY	2
CLASSIFICATION OF CRANIOFACIAL TYPES	5
: Cranial index	6
: Facial index	7
: Classification of profile	7
FACIAL DEFORMITIES	8
: Crouzon's disease	8
FACIAL ASYMMETRY	9
: The median line	11
: Mandibular asymmetries	12
: Hemiatrophy	12
: Hemihypertrophy	12
BODY IMAGE	13
: Categories of body image	13
: Psychological implications	13
SURGICAL AESTHETICS	16
: Soft tissue references	16
: Upper, middle and lower third of face	17
: The plastic surgeon	18
EVALUATION OF ASYMMETRY	20
: The role of the orthodontist	20
: Clinical evaluation	21
: Records	22
EVALUATION OF NATURAL HEAD POSITION	24
FRANKFORT HORIZONTAL PLANE	24
GRID TECHNIQUES FOR EVALUATION	25
: Renaissance art	25
: Morphanalysis	27

	<u>Page</u>
: Stereophotogrammetry	27
: Projected grids	28
: "Physiograph"	29
ORIGINAL WORK	32
INTRODUCTION	33
MATERIALS	33
: The head stabiliser	33
: The camera/projector	36
: The grid	37
METHOD	37
: Positioning the patient	40
: The photographs	40
DISCUSSION	43
DOCUMENTATION OF CASES - REFINEMENT OF METHOD	50
: Case 1	50
: Case 2	56
: Case 3	61
: Case 4	66
REVIEW OF MODIFIED PROCEDURE	67
SUMMARY AND CONCLUSIONS	78
BIBLIOGRAPHY	80

INTRODUCTION

Facial photographs have been used as a method of record taking within the field of Dentistry for many years. Orthodontists and facio-maxillary surgeons, have in particular, used them to advantage for documenting cases.

Numerous authors have written on methods of improving the quality of these photographs by means of variations in lenses, lighting and type of film, but few have discussed methods of standardisation of photographic techniques and positioning of the subject.

Herein, it is proposed to emphasise the standardisation of photographs, so that accurate longitudinal serialisation of treatment stages may be documented, as well as the ability to give meaningful comparison of these stages.

AESTHETICS

Prall (1967) states that "aesthetic experience is an experience of a person or an object as apprehended delightfully. This is primarily apprehended through the senses."

Since disagreements are so common between aesthetic judgements, it would appear that the processes of apprehension in the case of beauty differ from person to person much more widely than the processes of perception of ordinary sense qualities.

This depends on a person's schemata, which Abercrombie (1960) describes as "tools which help us to see, evaluate and respond". She quotes Bartlett's (1932) definition of "schemata" as "an active dramatisation of past reactions or of past experiences which must always be supposed to be operating in any well-adapted organic response".

The prime objectives in orthodontic treatment are:-

- i. Improvement in function
- ii. Improvement in aesthetics
- iii. Maintenance of these improvements.

Angle (1907) said: "The study of orthodontia is indissolubly connected with that art as related with the human face".

FACIAL HARMONY

Angle (1907) stated "what concerns the orthodontist most is whether the mouth is in harmonious relationship with the other features of the face, forehead, nose and chin". He wrote that all the essentials of beauty were found in the face of Apollo Belvedere which he used as a guide or a standard of beauty.

The classical concept of symmetry and harmony of the human face is that depicted by Leonardo da Vinci and by Abrecht Durer's drawings of 1490-1508. These depict the face as bisected by a vertical line running through the centre of the nose, lips and chin. The pupils of the eyes are equidistant from this vertical. A line drawn joining the pupils is perpendicular to the vertical.

Riedel (1950) examined the angles of facial convexity in 29 profile outlines. This was from Nasion to A point to Pogonion. He used this to analyse facial harmony. "Poor" profiles had an angle of convexity which was always in excess of 4.5° . This is the supplement of the angle subtended by the two profile lines. "Good" profiles had an angle of convexity not exceeding 4.0° .

Ricketts (1957 and 1968) describes the lips in relationship to an imaginary line drawn from the tip of the nose to the tip of the soft tissue chin. He considers

the most pleasing aesthetic relationship is when the upper lip is 4mm behind this line while the lower lip is 2mm behind for a normal nose and chin.

Clements (1969) evaluated the elements which contributed to the lack of facial harmony and the apparent lack of improvement in this with orthodontic treatment of Angle Class II malocclusions with large noses. He showed that there are signs which are almost pathognomonic of eventual nasal imbalance upon correction of the malocclusion and continued growth. These are:-

- " - A Class II (Angle) malocclusion with extensive overjet and short maxillary lip.
- A long nasal spine".

He felt that skilfully performed rhinoplasty can contribute remarkably to the establishment of satisfactory balance of facial parts as nasal growth continues into late teens and is independent of other facial parts.

Grignon (1972) said that the characteristics of the personality are conferred through the organs of movement, the eyes and the lips. These form the centre of attention between communicating people. If the nose and chin are not in balance, they act as a distraction from the eyes and lips.

Lischer (1919) considered variations in length of the upper lip as well as the relative protrusion and retrusion of the lips when viewed in profile.

Wuerpel (1937) discussed the necessity for the orthodontist to understand what type of face he is dealing with; whether it be Greek, Roman or other ethnic group. He stated that the orthodontic deformity should be corrected but that distortion of the facial type should be avoided. He stressed the importance of the length, and direction of the line forming the upper lip from the end of the nose to the beginning of the lip.

Peck and Peck (1970) studied cephalometric radiographs and photographs of 52 young adults, each judged as having pleasing aesthetics. The sample included models and beauty contest winners. They concluded that the general public admire a fuller, more protrusive dentofacial pattern than the usual orthodontic analyses allow.

Janzen (1977) stressed the importance of a well balanced smile as an orthodontic treatment objective. The ultimate position of the anterior teeth has a great influence on the relationship of the lips to each other and to the surrounding and underlying facial structures. He concluded that a large improvement in facial balance had been demonstrated as a result of intrusion of the maxillary incisors.

Lines, Lines and Lines (1978) studied profile silhouettes of both males and females. Groups of untrained, moderately-trained, and highly-trained persons, examined the profiles and gave their aesthetic preference. They showed statistically significant sexual differences in these profiles. Male preferences were for greater prominence in both nose and chin. Females preferred less prominence in nose and chin and a greater fullness in the lips.

CLASSIFICATION OF CRANIOFACIAL TYPES

The classification of skeletal or jaw and face relationships has been described in various ways using a combination of methods. Simon (from McCoy and Shepherd (1956)) used a gnathostatic approach and orientated the dentition to anthropometric landmarks in an attempt to show the actual relationships of the dentition in the face.

Perhaps the most universally used classification was introduced by E.H. Angle in 1899. The basis of this classification was the hypothesis that the maxillary first permanent molar is the "key to occlusion". Angle divided malocclusions into three broad classes:-

- i. Normal profile
- ii. Convex profile
- iii. Concave profile.

Ackerman and Proffit (1969) developed a classification system in which five characteristics and their inter-relationships are assessed. These were:-

- i. Alignment and symmetry of dentition.
- ii. Profile.
- iii. Transverse deviation i.e. cross bites.
- iv. Sagittal deviations.
- v. Vertical deviations.

The cranium and the face can be classified into basic types, according to ratios of width and length (Zwener and Lorber (1976)).

The cephalic index is this ratio of the cranium when viewed from above. These indices, expressed as a percentage, fall into the following categories:-

- i. Brachycephalic or square when this index is 80 or greater.
- ii. Dolicocephalic or long with an index of 74.9 or less.
- iii. Mesocephalic with an index of 75-79.9.

The facial index is the length of the face from the root of the nose to the bottom of the chin, expressed as a percentage of the greatest breadth across the cheek bones.

"Facial indices when subdivided conventionally, furnish us with a means of physical classification similar to the length-breadth index of the skull but much more noticeable than the latter " (Hooton (1947)).

- i. The face is europsopic or square with an index of 80 or less.
- ii. Mesoprosopic with an index of 85-89.9.
- iii. Leptoprosopic or long with an index of 90 or more.

Zwener and Lorber (1976) feel that the most successful classification of profile is based on the relationship of the face to the cranial base. They describe this as follows: "A straight face is one in which the anterior limits of the cranial base, the maxilla and mandible are in the vertical plane. If the maxilla and mandible lie posterior to such a plane, the face is said to be posteriorly divergent. When they are all in the same plane, whether or not it is vertical, it is orthognathic."

They defined convex profile as occurring when the teeth are forward in relationship to the face. Vice versa, the concave profile occurs where the teeth are retruded.

FACIAL DEFORMITIES

Converse and Horowitz (1969) divided facial deformities into:-

- i. Sagittal plane e.g. mandibular prognathism.
- ii. Vertical balance, e.g. severe skeletal open bite.
- iii. Horizontal plane which includes left/right asymmetries.

Prognathism and retrognathism may be the result of a developmental abnormality of either jaw and/or the unfavourable positional relationship of developing jaws. The former could be congenital or acquired while the latter may evolve as a secondary functional physiological aberration.

Converse and Coccaro (1975) divide these dysplasias into the following:-

- i. Macrognothia
- ii. Micrognathia
- iii. Hypoplasia
- iv. Hyperplasia

for both maxilla and mandible.

Flemming (1971) discusses Crouzon's disease and lists the essential features as follows:-

- i. Often has a hereditary component.
- ii. The skull is brachycephalic because of premature closure of cranial sutures with associated swelling of the frontal region.
- iii. Hypoplasia of the maxilla with recession of the infra-orbital ridges and shallow orbits.
- iv. Exophthalmus and occular hypertelorism.
- v. "Parrot beak" nasal deformity.
- vi. Mandibular prognathism.

He says "The aesthetic approval of the facial deformity is based upon accepted ideas of proportion - the vertical length of the face is usually one seventh the total height of the patient: the face is composed of approximately equal superior, middle and lower thirds".

Fig. 1

FACIAL ASYMMETRY

The subject of symmetry or lack of symmetry of the human face is of considerable interest particularly in the field of orthodontics.

Simon (1931) considered that bilateral symmetry is a most manifest morphological characteristic of the body and especially the head.

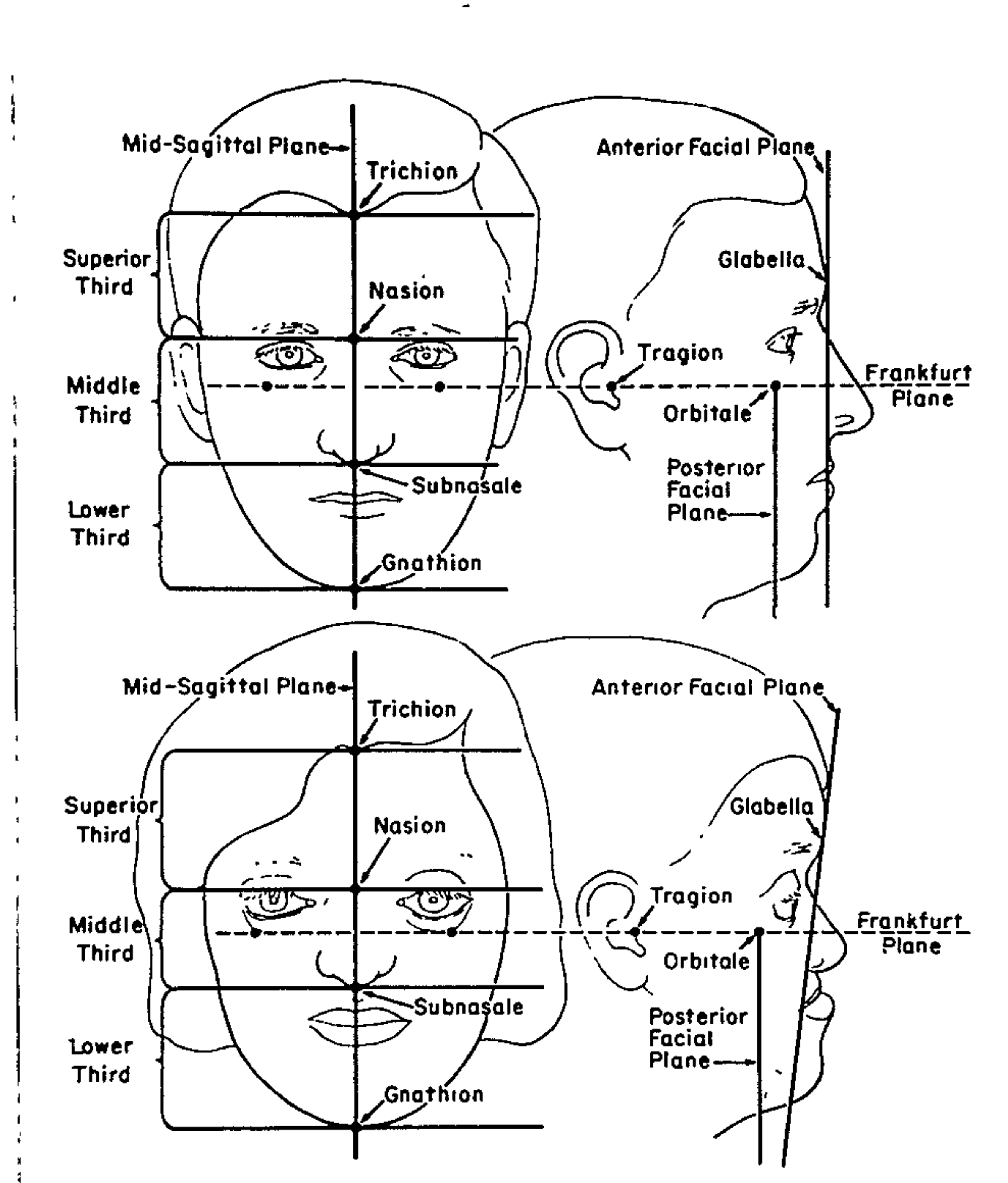


FIG. 1

Above: Normal anthropometric chart to contrast with that of a patient with Crouzon's disease, below. (From Flemming 1971).

Thompson (1943) regarded asymmetry as normal.

"This normal asymmetry is not very evident, whereas the abnormal asymmetry is quite obvious."

In studies of asymmetry of the facial structures, the main emphasis has been on asymmetry of maxillary bones, and particularly on the shape of the dental arch (Moore and Hughes (1942), Stanton (1922)).

Sutton (1968) studied lateral asymmetry of the face from a frontal aspect. He stated "The face is asymmetrical if, when it is in a condition of repose, one or more of the facial features which occur bilaterally are further from the median line of the face than is the corresponding feature on the other side, or if the centre of each impaired facial feature does not lie on that line." He then stressed the fundamental importance of defining the median line.

Hemley (1944) said "that median plane divides the body into halves. The median line is the periphery of the median plane". The median line is therefore the emergence of the median plane through the central features of the face.

Neger (1959) stressed the importance of soft tissue analysis as against that of hard tissues. He continues,

"Anthropologists have shown that this external covering made up of adipose tissue, connective tissue, muscular and neurovascular tissue, does not always distribute itself in a uniform way." These variations in soft tissue elements lead to asymmetries within the individual.

Hewitt (1975) showed asymmetries involving hyperplasia of the first branchial arch to be more common on the right side. However, cleft lip, when it is unilateral, is more common on the left.

Persson (1973) examined mandibular asymmetries. These may be due to condylar hyperplasia, an enlarged head or elongated neck of the condyloid process. With unilateral mandibular hyperplasia there is unilateral enlargement of the mandible. This varies widely in extent and includes the head and neck of the condyloid process as well as the mandibular ramus and body. "These hyperplasias are also known as macrognathias", Persson (1973).

Lundstrom (1961) described facial hemiatrophy and hemihypertrophy. The former is characterised by a pronounced underdevelopment of one half of the face in which a sharp line of demarcation can sometimes be seen between the normal side and the shrunken side. In hemiatrophy, the maxilla and zygomatic bones are involved in the anomaly. The mandible also presents definite symptoms of the condition just as can the facial soft tissues.

