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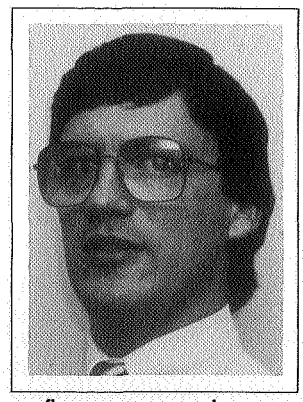

Diagnostic imaging of the face using projected grids

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Abstract: Procedures for taking standardised facial photographs are described using a single lens reflex camera and bilateral projected grids. The subject is positioned in the natural head position and supported with a specially designed head stabilizer. The contours of the face may then be digitised and processed using computer aided drafting (CAD) techniques to provide three dimensional co-ordinates of the face as an aid in planning orthognathic surgery.

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INTRODUCTION

Treatment planning in orthodontics and orthognathic surgery has traditionally used cephalometric analyses as a standard diagnostic tool. A correctly positioned and exposed lateral head film permits analysis of the patient's profile, soft tissue thickness as well as bony dimensions. Tooth angulations and their relationship to bony bases may also be measured, and together these provide essential information in treatment planning for orthodontics and orthognathic surgery. However, cephalometric analyses carry no information about the actual curvature of the face and consequently bring about a loss of morphological information. (Sperwein 1985).

Wylie et al (1987), compared five different cephalometric analyses used in the diagnosis of dentofacial deformities. They concluded that cephalometrics cannot be considered the primary diagnositic tool in the correction of dentofacial deformities, as no single cephalometric analysis agreed with the actual surgical treatment more than sixty per cent.

Facial photographs and study models are essential to complement cephalometric radiographs. People seldom see themselves or others in true profile in day to day life, therefore lateral head films represent only a limited aspect of facial aesthetics.

Hunt and Rudge (1984) summarise the more commonly used soft tissue analyses related to facial profile but further comment that an evaluation of frontal photographs is also of importance as this is the view generally noted by the patient and others.

This paper describes the production of standardised facial photographs and its integration with computer aided drafting (CAD) techniques, as the basis for three dimensional analysis of the face.

LITERATURE REVIEW

Photogrammetry may be defined as the "acquisition of data from photographs" (Von Thomann and Rivett, 1982). Stocksted and Guttierrez (1981) describe a photographic analysis to assess facial harmony. They discuss the planning of rhinological procedures to improve the function of the nose as well as the physical appearance. Larrabee et al (1985) used profile photographs in the natural head position. Various landmarks were located in the pre-operative and post-operative assessment for facial surgery. Telecentric photogrammetry has been described by Robertson and Volp (1981). They produced full face and profile photographs using a single camera as an aid to diagnosis and treatment planning.

Biostereometrics developed as a method of using twin cameras to provide a stereo image of biological form. It may be defined as "the spatial and spatio temporal analysis of biological form based on the principles of analytical geometry "(Kakara 1979). These stereo images follow the same principle as binoccular 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.

A number of authors have described applications of stereogrammetry in combination with computer technology to measure the face in three dimensions. Von Thomann and Rivett (1982) used a cephalostat to locate the head and took stereo photographs. These were plotted using surveying techniques to provide three dimensional coordinates of facial form. Burke et al. (1983) describe the measurement of three dimensional changes following facial surgery. They used stereo cameras and digitised the contours through a microcomputer. Savara et al (1985) describe the development of contourgrams from stereo cameras in diagnosis and treatment planning of facial deformities. Hay et al. (1985) applied photogrammetry to the measurement of facial swelling following oral surgery in a drug trial.

Travan et al. (1986) and Vergeest et al. (1987) applied three dimensional coordinate data derived from stereogrammetry to computer aided drafting (CAD) programs. By integrating this with a numerically controlled milling machine, a solid model of the face may be produced as an aid in pre operative planning for surgical procedures.