Hemihypertrophy is essentially the opposite of the above. There is overdevelopment of the maxilla and zygomatic bones along with the ear and the tongue in some cases.

BODY IMAGE

Giddon, Hershon and Lennartsson (1974) showed that subjects varied in their ability to reproduce their own profiles as a function of psychological factors other than differences in perceptual motor ability. They found that subjects tended to underestimate less desirable features.

Gorney and Harries (1974) divided body image into four categories:-

- i. What they see in the mirror.
- ii. What they see in photographs.
- iii. What they see in their minds.
- iv. The way they look to others.

In their pre-operative assessment, they had the patient look into a mirror and carefully point out the asymmetries. They then used a reversing mirror to give an objective image. In most cases the patient was amazed at the difference.

Grignon (1972) states "that most patients have a psychological basis as part of their body image". He says "modern advertising and publicity are partly to blame for

the big increase in demand for cosmetic surgery". He feels it is of the utmost importance to know the needs of the patient to guarantee post-operative satisfaction, and know the extent of their expectations of change!

Lefebvre and Munro (1978) felt that the psychological assessment of the child in the socio-cultural context of his family and community, is an essential factor in the decision for, and timing of, major reconstructive surgery.

A severe congenital facial deformity does not usually affect a child's body image, but it can have a great impact on the total self image which relates to social interactions.

They therefore feel that surgery should be performed ideally before school age when the child is subjected to most teasing.

Cox and Van der Linden (1971) found that persons with poor facial aesthetics, in general had relatively more convex faces. This is particularly so amongst females with more anteriorly placed manillary incisors.

The authors state that the full face and profile seldom dominate facial beauty as it is appreciated in common life. Faces are usually observed somewhere between full face and profile. Hence lateral head films represent only a certain and limited aspect of facial beauty.

Secord and Backman (1959) found that some personality characteristics may be stereotypically attributed to individuals on the basis of their dental appearance, e.g. sincerity, intelligence and conscientiousness tended to be associated with straight teeth.

Stricker (1970) pointed out that an individual's physical appearance had implications for his psychological development. The psychological benefits of orthodontic treatment carried out to improve appearance could be twofold:-

- i. Direct, where a child who previously felt self-conscious gained in positive self image.
- ii. Indirect, where a child in future interpersonal situations is met with a more favourable response.

Cohen and Horowitz (1970) posed the question: Do children perceive variations in facial appearance associated with different occlusal relations? If they do, do children associate such differences with their own appearance? They showed a series of drawings for male and female covering a range of occlusal relations. They found that there was generally a uniform hierarchy of preferences for pictures of occlusal relations. Children who perceived themselves as having a certain type, tended to rate that condition as high on a preference scale, or a little higher compared to those who did not perceive themselves with that condition.

Horowitz, Cohen and Doyle (1971) followed up the above and reported that a child's actual occlusal condition may be associated with his self image and to a lesser extent his preference for that condition.

SURGICAL AESTHETICS

"One essential reason for the undertaking of osteotomy and correction of mandibular protrusion is the patients' wish to have their appearance improved. The results should therefore be judged with reference to the soft tissue characteristics before and after the operation." (Fromm and Lundberg (1970)). These authors felt that the most important factor to take into consideration is the configuration of the lips. If the lips remain in approximately the same procumbancy, there is no reason to expect an improvement in aesthetic evaluation.

Broadbent and Mathews (1957) studied the artistic relationships in surface anatomy of the face. They said, "In the planning stage of all surgery, there is distortion to be corrected. In planning the best method of correction, one's first major hurdle is to see what we look at".

They stressed the importance of looking at each item, not as a separate entity but in its anatomic environment. Allowances must be made for each individual to balance all the related features.

Epker and Wolford (1975) say that when considering osteotomies, three basic features must be evaluated:-

- i. Aesthetics
- ii. Supporting skeletal structures
- iii. Occlusion.

Middle third face osteotomies require special attention to aesthetics. They feel that little attention has been given to left/right or full-face deformities, despite the fact that these are of more concern to the patient than anterior-posterior relationships.

Grignon (1972) and Bishara (1973) both stress the importance of achieving balance between the nose and the chin.

D'Ottaviano and Baroudi (1974) divided surgery of the face into three sections in order to achieve an aesthetic result. They stated that "the deformities of the facial profile almost invariably require correction of two or more aspects of the profile".

They divided the face into upper, middle and lower thirds. The upper third, which they felt was usually least affected aesthetically, extended from the hair line to the nasal vertex.

The middle third extends from the Nasion to the base of the nose. This can be projected in or out from the facial plane.

The lower third extends from the base of the nose to the base of the chin.

Schendel, Eisenfield, Bell and Epker (1976) studied soft tissue changes after maxillary surgery. They found that, post-surgically, the reduction of the lower face height and amount of maxillary incisor exposure resulted in improved facial balance.

Worms, Isaacson and Speidel (1976) warn that when treatment plans include surgical procedures, dramatic changes in facial soft tissue contour can be produced. Sometimes these changes can be inappropriate. Substitution of one poor facial contour for another, is hardly in the best interests of the patient.

"To the plastic surgeon the aesthetic balance and the appearance of the integumental contour are the principal interests. These views are complementary and some appreciation of them is of great assistance in the diagnosis and treatment of malformations of the face."

(Converse, Horowitz and Wood-Smith (1964)). These authors state that there is no quantitative norm of beauty. It is the individual's concept based on the person's ethnic, racial and aesthetic background and experiences.

Mills (1969) describes cosmetic surgery as a "masking procedure", which he lists as one of the three basic approaches to surgery. The others are, maxillary dentoalveolar techniques and several mandibular operations.

Mills (1969) lists these cosmetic operations as including genioplasties, chin implants, labioplasties and rhinoplasties. These all require the services of a plastic surgeon. He feels that genioplasties and chin implants are by far the most important masking procedures available. Profile contours of the lower face can be greatly improved by these approaches.

Gillies (1957) comments on the individuality of the plastic surgeon. He remembers his experience during World War I and says "With our artistic efforts constantly on display around the wards, not only the patients judged our results but we, too, if only out of the corners of our eyes, jealously compared our work with that of our

colleagues. It was obvious that this promoted stimulating competition. Each surgeon had his own characteristic style, somewhat in a minor way, like the distinctive individuality of a Rembrandt, a Constable or a Disney. It soon became quite easy to pick out".

EVALUATION OF ASYMMETRY

Pruzansky and Aduss (1976) see the orthodontist as having an overview of the total plan with regard to a combined surgical-orthodontic approach to the treatment of a deformity. He is disciplined to obtain detailed data on the initial state of the patient and can then guide the orthodontic treatment in accord with surgical objectives, thereby avoiding cook-book routines in treatment. Through analysis of photographs, study models and radiographs, the individuality of the patient is recognised.

Broadbent and Mathews (1957) described the face and head as basically consisting of a ball with an extension for the lower face and the sides of the ball removed at the ear position. They then located the facial features at specific levels on the ball. When an anatomical enlargement or deficiency is present, they found that the change is usually in relationship to the mid-sagittal plane.

Horowitz and Hixon (1966) stressed the clinical evaluation as a prerequisite to orthodontics and surgery. They set out steps in this examination:-

- i. Observe vertical and horizontal facial balance as both prognathism and asymmetry may be present.
- ii. Record patients' customary head posture. Patients are occasionally observed where an apparent prognathism is caused by posture rather than by a structural deformity.
- iii. Observe functional asymmetries. Mediolateral excursions on opening and closing of the mandible may indicate TMJ dysfunction or neuro-motor disability.
- iv. Note the habitual posture of the orofacial musculature both in repose and function.

Neger (1959) studied soft tissue profiles from photographs using six profile angular relationships between maxillary lip, mandibular lip and chin. He found that a proportionate change in soft tissue profile does not necessarily accompany extensive dentition changes and therefore one can no longer rely entirely on a dento-skeletal analysis for accurate information about the soft tissue changes. He stressed the need for evaluating soft tissue profiles as a separate entity if scientific accuracy was required.

Simon (from McCoy and Shepherd 1956) developed a gnathostatic denture reproduction system. This showed:-

- i. The denture detail
- ii. The dento-cranial relation
- iii. Gave a picture of height, width and length of the denture
- iv. A view of asymmetrical growth manifestations.

He used photographs orientated to the Frankfort plane. Spots are made on the patient at Orbitale, Tragion and Gonion. The photograph is then taken. A line is then drawn on the print for Frankfort plane as well as from Orbitale to chin and from Tragion to Gonion to form the orbital plane and mandibular plane respectively.

Epker and Wolford (1975) evaluated the patient using a series of masking procedures with small pieces of cardboard. They observed the patient in natural position directly facing the examiner. Interpupillary distance was noted as well as the left to right relationships of the orbits and the malar eminences. The lip position in relation to the teeth and other facial structure was evaluated, with the patient relaxed in centric. The profile was then examined in six steps:-

- i. Relation of supra-orbital shape of the forehead to the rims of the globe.
- ii. The nasal bridge to the forehead and orbits.

- iii. The entire nose to the whole face.
- iv. Middle third of the face, particular attention was paid to nose-lips relation and maxillary lip to maxillary teeth.
- v. Middle third of the face to the lower third.
- vi. The chin to the lips and nose.

Hautvaust (1971) used linear measurements from standardised full face and profile photographs. To get proportional data, five dimensions were added and the ratio of every dimension with regard to that sum total was calculated and given in percentages, forming a breadth pattern of the face from the full face photograph. The profile shows the depth pattern of the face.

Grignon (1972) used facial photographs in profile and full face to determine the most satisfactory equilibrium between the various stages, but stressed this gives only a static result. He relied more heavily on clinical examination. This involved observation of the patient during conversation. Their attention and discussion allowed him to give more complete information. He saw the question as being how to modify the various parts of the face concomitant with the personality in general as defined by the eyes and the lips.

Macary (1957) in his study on historical busts, summed up by saying, "It is by direct vision of the person and not that of radiographs that one appreciates and judges the symmetry and attractiveness of faces."

EVALUATION OF NATURAL HEAD POSITION

Moorrees and Kean (1958) tested the relative constancy of this position in man and showed it to be reliable for use in radiographic and photographic analysis. They quote Broca's definition (1862) "when a man is standing and when his visual axis is horizontal, he (his head) is in the natural head position." It was recognised that a true horizontal line cannot pass through the same two anatomical landmarks in all individuals.

Ackerman and Proffit (1975) state that this overcomes the problem of cranial base reference planes especially in those cases of gross facial deformity.

FRANKFORT HORIZONTAL PLANE

Moorrees and Kean (1958) say "this is probably the best known and most acceptable approximation of the physiological horizontal". This line from Porion to Orbitale was labelled the German Horizontal. It became the Frankfort Horizontal after being adopted at the Craniometrical Conference of Frankfort am Mein in 1884.

GRID TECHNIQUES FOR EVALUATION

Various authors have developed grid systems for facial analysis. Leonardo da Vinci (1490) divided the body into proportion. This gave him the idealised symmetry between left and right. He also had a grid for the full profile in order to better evaluate the proportions of the face. FIG. 2.

Albecht Durer (1528) published a book on human body geometry. He built up a system of co-ordinates. He marked the relative size of various features and then joined these anatomical points to form a lattice.

D'Arcy Thompson (1917) used a series of rectangular equidistant co-ordinates.

Rabey (1968) developed a system which he called "Morphanalysis". He exposed a grid onto a photographic plate then double exposed this with a photograph of the patient. This he did in three planes, along the X, Y and Z axes. This then allowed Rabey to fix the head in "labelled" space.

The final photograph with the superimposed grid does not however give a three dimensional picture.

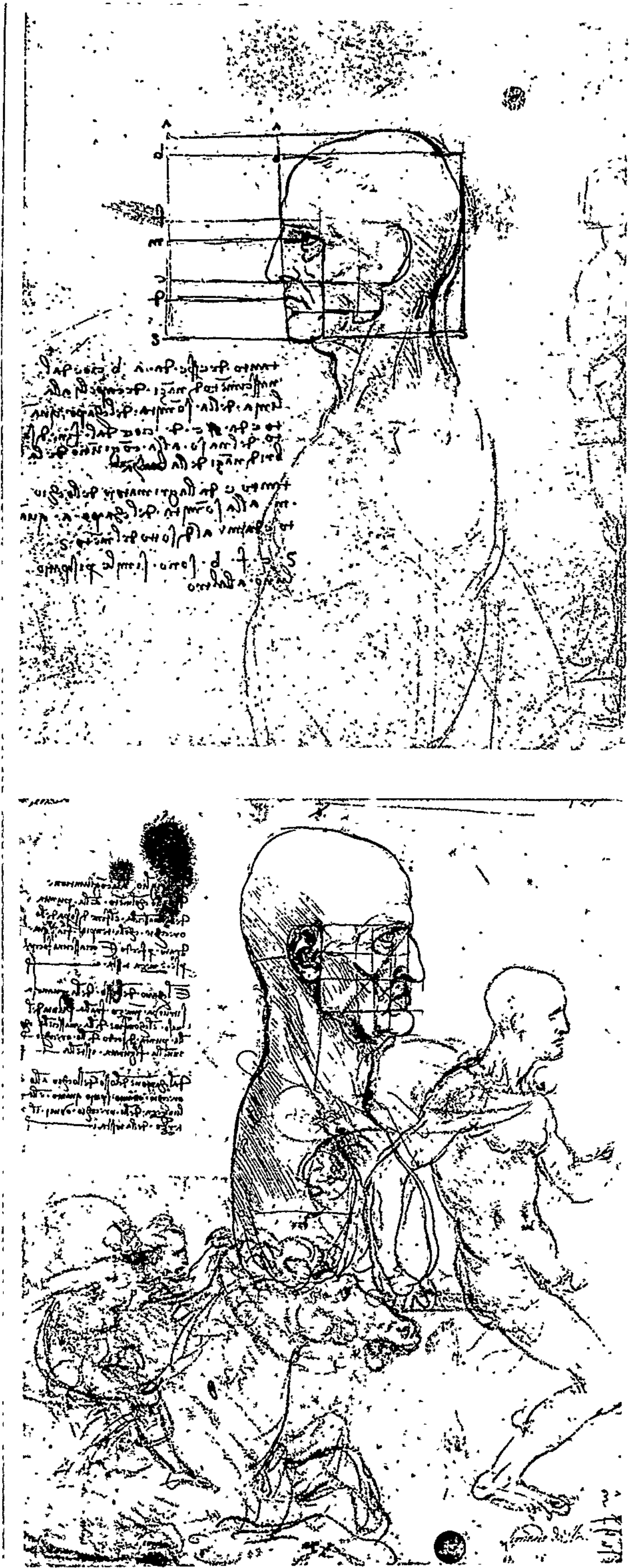


FIG. 2 Drawings of left and right profiles showing use of facial grids for use assessing proportion. (From Da Vinci)

Rabey then proposed to use a rectangular co-ordinate system for a complete record bank for models, photographs and radiographs. All of these have the "built-in" reference features which relate them to each other and to records of other patients.

The RAF and the Royal Aircraft Establishment have both been working on methods for quantifying the contours of a man's skin.

Hertzberg, Dupertuis and Emanuel (1957) of the RAF adapted a method of stereophotogrammetry for the design of form fitting protective clothing for pilots. These techniques were similar to those used in mapping of land forms in aerial photography.

The basic principle of stereophotogrammetry is exactly that of binocular vision. The two eyes send slightly different images of an object to the brain, where they are interpreted in terms of depth as well as length and breadth.

Burke and Beard (1967) have applied this to the face.

Robertson (1976) comments that stereogrammetry is expensive as regards the equipment required for it and the running costs for any project using it are high.

Lovesey (1973) from the Royal Aircraft Establishment looked for a suitable method for recording three dimensional shape with the specific purpose of relating this to the design of well fitting prosthetic devices and for the construction of comfortable gas-tight breathing masks.

The author used a projected grid technique but modified it so that the grid is projected onto the face at right angles to the camera axis. Thus the grid of equal spacing is projected onto the side of the object and then the object is photographed from the front. The author used telecentric lenses to keep the projected beams parallel. Robertson (1976) then modified Lovesey's (1973) technique. Robertson used bilateral illumination of the subjects and standardised them in a cephalostat. The author also used telecentric lenses to overcome the problem of divergence of the projected beams.

Robertson envisaged this technique for use in producing clinical and research records, for example:-

- i. Pre and post orthodontic treatment records.
- ii. Pre and post surgical records, to assist with pre-operative planning and assessment of results.
- iii. Assessment of facial asymmetries.

Lange and Lange (1973) comment that radiographs show only the greatest contour of the object and therefore have limited uses in measuring soft tissues of the face. They feel that the use of projected light has proven to be the most satisfactory method of measuring facial contours.

They used this method to ascertain soft tissue contour changes over five years. The authors stress that accurate repositioning of the head is absolutely necessary with the projected grid method in order to record changes quantitatively.

The head is positioned using a nasion rest in a relaxed position. Successive repositioning of the patient is accomplished by the use of the first image. A tracing of this is then superimposed over the upper contours of the new image to orientate the patient.

Krogman and Sassouni (1958) defined the "physiograph" as a set up by means of which the head is orientated in the Frankfort horizontal without the need for a head holder. It consists of a standard slide projector with a millimetre grid projected onto the face. One heavy line is for the Frankfort horizontal and one vertical for the mid-sagittal plane. The head is orientated so that the line passes through left Orbitale and right and left Tragii.

A head rest is used to support the head. This then gives a three dimensional picture of the face.

Krogman and Sassouni (1958), Hertzberg, Dupertuis and Emanuel (1957), Lovesey (1973) and Robertson (1976) all refer to techniques for evaluation of soft tissue contour. However, they do not satisfactorily describe the methods of actually quantifying the soft tissue dimensions. Hertzberg, Dupertuis and Emanuel (1957) conclude that "stereophotogrammetry is capable of providing data on body diameters and surface dimensions as well as body proportions."

Lovesey (1973) describes the projected grid method as a simple and cheap method of recording three dimensional shapes.

Robertson (1976) describes a projected grid method, simply as the means of record-taking both for orthodontic and plastic surgery purposes.

Morrello, Converse and Allen (1977) present a technique for producing uniform records in plastic surgery. The authors stress the key to success is consistency in camera settings, lighting, alignment and positioning. They use a 35mm S.L.R. camera with a grid mounted in the view finder. This gives one horizontal line for Frankfort horizontal and one vertical line for the mid-sagittal plane.

The patient's head position is adjusted until these planes are correctly adjusted.

The camera position and the distance from the patient to the camera are not standardised. This can result in inaccuracies in comparison from one photograph to another.

The method of localisation of the head does not localise it in all axis of rotation. The full face may vary by the head being raised or lowered, while the profile may vary by the head tilting to one side.

ORIGINAL WORK

INTRODUCTION

A method is proposed to standardise facial photographs. This method incorporates a projected grid technique with the patient orientated according to the natural head position.

A new apparatus was designed to stabilise the head in a standardised position and another bracket was designed to support both the projector and the camera.

MATERIALS

THE HEAD STABILISER

Fig. 3

The head is stabilised by means of a modified set of sound suppressors which fit over the ears. These are connected to two flexible spring steel strips which allow for ease of release, yet are close enough to give firm support of the head. Each of these steel strips is fitted to a brass slotted section 20cms in length and permits movement of the ear covers together to a distance of 2.5cms separation.

The brass slotted section is bolted at its mid-point to a brass rod 14cms in length. The rod is attached to a beam through a horizontal section which allows rotation

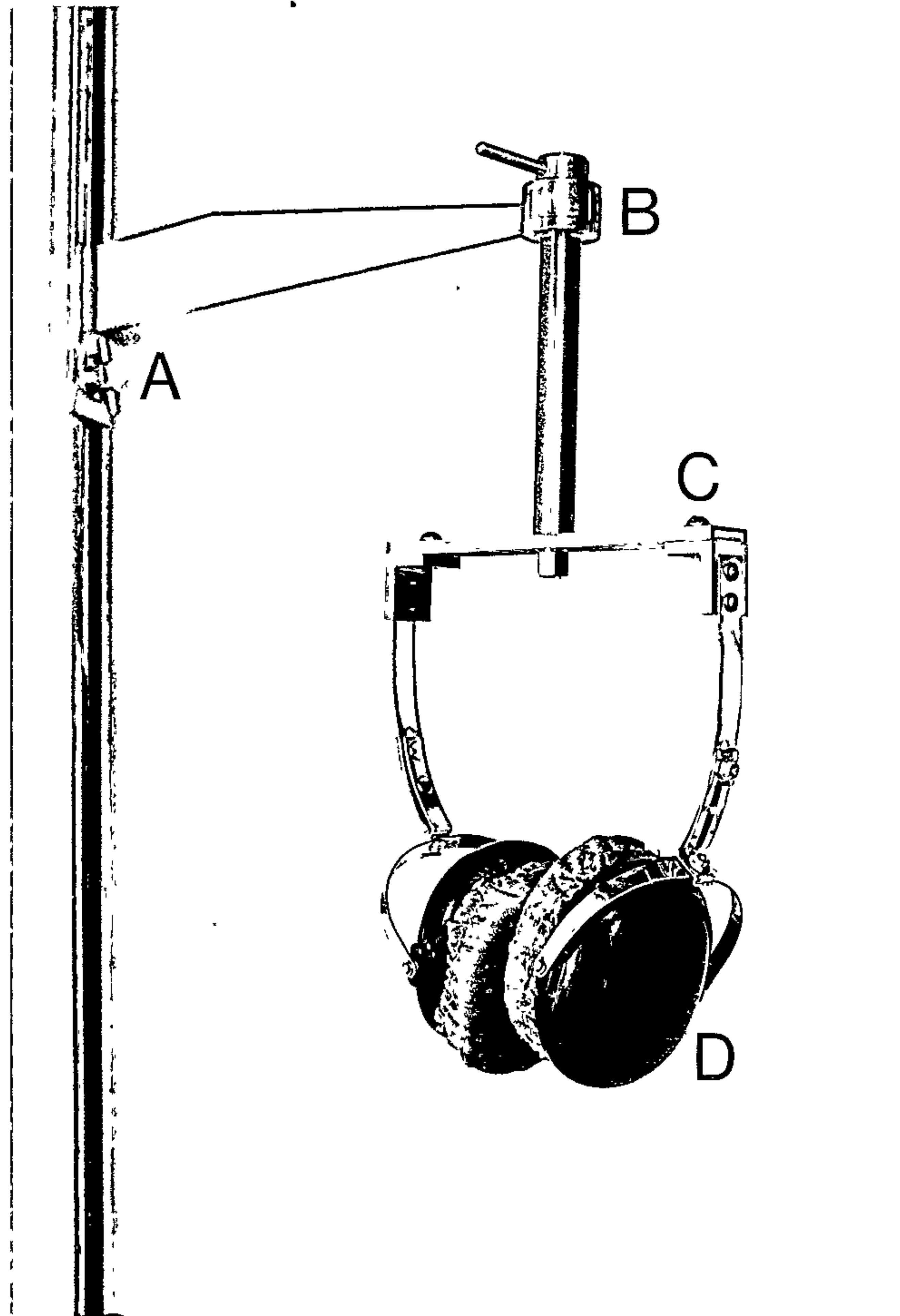


FIG. 3 View of head stabiliser:
 A, wing nut for securing the sliding beam in the wall channel.
 B, graduated drum through the head stabiliser may be rotated and secured. C, nuts to allow adjustment of width of head stabiliser. D, muffs which fit over the patients ears and are secured to flexible steel strips.

of the whole head stabiliser through 360° . This section is housed within a drum which is graduated every 45° and may be secured by means of a wing nut.

A brass beam extends from the drum through a distance of 41cms and slots into a galvanised steel channel of length 178cms. The whole apparatus is then adjustable for height through the channel and is secured at the desired height by means of a wing nut. The channel is permanently fixed to the wall while the head stabiliser can be completely removed for storage purposes when the apparatus is not being used and refitted quickly and simply.

This is the second design tested for the head stabiliser. The original design was produced so that the ear supports were set at right angles to the rod which extends from the beam. An adjustable head rest was incorporated into the base of the rod and was fixed by means of a wing nut.

This design gave satisfactory standardisation for full face photographs but when the patient was positioned into the left or right profiles, the head was immediately offset from the central axis from the stabiliser to the camera/projector bracket. It was then realised that the head stabiliser should be set in a vertical position and rotate about the central axis along the rod.

THE CAMERA/PROJECTOR Fig. 4

The camera/projector bracket consists of a flat platform 21cms wide and 43cms deep. The platform is carried in two channels each 149cms long and is supported on nylon runners to facilitate adjustment. The platform has a 45° strut each side and these are connected at their mid-point for stability. A single wing nut at the base of each strut secures the platform at the required height.

At the end of the platform, away from the wall, a square section of brass is fitted with a vertical arm to engage the camera.

The whole platform can be removed from the wall in the same manner as the head stabiliser.

The projector used was a Kodak Carousel slide projector, S. AV. 2000 with a Kodak 70-120mm zoom lens.

The camera was a Pentax S.L.R. 35mm with a 105mm lens. This is mounted on the vertical arm by means of a screw in its base.

The projector and camera are mounted so that the lenses are 10cms apart. The central axis from the head stabiliser taken from the vertical rod, is then at the mid-point between these two lenses so that parallex error

is cancelled out. The camera and projector are adjusted on the platform to give an included angle at 5 feet of $4^{\circ}.15'$
Fig. 5.

THE GRID

A photograph was taken from 2mm green graph paper and a contact slide of this was produced by the Audio-Visual department. Various filters were used in an effort to increase the contrast on the slide but these were all found to be unsatisfactory.

Sheets of 2mm and 2.5mm graph paper were ruled with black ink and contact slides of both were produced. Test shots showed the 2mm grid slide to be the more satisfactory.

METHOD

For each case, two series of photographs were taken which included:-

- i. Full face.
- ii. Left profile.
- iii. Right profile.
- iv. Three quarter.

One series was photographed with the grid projected, while the other was photographed without the grid using a Metz 402 electronic flash.

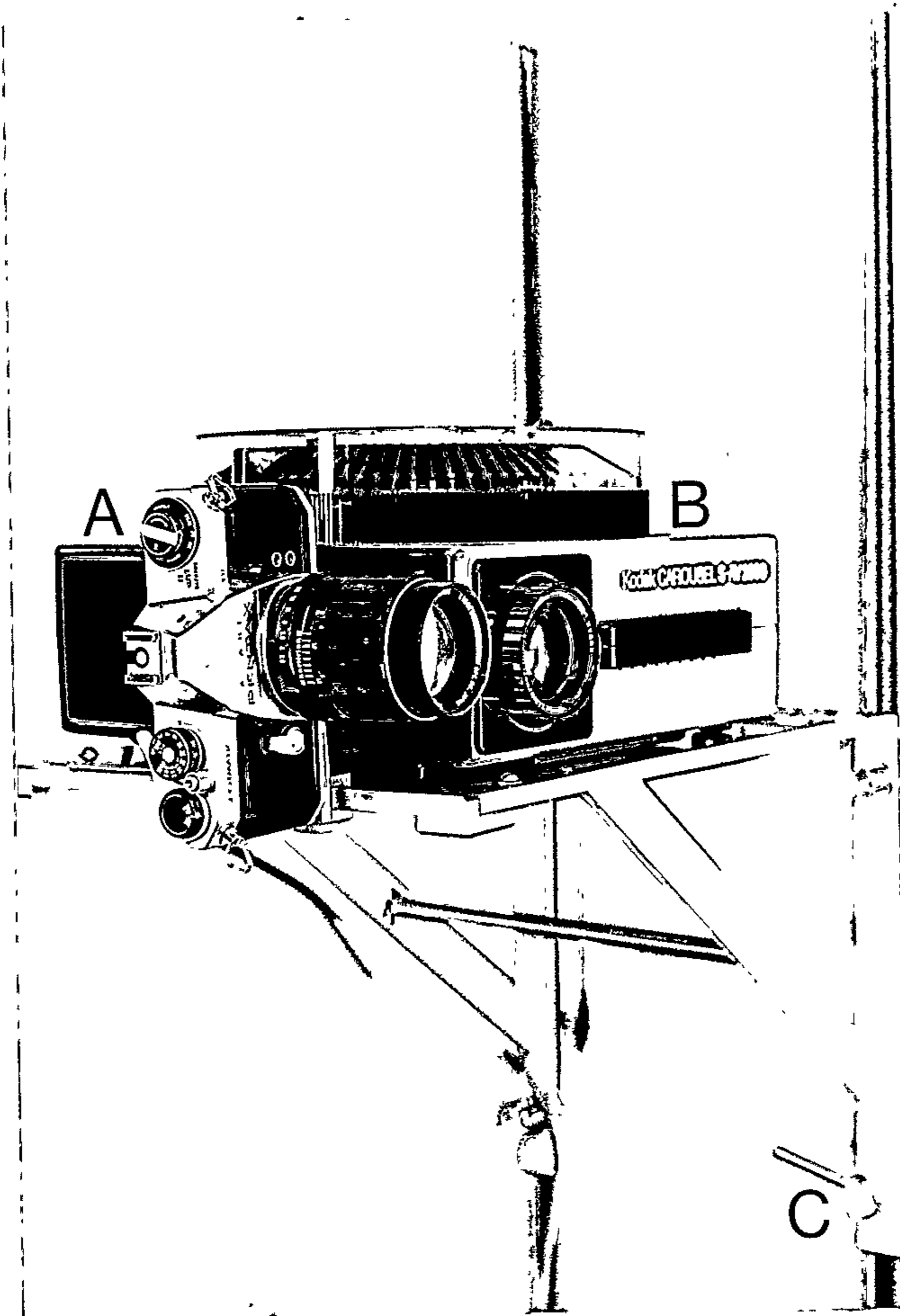


FIG. 4 View of camera/projector bracket. A, camera. B, projector. C, wing nut to secure sliding platform to wall channel.

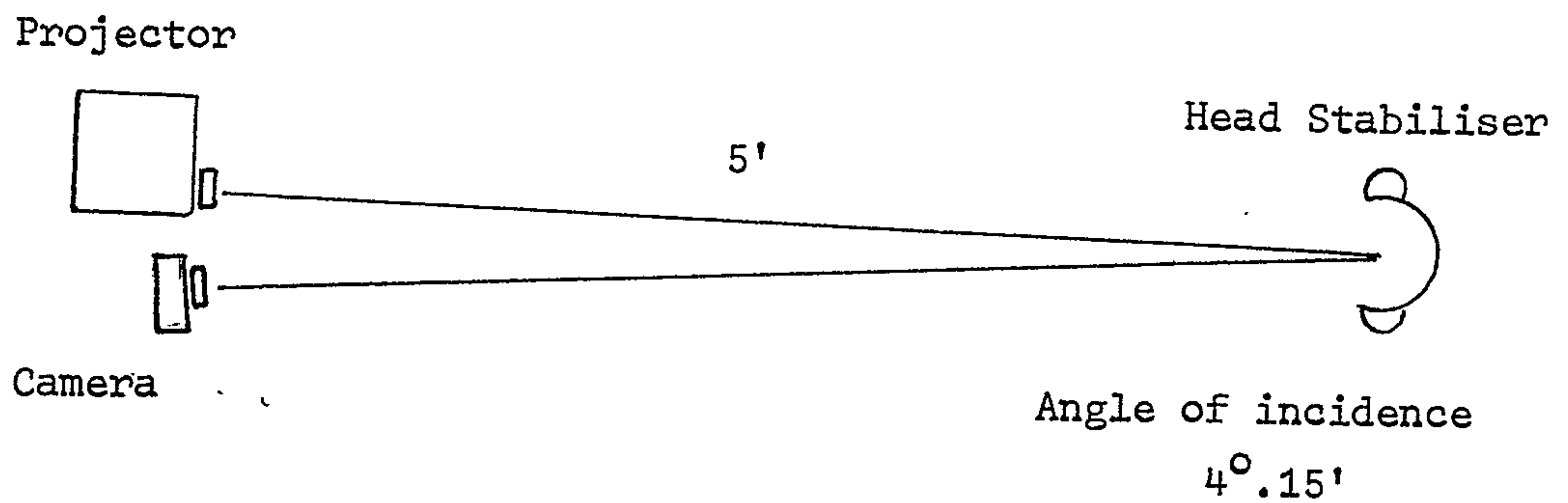
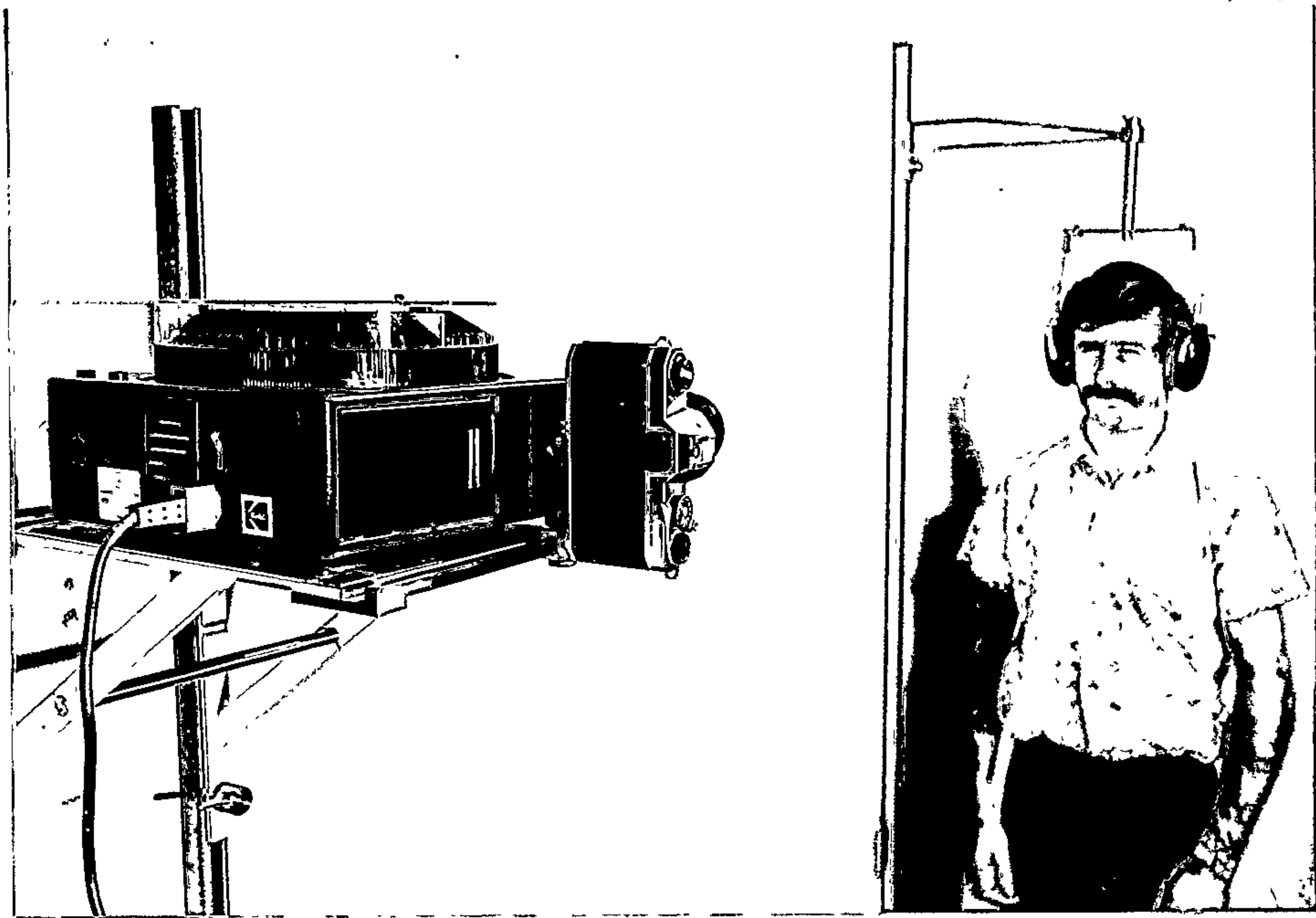


FIG. 5 above: view of apparatus in use.

below: plan view: Camera and projector set at angle so that their axes converge at the head stabiliser at an angle of incidence of 4° .15'.

The film used for both series was Kodak Plus X Pan, ASA 125. Lighting for both series, was by means of fluorescent ceiling lights and only the rear lights of the studio were illuminated.

The exposure for the series with the grid was 1/15 second at F 5.6, while the exposure on the series without the grid was 1/60 second at F 16/22.

POSITIONING THE PATIENT

The patient stood next to the head stabiliser and this, along with the camera/projector bracket, was adjusted for height and the head stabiliser locked at 90°. to the axis. The operator then stood behind the head stabiliser and while he was holding the ear supports apart, the patient was positioned inside the head stabiliser. By means of a mirror in front of the camera and projector lenses, the patient was sighted in the natural head position according to the method of Moorrees and Kean (1958). The ear supports were then released and the head was stabilised in the natural position.

THE PHOTOGRAPHS

The grid was projected onto the face and adjusted by raising or lowering the bracket so that the orbital line

was crossed by a heavy line along with the median plane, as taken from the soft tissue Nasion.

Dots were placed on the face in the region of the infra orbital fissures, along the orbital line. These served to check the orientation of the patient for the profile and three quarter views. A photograph was then taken with the grid projected after which the projector was turned off and a normal full face photograph with electronic flash was taken.

The head stabiliser was then released at the drum and the head stabiliser and the patient were rotated through two 45° graduations on the drum. The head stabiliser was then secured in this position and the grid was projected. The patient was checked for standardised position by means of the dots, making sure they fell on the same horizontal line. Two photographs were taken in the same manner as for the previous view. This procedure was repeated by rotating the head stabiliser one graduation of 45° for a three quarter view and then rotation through three 45° graduations for the opposite profile.

The grid was measured across the brow of each patient so that life size prints could be produced.

Photographs were also taken of a corner of a box mounted in the head stabiliser, as well as of a flat sheet.

These were used to evaluate the distortion of the grid as projected onto these surfaces. As an addition, it was decided to test the projected grid technique with the camera and projector at right angles to each other in the manner of Robertson (1976) using bilateral projection, but with the patient still in the natural head position.

Unfortunately there was not sufficient time to adjust the apparatus for absolute standardisation, but the results were most encouraging.

The method used was to mount identical Kodak Carousel S. AV 2000 projectors at a distance of 5 feet either side of the head stabiliser. A second wall bracket for the projector was not available, so the projectors were mounted on benches and the lenses lined up to be opposite each other.

A camera was mounted on a tripod and to facilitate the positioning of the projectors the patient was orientated in the natural head position while seated on a stool. The projectors were adjusted so that the left and right lines of the identical grids, coincided exactly across the face.

A series of full face, left and right profile and three quarter views, was taken with only the projected grid, in the manner previously described.

DISCUSSION

In the design of the head stabiliser the author chose a design that was simple and would enable the photographs to be standardised at any angle required, including the three views shown.

The natural head position was chosen, as it gave a reference plane outside the cranium. It overcomes problems in cases of facial asymmetries. Where the patient is orientated according to the Frankfort horizontal, it is assumed the transmeatal plane is perpendicular to the median plane. To do this in facial asymmetry cases will produce errors in diagnosis (Moorrees and Kean (1958)).

Many practitioners use a cephalostat in an effort to standardise their photographs. However, this necessitates the use of ear rods which may produce errors. These occur when the ear rods are inserted into the external meati with aim of establishing fixed points from which to determine the transverse axis of the skull (Sutton (1968)). The meati may not lie at the same vertical level and one may be more anterior than the other. The standard method to adjust an apparatus with ear rods, is to adjust these so that an equal reading is obtained on the graduated scales of both rods. It is then assumed that the head is situated centrally in the apparatus. Without

sophisticated apparatus such as that of Rabey, (1968) with his electronic ear plugs for placement of the ear rods, the operator cannot be sure that the head is centrally located in the head holder. Support of the head was achieved by means of the ear muffs which overcame the problem of the ear rods, yet gave firm support of the head.

It was felt that it would be simpler to set the camera and projector in one position and to adjust the patient for each view required. The head stabiliser was constructed to rotate through 360° and graduated every 45° so that it could be used for any view from full face to the opposite three quarter. The apparatus was made adjustable for height by slotting into a wall channel because the proposed method required the patient to be standing, rather than sitting on an adjustable stool. This necessitated the camera and projector being on an adjustable bracket.

A distance of 5 feet was chosen from the head stabiliser as a satisfactory distance for the photographs, as this is the distance at which the patient appears undistorted (Dickason and Hanna (1976)).

An attempt was made to mount the camera above the projector with the lenses in line in the vertical plane. However, this was not feasible, so the camera and projector

were mounted in the same horizontal plane. These were both mounted so that their foci were parallel, but this threw the central focus of the camera off from the central axis of the head stabiliser. The camera and projector were then adjusted with the lenses 10cms apart and their axes converged to an angle of incidence at 5 feet of $4^{\circ}15'$. It was hoped that this would allow for parallex error, but when tested in Cases 1, 2 and 3, it showed that the views as described were in fact not correct. This was due to the fact that the camera and head stabiliser were not in the same axis so that the patient was always turned slightly further away from the camera than measured on the graduations on the drum. This problem was overcome in Case 4, where the accuracy of the views was more precise.

When the projected grid experiment was first proposed, it was supposed, wrongly, that if the camera and projector were in the same axis, a form of contour mapping of facial form would result. After Cases 1 and 2, a closer look at the optics of the method revealed the reason. Fig. 6.

If the camera and projector are in the same axis, then although the projected grid falls onto the contours of the face, the camera image merely follows this projection and the result is a photograph of a grid overlaid onto a face. The only distortions in the grid as photographed, are due to divergences in projection.



From Projector : parallel beams

FIG. 6 Grid interval, d ; interval between grid points, l ; Camera interval, δ ; Angle of incidence, θ .

$$\sin \theta = \frac{d}{l}$$

$$l = d \operatorname{cosec} \theta$$

$$\cos \theta = \frac{\delta}{l}$$

$$\delta = l \cos \theta$$

$$= d \operatorname{cosec} \theta \cdot \cos \theta$$

$$= d \cot \theta$$

It is only when the plane is viewed at right angles to the projection, that the grid will be distorted. Figs. 7 and 8.

The photograph of the flat plane showed errors in the actual drawing of the grid. However, when this was compared to the photograph of the corner of the box there was negligible difference. The grid pattern still appeared as a flat plane grid pattern.

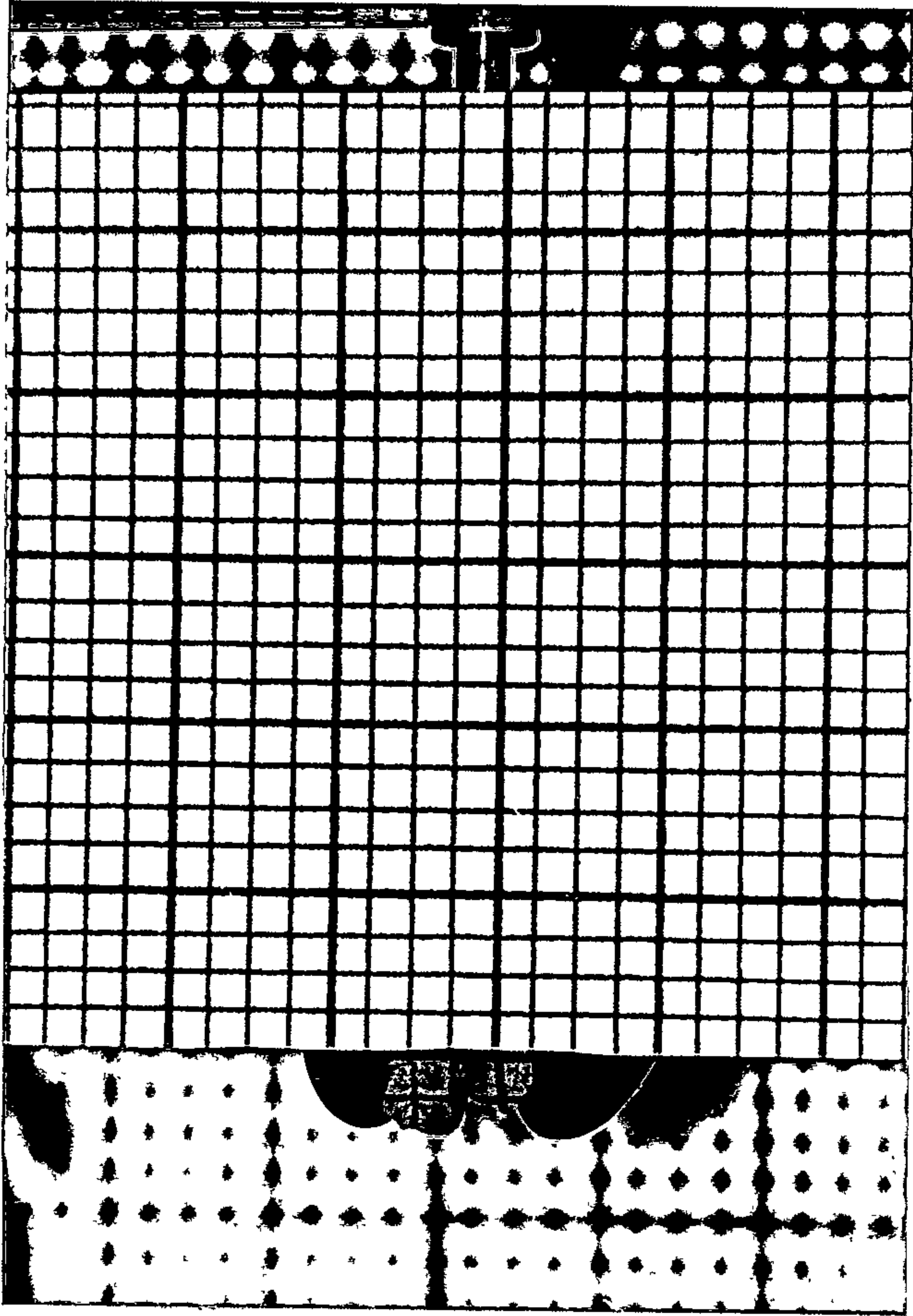


FIG. 7 View of grid as projected
onto a flat plane at 5 feet.

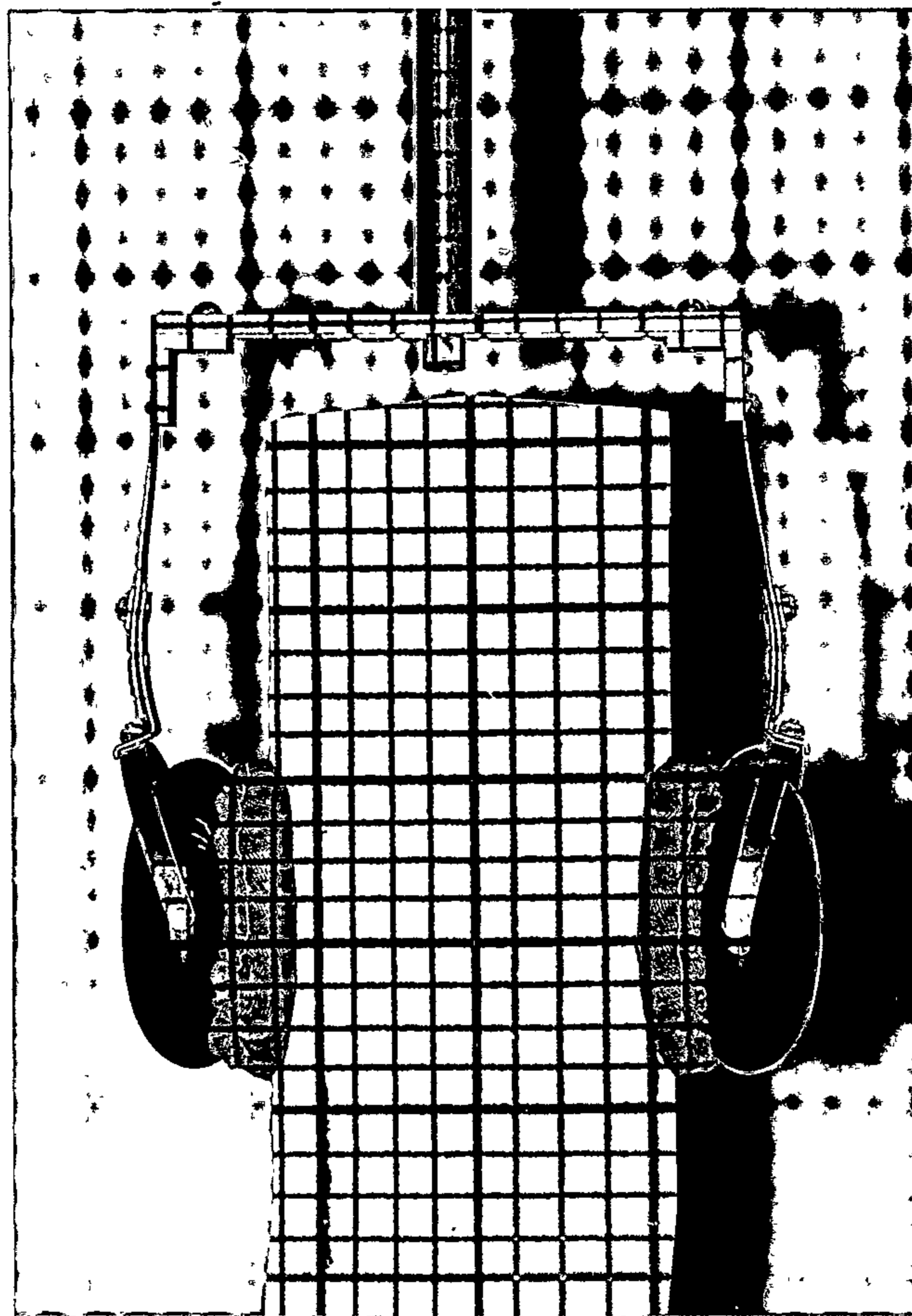


FIG. 8 View of grid as projected onto a corner of a box at 5 feet. The grid appears as if projected onto a flat plane with the grid lines at 90° to each other.

DOCUMENTATION OF CASES - REFINEMENT OF METHOD

CASE 1: Miss A.F.

Year of Birth: 1953

History: Mandibular prognathism

Pre-operative photographs for mandibular osteotomy.

The camera and projector are on the same axis.

Full Face With Grid

The orbital plane grid reference line was adjusted by raising the camera/projector bracket. Its vertical line was centred in the median plane from soft tissue nasion. In this case, the author neglected to adjust for a heavy line as the median plane. Dots were placed on the orbital line at the intersection of the orbital line and the vertical line in the region of the outer canthus of each eye.

Full Face

Examination of both this and the above photograph (identical head position), show that the patient is turned slightly to the right due to the fact that the camera is set to the right of the grid projection and mid-sagittal axis.



Case 1 Miss. A.F.
Camera and projector on same axis.
Full face; above, without grid;
below, with grid.

Left Profile With Grid

The head is localised to the standardised natural head position by checking that one orbital dot coincides with the same horizontal grid line as for the full face view.

Left Profile

Examination of this view shows the departure from a true lateral view. This becomes more obvious when this view is compared with the opposite profile.

Right Profile With Grid

This view is similarly located using the orbital line.

Right Profile

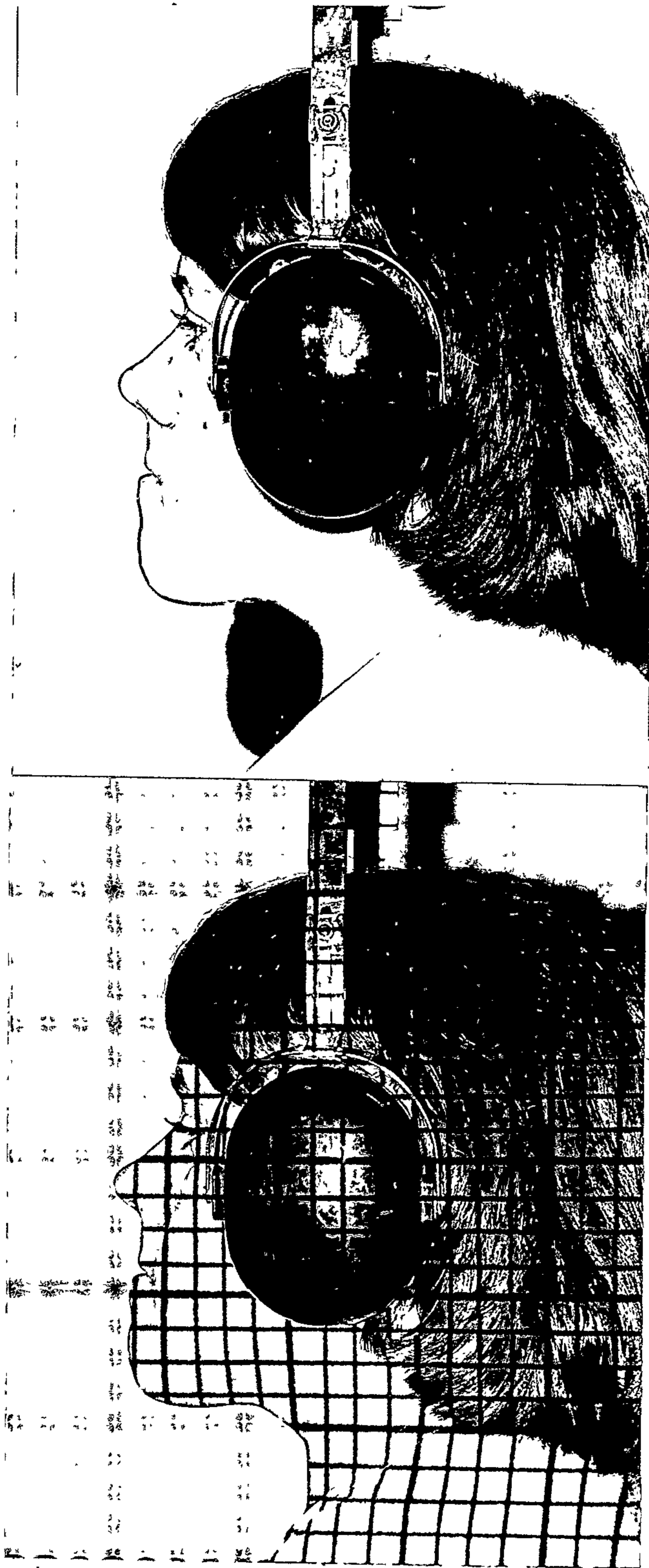
Examination of this view also shows the departure from a true lateral view.

Three Quarter With Grid

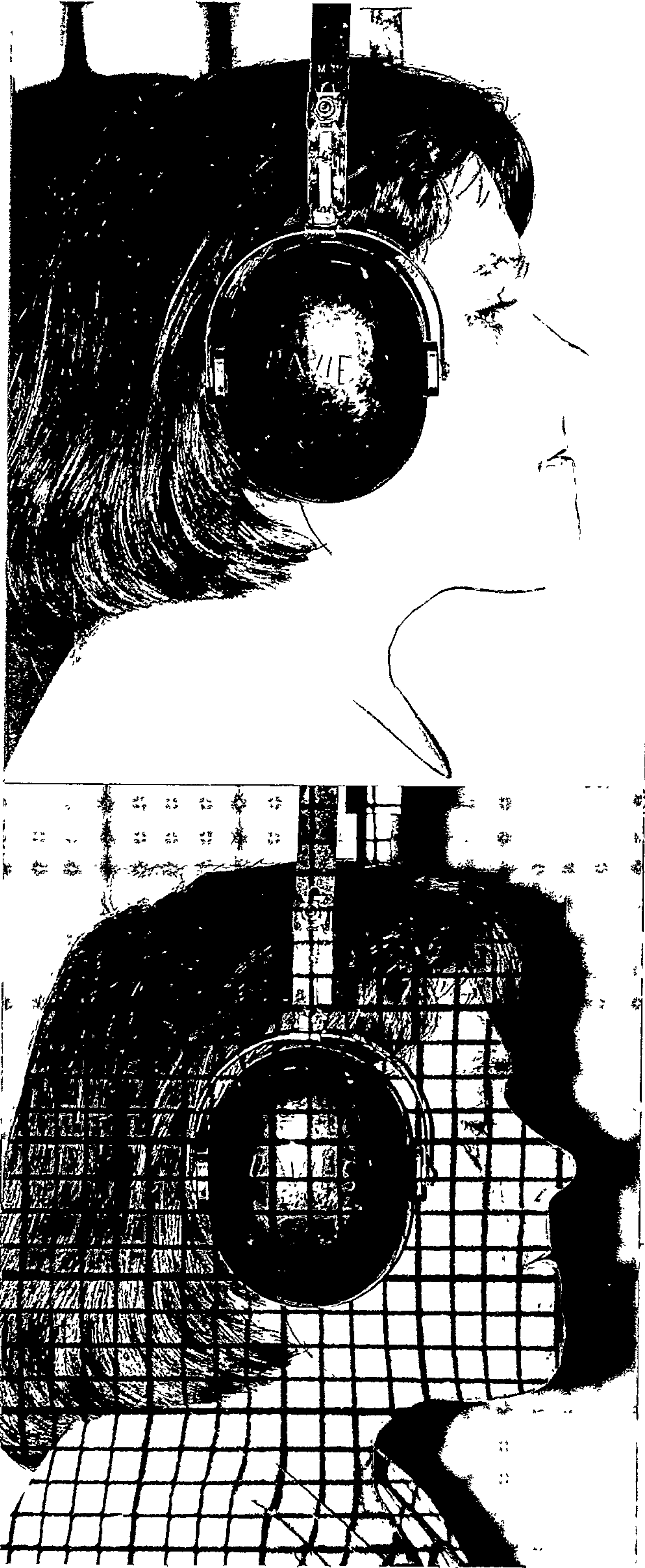
Is related to the orbital dots.

Three Quarter

Examination of this view shows that they are not exactly 45° to the axis, for the same reason as for the previous views. In the author's opinion, this view gives the best overall picture of the patient. Allowing for the



Case 1 Miss. A.F.
Camera and projector on same axis.
Left profile; above, without grid;
below, with grid.



Case 1 Miss. A.F.
Camera and projector on same axis.
Right profile; above, without grid;
below, with grid.



Case 1 Miss. A.F.
Camera and projector on same axis.
Three quarter view; above, without
grid; below, with grid.

error previously described, it is a view midway between the full face and profile and complements these views.

CASE 2: Miss A.F.

Year of Birth: 1953

History: Bilateral mandibular sagittal split osteotomy.

Post-operative photographs of Case 1.

The camera and projector are on the same axis. This series was taken five days post-operatively and demonstrates the value of a projected grid technique in cases of surgical corrections.

Full Face With Grid

The median plane has been adjusted for a heavy line, but this is still not absolutely precise. There was also a lack of consistency through using a finer line for the orbital line.

Full Face

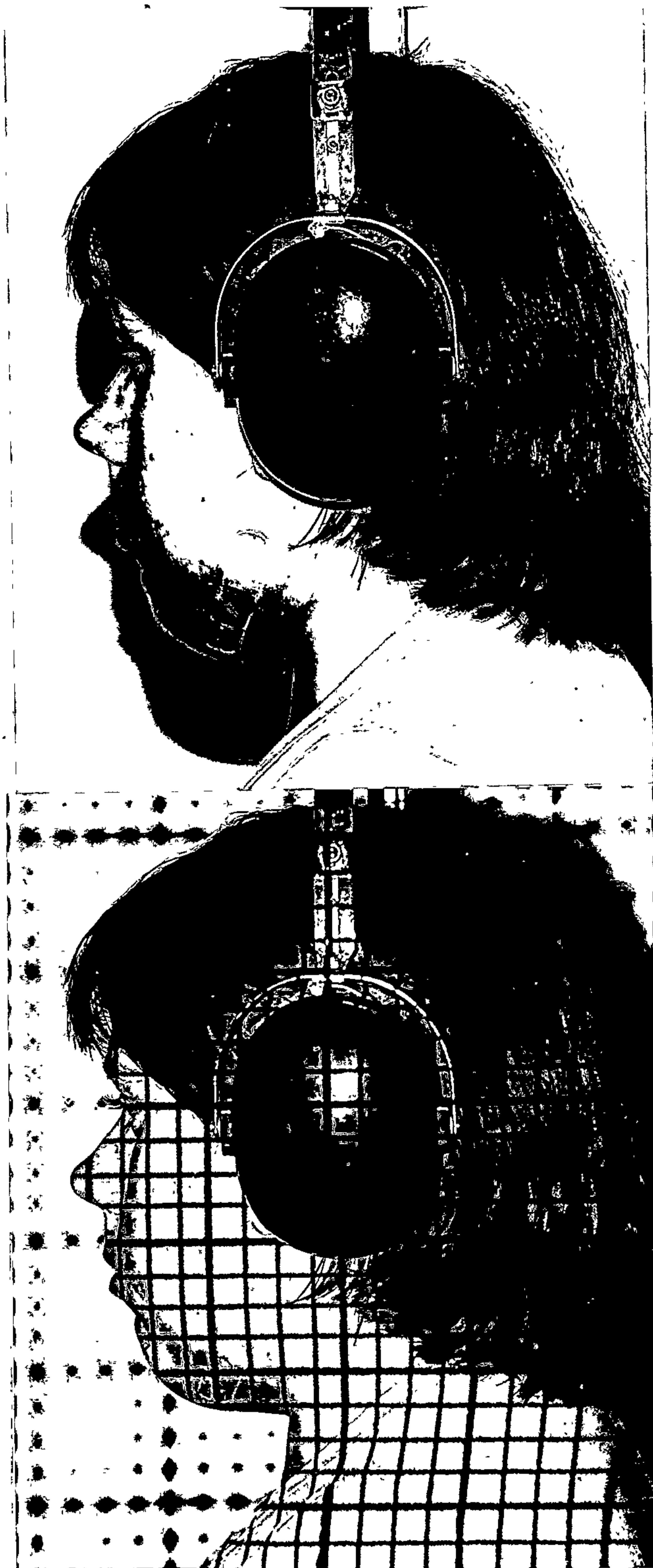
Demonstrates the same inaccuracy due to the camera angle as in the previous case.

Profile With Grid

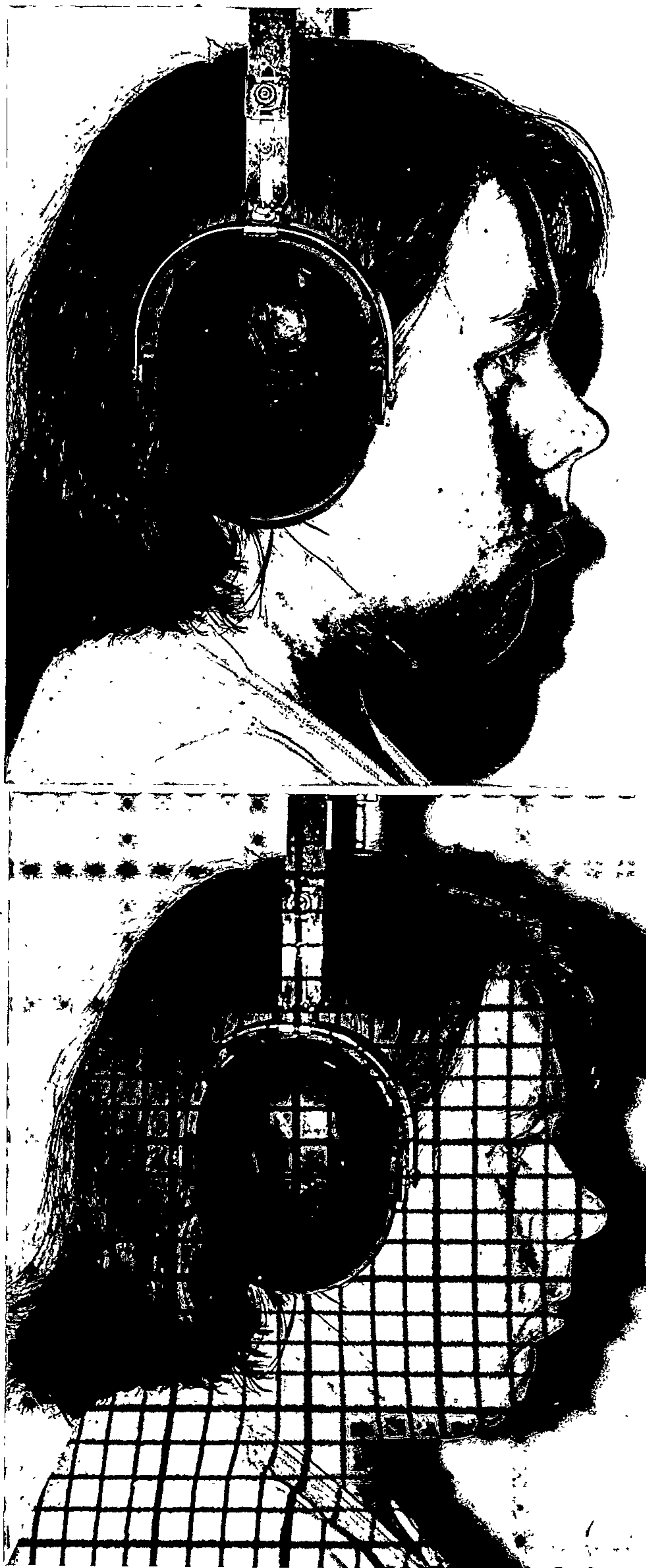
The left and right profiles were localised in the same manner using the orbital line.



Case 2 Miss. A.F.
Camera and projector on same axis.
Full face; above, without grid;
below, with grid.



Case 2 Miss. A.F.
Camera and projector on same axis.
Left profile; above, without grid;
below, with grid.



Case 2 Miss. A.F.
Camera and projector on same axis.
Right profile; above, without grid;
below, with grid.



Case 2 Miss A.F.
Camera and projector on same axis.
Three-quarter; above, without grid;
below, with grid.

Profile

The left and right profiles show the same departure from true lateral as those of Case 1.

Three Quarter

Related to the orbital line. Once again, this appears to give a more complete view of the patient for aesthetic appraisal and may be standardised as simply as either full face or profile.

CASE 3: Miss S.S.

Year of Birth: 1962

History: Craniostenosis, displaying facial asymmetry.

Surgical History: Supra-osseous silastic implants to the right supra-orbital region and the left infra-orbital region.

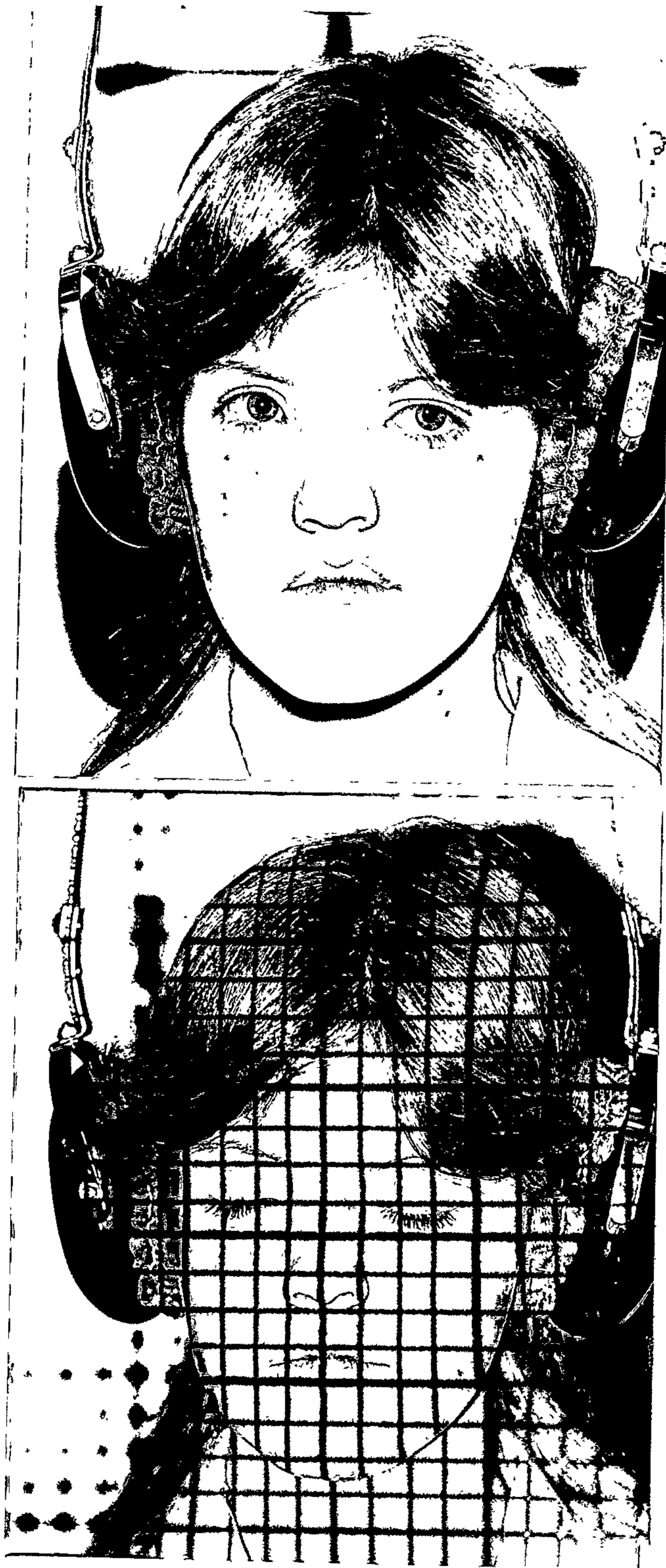
Camera and grid are on the same axis.

Full Face With Grid

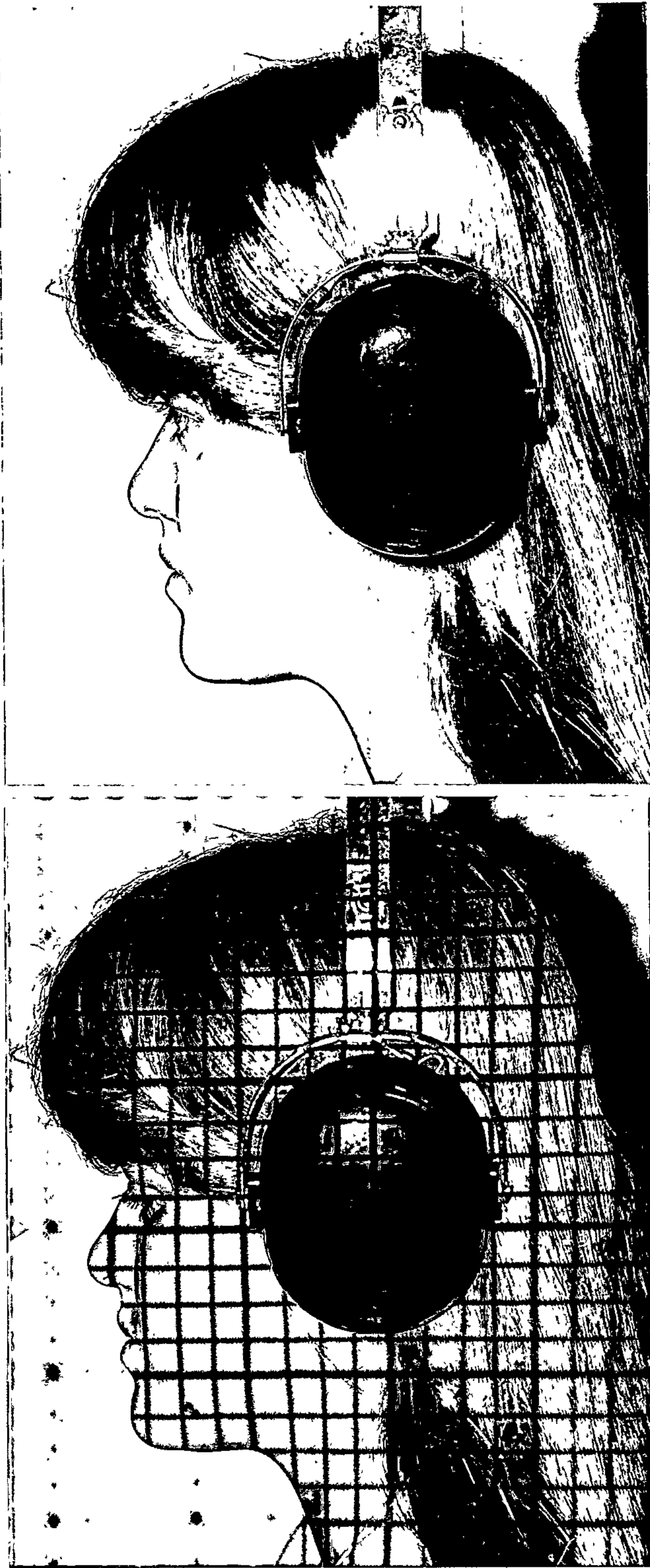
The technique of proper adjustment had by now been refined, so that the median plane and the orbital line were both heavy lines.

Full Face

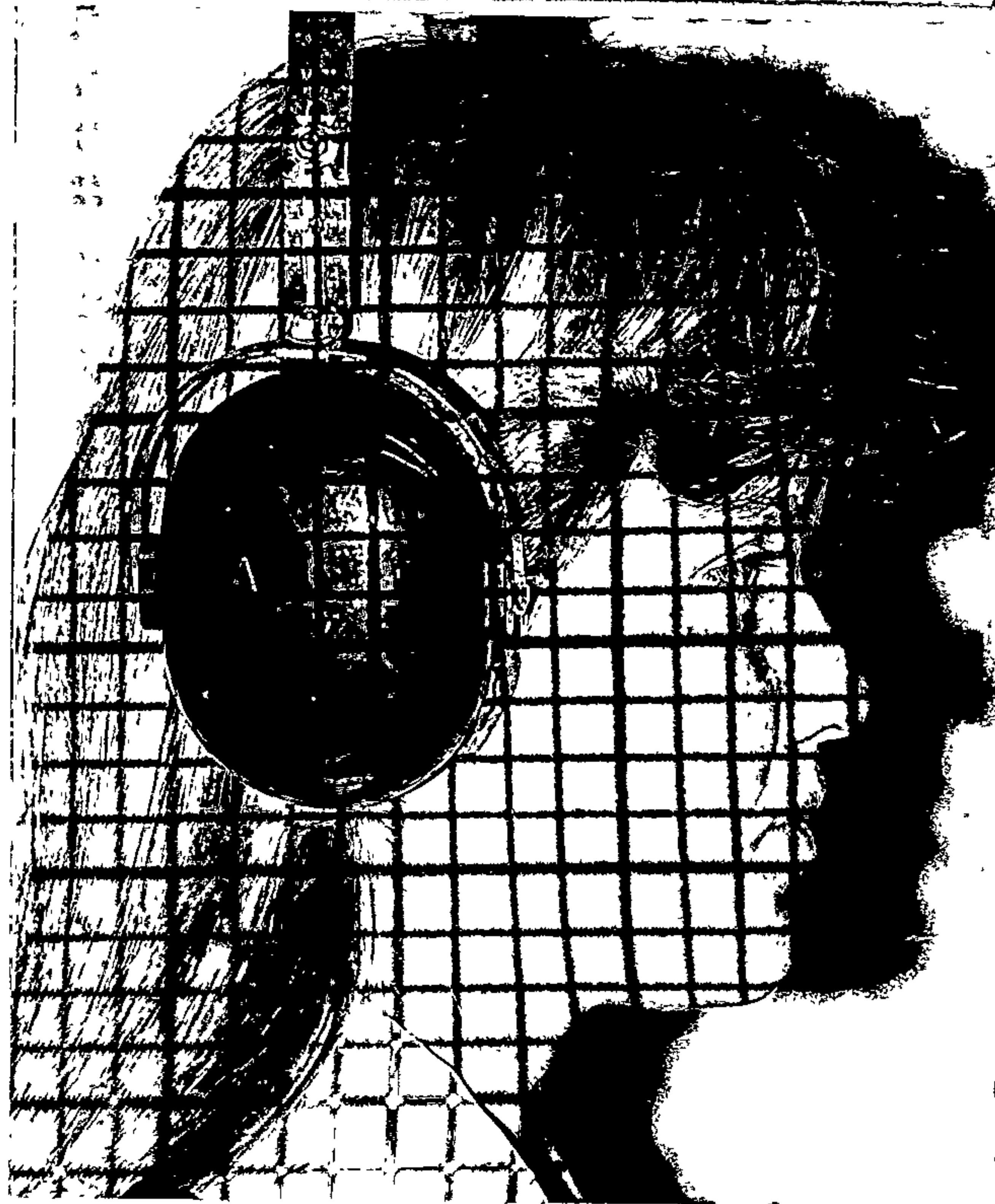
As with the previous cases, there is still a departure from the true full face.



Case 3 Miss. S.S.
Camera and projector on same axis.
Full face; above, without grid;
below, with grid.



Case 3 Miss. S.S.
Camera and projector on same axis.
Left profile; above, without grid;
below, with grid.



Case 3 Miss. S.S.
Camera and projector on same axis.
Right profile; above, without grid;
below, with grid.



Case 3 Miss. S.S.
Camera and projector on same axis.
Three-quarter view; above, without
grid; below, with grid.

Profile

Left and right profile views were located as for the previous cases and show the same departure from the true lateral.

Three Quarter

These views were related to the orbital line as for the previous cases and similarly gave a more complete picture of the patient.

CASE 4: Miss S.S. As in Case 3

Double projection was used with the camera at 90° to the projector axis.

Full Face With Grid

This is a true full face, the error of the earlier cases having been eliminated. It can be seen from the photographs, that the horizontal lines are not truly horizontal. This is because the projectors were not set below the level of the patient's orbital line. It can be seen that the grid is distorted along the facial contours.

Profile

The left and right profile views were true laterals, with the patient's visual axis exactly at 90° to the camera.

Three Quarter

This view was exactly 45° to the camera axis. When this view is compared to this patient's first three quarter view (Case 3) the improvement can be seen.

REVIEW OF MODIFIED PROCEDURE

Use of this modified procedure, allows the building up of a three dimensional representation of the patient. Fig.9. Each horizontal line on both sides of the face may be plotted to produce a section of the face. These sections may then be superimposed, similarly to tomograms, to produce the three dimensional representation.

When projecting from the side of the face, the projected grid as it reaches the nose will be of different magnitude over a distance of 5 feet. This will produce errors in the plotting of the contours. Fig. 10a. For example, if the head is 240cms wide, then by proportion,

l = unit at side of face

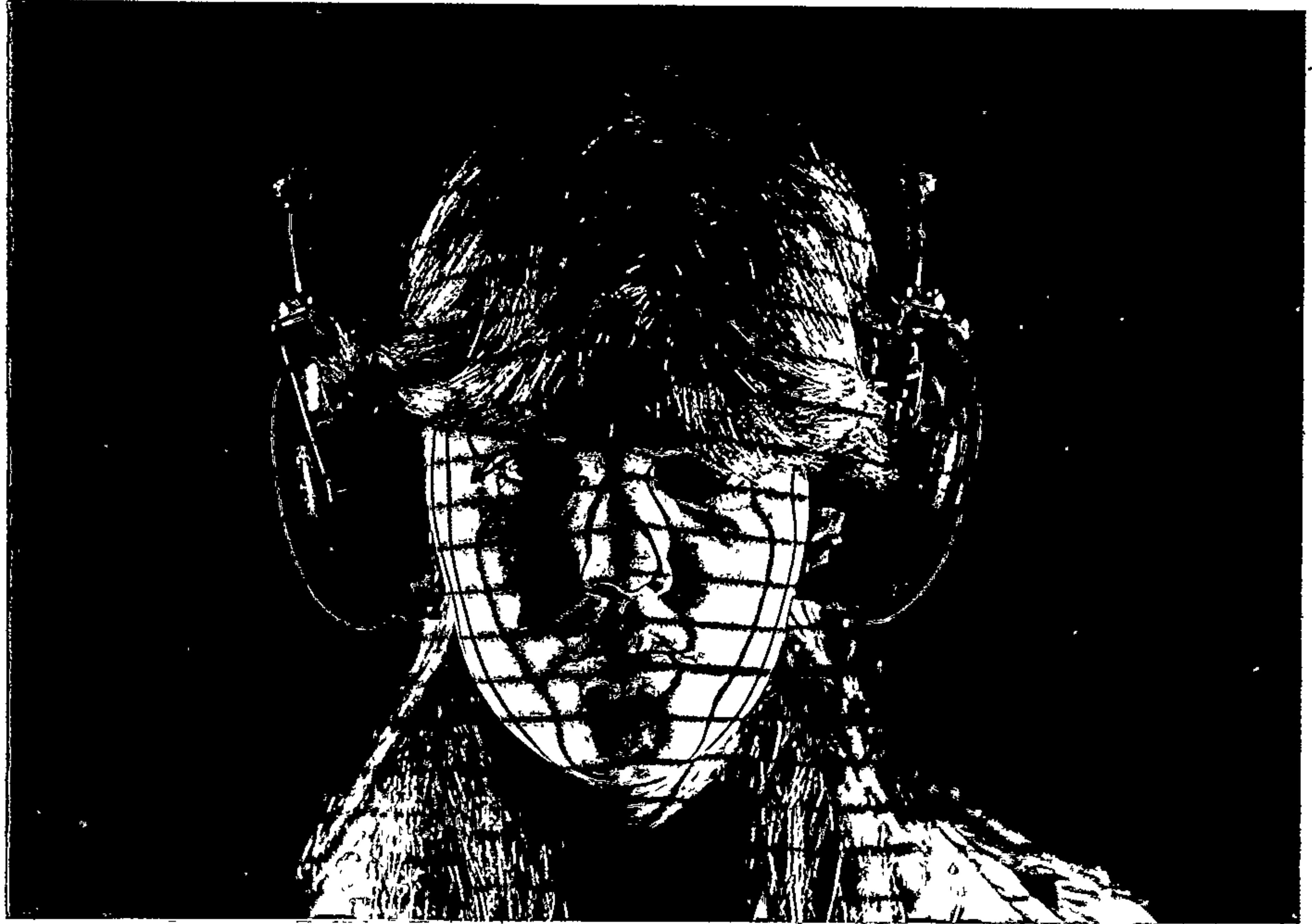
d = unit grid at mid-line

$$l = \left[\frac{1500 - 120}{1500} \right] \times d$$

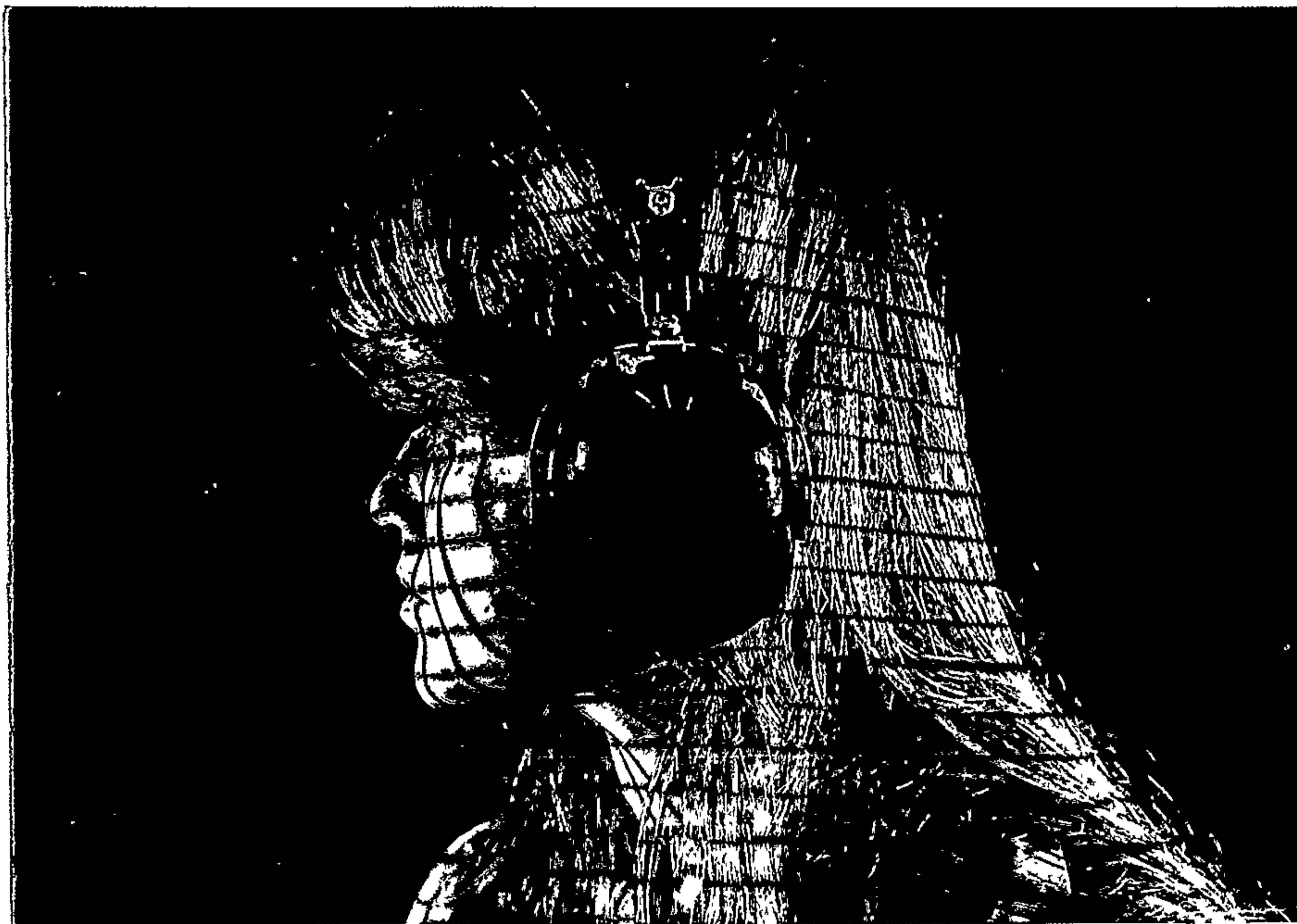
$$l = \frac{23}{25} \times d$$

l is reduced by 8%

NB. 5 feet = 1500cms.



Case 4 Miss. S.S.
Camera and projector at 90°.
Full face with grid.



Case 4 Miss. S.S.
Camera and projector at 90° .
Left profile with grid.



Case 4 Miss. S.S.
Camera and projector at 90°.
Right profile with grid.



Case 4 Miss. S.S.
Camera and projector at 90°.
Three-quarter with grid.

However if the grid is measured at the mid-point between the ear and the median plane, the following is valid. Fig. 10b.

In this case, the standard unit d , is slightly enlarged at the median plane and slightly decreased at the plane of the ear. To use this mid-point will reduce the error by half and for the above to a maximum error of 4%. The procedure is as follows:-

1. Two adjustable brackets are required for the projectors, similar to the original design. The camera attachment is removed and a 15 x 10cms mirror placed in front of each projector lens on a hinge bracket to allow them to be swung away from the lens. The projector brackets should then be mounted 5 feet from the head stabiliser and fixed to the wall.

Markings are made from a point directly beneath the central shaft of the head stabiliser and checked by means of a plumb bob, to a point 5 feet from this and at 90° to the projectors. This spot marks the position for the camera.

Parallel lines are marked on the floor below the head stabiliser each side of the previously

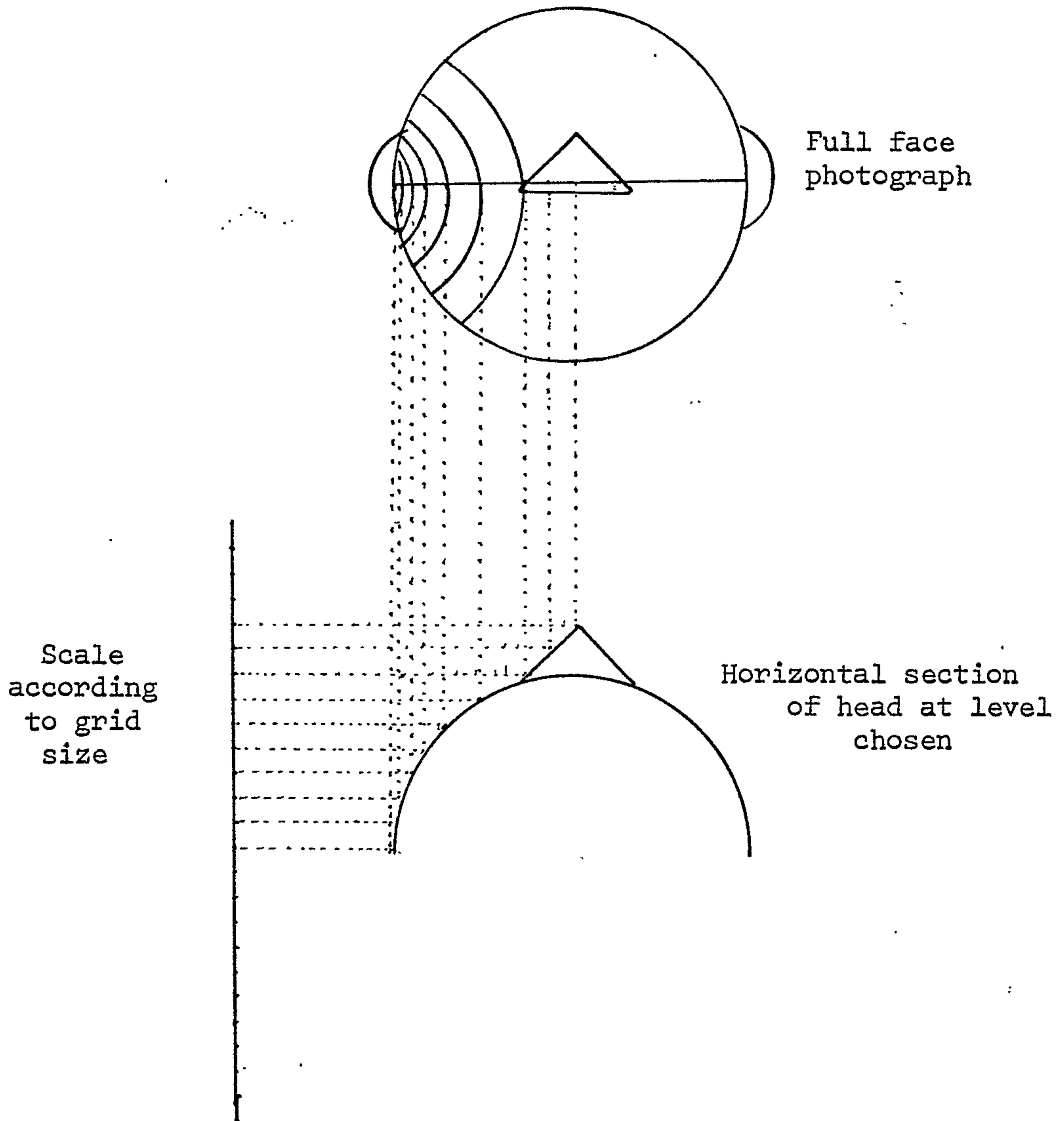
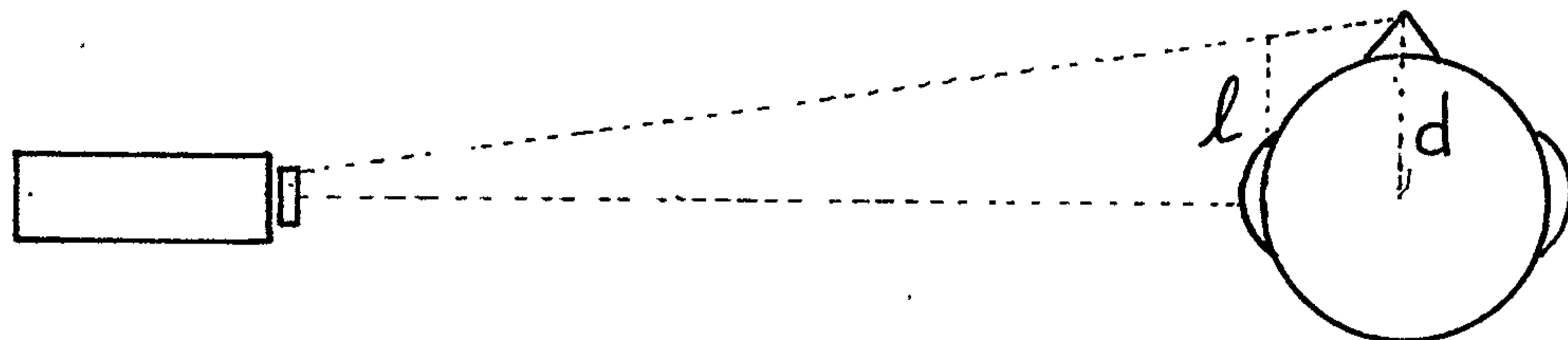
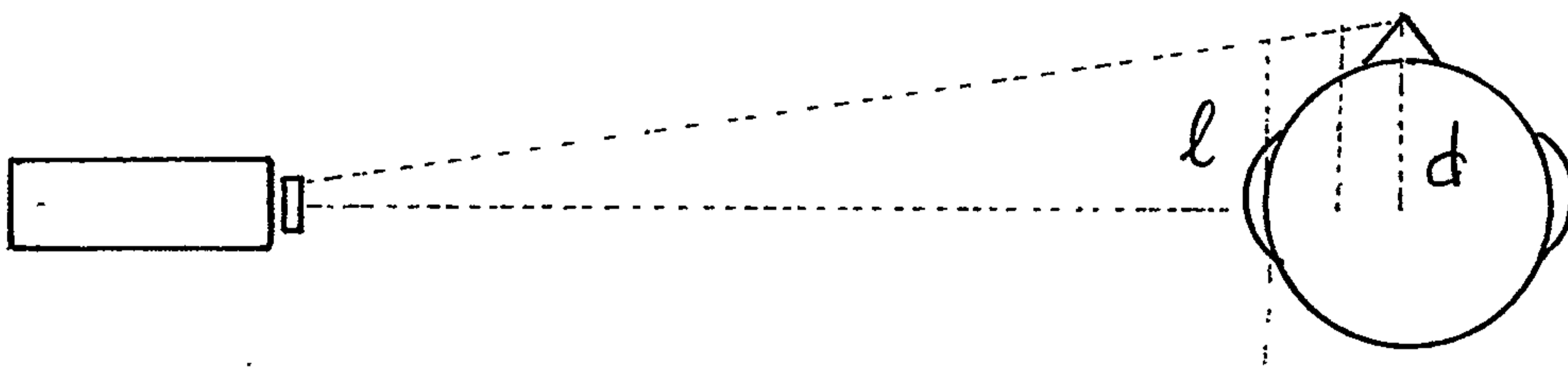


FIG. 9. Diagrammatic representation of method of plotting the intersections of the vertical and horizontal projected grid lines as they appear on a full face photograph.

The net result is a graphic representation of a horizontal section of the head at the level chosen, similar to a tomogram.



a.



b.

FIG. 10 a. The variation in grid size at the nose d , and the tragus l when parallel beams are not used.

b. The projected grid is focussed at the bisected distance between d and l to minimise measurement error.

demarcated spot below the shaft of the head stabiliser. These lines should be 250cms apart and at 90° to the projected axis. These lines are used to standardise the position of the patient for either profile, so that the position of the head, in an anterior-posterior position, with respect to the head stabiliser, is reproducible.

II. The two projectors are adjusted using a spirit level, to lie in a horizontal plane with the lens of one projector centring on the lens of the opposite projector. A height gauge is used to measure the orbital spot, recorded on the patient's face while the patient is standing erect. The vertical median line of each grid should lie in the centre of the lens and fall along the shaft of the head stabiliser. The orbital line should also lie in the centre of the lens so that each projector may be adjusted for height, by means of the height gauge, to the mid-point of each lens.

III. The patient is positioned for the profile view by first locating them on the lines drawn below the head stabiliser. The patient stands with his/her heels on the line behind the plumb bob spot. The head is orientated to the natural position in the manner previously described, with the mirror

swung up in front of the projector lens. With the head stabiliser set at 90° to this axis, the ear muffs are closed to support the head in this position. For the full face view, the patient is rotated through 90° and checked by means of the horizontal orbital line, viewing along the axis of the projector. The opposite profile view is rotated 90° again and the position of the feet are reset on the opposite line with the head stabiliser open. The patient is checked for natural head position and the stabiliser is closed over the ears and patient's head is supported. Either three quarter view may be taken by rotating the patient 45° from the profile position. For gross asymmetry cases, problems may arise where the orbits are at different levels. In view of this, one orbit may be chosen as being of normal height and this spotted "Normal" being the operator's decision which he must note and consistently repeat with successive photographic records.

- IV. The unit size of the projected grids are standardised by using either, predrawn or photographed grids. This grid is located at the bisected distance of the median plane and the tragus. The grid is focussed by moving

the projector back or forth and is done for both projectors, making sure they are horizontal.

- V. The camera is mounted on an adjustable tripod. This is located by means of a plumb bob precisely over the spot previously determined, at 5 feet from the head stabiliser. The camera is adjusted for height using the height gauge so that the mid-point of the lens is at the same height as the patient's orbital line. It is essential to check with a spirit level that the camera body base, and hence the lens, is horizontal.

SUMMARY AND CONCLUSIONS

A method has been presented to standardise facial photographs using the natural head position. A new head stabiliser was designed and a projected grid technique incorporated to facilitate comparison of views and to enable a three dimensional representation of the two dimensional image to be produced.

Certain deficiencies in the method became apparent while the method was being tested. Firstly, the ear muffs were too large and tended to cover too much of the face. These should be reduced in size, so that they cover no more than the ears themselves.

Secondly, the grid size is too large and makes the plotting of the sections on the face coarse. A finer grid of 1mm is recommended. A further recommendation would be a lens system (telecentric), so that the projected grid beams are parallel.

Two projection techniques were tested, one with the camera and projector on the same axis and the other with the camera and double projection at 90° to each other. The second method was the method of choice, as it gave visual representation of facial contours as well as allowing building up of the three dimensional image.

The photographs may be used for pre-treatment, mid-treatment and post-treatment records. For plastic surgery purposes, the projected grid may be used on a diagnostic facial moulage, to assess the proposed treatment plan.

Facial photographs have the advantage over radiographs, in that one sees the patient as they really are. Also, the parents and the patient can relate to these far better than to skull radiographs. For standardisation of all craniofacial imaging, photographs and radiographs may be taken using the same principles of head positioning.

The technology is already available to enable quantification of facial morphology using the photographic techniques presented in this thesis. This is done by means of tracing the grid on the full face photograph, using a stylus on a digitiser, which transfers the information to a computer. The computer will transform the information to a visual display unit, so producing a three dimensional image. At the operator's request, this three dimensional image may be rotated or tilted to any angle to view the face completely.

U
BIBLIOGRAPHY

- Abercrombie, M.L. (1960). The Anatomy of Judgement, p.28. Hutchinson, London.
- Ackerman, J.L. and Proffit, W.R. (1969). The characteristics of malocclusion: A modern approach to classification and diagnosis. Am. J. Orthod. 56: 443-454.
- Ackerman, J.L. and Proffit, W.R. (1975). Ch.1. Diagnosis and planning treatment in orthodontics. In: Current Orthodontic Concept and Techniques, 2nd. Edn. (Edited by Graber, T.M. and Swain, B.F.) Vol.1, pp.63-65. Saunders, Philadelphia.
- Angle, E.H. (1907). Treatment of Malocclusions of the Teeth. 7th. Edn. p.60. S.S. White, Philadelphia.
- Bartlett, F.C. (1932). Remembering. Cambridge University Press, Cambridge.
- Bishara, S. (1973). Treatment planning in maxillary prognathism. Am. J. Orthod. 64: 384-403.
- Broadbent, T.R. and Mathews, V.L. (1957). Artistic relationships in surface anatomy of the face: Application to reconstructive surgery. Plast. Reconstr. Surg. 20: 1-17.
- Burke, P. and Beard, L. (1967). Stereogrammetry of the face. Am. J. Orthod. 53: 769-782.
- Clark, M.S., Limongelli, W.A., Hayward, H., Norris, J.E.C. and Williams, A.C. (1977). Photocephalography for evaluation of tissue relations in mandibular surgery. J. Oral. Surg. 35: 319-320.
- Clements, B.S. (1969). Nasal imbalance and the orthodontic patient. Am. J. Orthod. 55: 477-498.
- Cohen, L.K., Horowitz, H.S. (1970). Occlusal relations in children born and reared in an optimally fluoridated community. III Social psychological findings. Angle Orthod. 40: 149-169.
- Converse, J.M., Coccaro, P.J. (1975). Diagnosis and treatment of maxillo-mandibular dysplasias. Am. J. Orthod. 68: 625-644.

- Converse, J.M. and Horowitz, S.L. (1969). The surgical orthodontic approach to the treatment of dentofacial deformities. Am. J. Orthod. 55 217-242.
- Convese, J.M., Horowitz, S.L. and Wood-Smith, D. (1964). Deformities of the jaws. In: Reconstructive Plastic Surgery (Edited by Converse, J.M.). pp.869-947. Saunders, Philadelphia.
- Cox, N.H. and Van der Linden, F.P. (1971). Facial harmony. Am. J. Orthod. 60: 175-183.
- Da Vinci, L. (1490). In: The drawings of Leonardo da Vinci. pp.191 and 216. The Reprint Society, London. 1953.
- Dickason, W.L. and Hanna, D.A. (1976). Pitfalls in comparative photography in Plastic and Reconstructive surgery. Plast. Reconstr. Surg. 58: 166-175.
- D'Ottaviano, N. and Baroudi, R. (1974). Surgical and esthetic aspects of facial profile. Int. J. Oral Surg. 3: 243-247.
- Durer, A. (1528). Vier Bücher Van Menschlicher Proportion. In: Encyclopaedia Britannica, Vol.7, p.759. Encyclopaedia Britannica London. 1958.
- Epker, B.N. and West, R.A. (1972). Posterior maxillary surgery: Its place in the treatment of dentofacial deformity. J. Oral. Surg. 30: 562-571.
- Epker, B.N. and Wolford, L.M. (1975). Middle third facial osteotomies: Their use in the correction of acquired and developmental dentofacial and craniofacial deformities. J. Oral Surg. 33: 491-514.
- Farkas, R., Ross, R.B. and James, J.S. (1977). Anthropometry of the face in lateral facial dysplasia: The bilateral form. Cl. Pal. J. 14: 41-51.
- Flemming, J.P. (1971). Improvements in the face in Crouzon's disease by conservative operations. Plast. Reconstr. Surg. 47: 560-564.
- Fromm, B. and Lundberg, M. (1970). The soft tissue facial profile before and after surgical correction of mandibular protrusion. Acta. Odont. Scand. 28: 157-177.

- Giddon, D.B., Hershan, L.E. and Lennartsson, B. (1974). Discrepancy between objective and subjective profile measures. Scand. J. Dent. Res. 82: 527-535.
- Gillies, H. (1957). In: The Principles and Art of Plastic Surgery. Gillies, H. and Millard, D.R. Vol.1, p.38. Butterworth, London.
- Gorney, M. and Harries, T. (1974). The pre-operative and post-operative considerations of natural facial asymmetry. Plast. Reconstr. Surg. 54: 187-191.
- Grignon, J.L. (1972). La préoccupation esthétique chez l'opéré et le chirurgien: Responsabilité de l'équilibre nez-menton. Actual. Odontostomatol. (Paris). 26: 455-465.
- Hautvaust, J. (1971). Analysis of the face by means of photogrammetric methods. Anthropol. Anz. 33: 39-47.
- Hayward, H.L. The human face: A focus for multi-disciplinary integration. N.Y. Dent. J. 46: 159-165.
- Hemley, S. (1944). Fundamentals of Occlusion. Saunders, Philadelphia. pp.26 and 173.
- Hertzberg, H.T.E., Dupertuis, C.W. and Emanuel, I. (1957). Stereogrammetry as an anthropometric tool. Photogrammetric Eng. 23: 942-947.
- Hewitt, A.B. (1975). A radiographic study of facial asymmetry. Br. J. Orthod. 12: 37-40.
- Hooton, E.A. (1947). Up from the Ape. pp.503-504. McMillan, New York.
- Horowitz, H.S. Cohen, L.K. and Doyle, J. (1971). Occlusal relations in children in an optimally fluoridated community: IV clinical and social psychological findings. Angle Orthod. 41: 189-201.
- Horowitz, S. and Hixon, E. (1966). The Nature of Orthodontic Diagnosis. p.257. C.V. Mosby, St. Louis.
- Janzen, E. (1977). A balanced smile. A most important treatment objective. Am. J. Orthod. 72: 359-372.

- Krogman, W. and Sassouni, V. (1958). The physiograph cephalostat. Am. J. Orthod. 43: 307. (Abstract)
- Lange, K.W. and Lange, K.O. (1973). A new method of measuring facial geometry. J. Prosthet. Dent. 29: 132-138.
- Le Febvre, A. and Munro, I. (1978). The role of psychiatry in a craniofacial team. Plast. Reconstr. Surg. 61: 564-569.
- Lines, P.A., Lines, R.R. and Lines, C.A. (1978). Profilometrics and facial esthetics. Am. J. Orthod. 73: 648-657.
- Lines, P.A. and Steinhauser, E.W. (1974). Diagnosis and treatment planning in surgical orthodontic therapy. Am. J. Orthod. 66: 378-397.
- Lischer, B.E. (1919). Variations and modifications of facial features. Int. J. Orthod. 5: 495-504.
- Lovesey, E.J. (1973). A simple photographic technique for recording three dimensional head shape. Med. Biol. Illus. 23: 210-213.
- Lundstrom, A. (1961). Some asymmetries of the dental arches, jaws and skull and their etiological significance. Am. J. Orthod. 47: 81-106.
- Macary, A.F. (1957). Etude de la ligne de profil du visage sur des cas historiques: Application au diagnostic et à la thérapie fonctionnelle maxillo-thoracique. In: Report of 33rd Congress. Europ. Orthod. Soc. pp.118-134.
- McCoy, J.D. and Shephard, E.E. (1956). Applied Orthodontics 7th Edn. Lea and Febiger.
- Mills, P.B. (1969). The orthodontists' role in surgical correction of dentofacial deformities. Am. J. Orthod. 56: 266-272.
- Moore, G.R. and Hughes, B.O. (1942). Familial factors in diagnosis, treatment and prognosis of dentofacial disturbances. Am. J. Orthod. 28: 603-639.
- Moorrees, C.F.A. and Kean, M. (1958). Natural head position - a basic consideration in the interpretation of cephalometric radiographs. Am. J. Phys. Anthropol. 16: 213-234.

- Morello, D., Converse, J.M. and Allen, D. (1977). Making uniform photographic records in plastic surgery. Plast. Reconstr. Surg. 59: 366-372.
- Neger, M. (1959). A quantitative method for the evaluation of the soft tissue profile. Am. J. Orthod. 45: 738-751.
- Peck, H. and Peck, S. (1970). A concept of facial esthetics. Angle Orthod. 40: 284-317.
- Persson, M. (1973). Mandibular asymmetry of hereditary origin. Am. J. Orthod. 63: 1-11.
- Prall, G. (1967). Esthetic Judgement. Ch.2. Crawell, New York.
- Pruzansky, S. and Aduss, H. (1976). Interview on cleft lip and palate. J. Clin. Orthod. 10: 380-395.
- Rabey, G.P. (1968). Morphanalysis. Lewis, London.
- Ricketts, R.M. (1957). Planning treatment on the basis of the facial pattern and estimate of its growth. Angle Orthod. 27: 14-36.
- Ricketts, R.M. (1968). Esthetics, environment and the law of lip relation. Am. J. Orthod. 54: 272-289.
- Riedel, R.A. (1950). Esthetics and its relation to orthodontic therapy. Angle Orthod. 20: 168-178.
- Robertson, R.E. (1976). Contour photography. Br. J. Orthod. 3: 105-109.
- Schendel, S.A., Eisenfield, J.H., Bell, W.H. and Epker, B.N. (1976). Superior repositioning of the maxilla: Stability and soft tissue osseous relations. Am. J. Orthod. 70: 663-674.
- Secord, P.F. and Backman, C.W. (1959). Malocclusion and psychological factors. J. Am. Dent. Assoc. 59: 930-937.
- Simon, P.W. (1924). On gnathostatic diagnosis in Orthodontics. Int. J. Orthod. 10: 755-777.

- Simon, P.W. (1931). A systematic diagnosis of dental anomalies. In: Sved, A. The analysis of the most important diagnostic methods used in orthodontia. Angle Orthod. 1: 139-160.
- Stanton, F.L. (1922). A consideration of normal and abnormal dentures as a problem of three dimensional spaces and its bearing on orthodontic classification and terminology. Int. J. Orthod. 8: 185-204.
- Stricker, G. (1970). Psychological issues pertaining to malocclusion. Am. J. Orthod. 58: 276-283.
- Sutton, P.R.N. (1968). Lateral face asymmetry - Methods of assessment. Angle Orthod. 38: 82-92.
- Thompson, D.W. (1917). On Growth and Form. Cambridge, Cambridge.
- Thompson, J.R. (1943). Asymmetry of the face. J. Am. Dent. Assoc. 30: 1859-1871.
- Worms, F., Isacson, R. and Speidel, T. (1976). Surgical orthodontic treatment planning. Profile analysis and mandibular surgery. Angle Orthod. 46: 1-24.
- Wuerpel, E.H. (1937). On facial balance and harmony. Angle Orthod. 7: 81-89.
- Zwener, T. and Lorber, R. (1976). Dent. Clin. Nth. Am. 20: 641-660.