MATERIALS AND METHOD

Standardised facial photographs are taken in true profile, full face and three quarter views. The subject is positioned, standing erect and looking into their own eyes in a mirror. This mirror is mounted at a distance of 1.5 metres and establishes the natural head position according to the visual axis (Moorees and Kean, 1958). Once the subject is located, a specially designed head stabiliser (patent number 527289) is closed over the ears of the subject to support the head. (Fricker 1982). Attached to the head stabilizer is a projection box housing two projectors with 35mm transparencies of 2mm grids.

(Figure 1). These project to each side of the face so that when the face is viewed at right angles to the projector axis, it appears to have contour lines following the topography of the face. *(Figure 2)* (Fricker 1985). A mark is placed on the face beneath the horizontal projected grid line, nearest the external meatus to check the orientation of the head for the profile and three quarter views.

The head stabilizer may be rotated through 180 degrees and is calibrated to locate 45 degree and 90 degree positions for the three quarter and true profile views. As the subject is positioned into each view, the facial marking is checked so that it remains on the same horizontal projection line and thus determines the same superior/inferior positioning of the head. Once the subject is positioned for each view, the projectors are turned off and a standardised photograph was taken. *(Figure 3)*.

The computerisation of the technique was carried out at the IBM™* Computer Integrated Manufacturing and Management Centre, (CIMM), School of Mechanical Engineering, Regency College of TAFE, South Australia. An IBM model 5080 graphics work station was used, running a three dimensional CAD program called CATIA (Dassault Systems France).

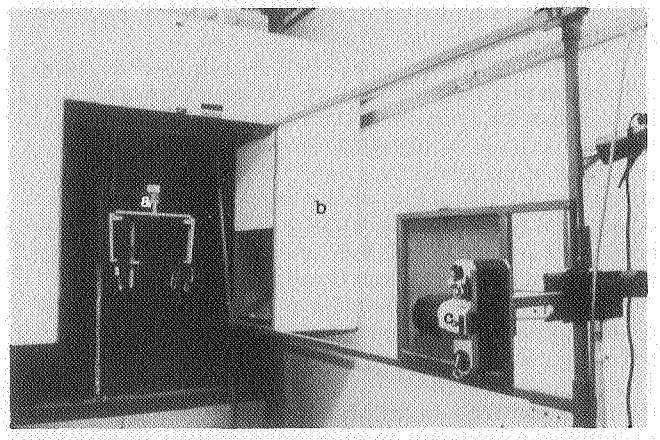

Figure 1. The apparatus. (a) Head stabiliser (b) Projection box (c) SLR camera with 105 lens

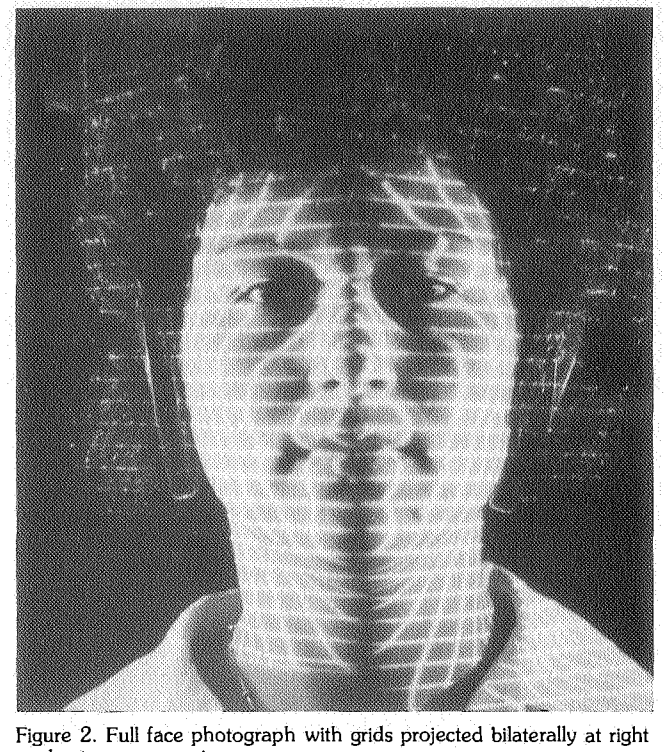

Figure 2. Full face photograph with grids projected bilaterally at right angles to camera axis

* IBM is the registered trademark of International Business Machines, U.S.A.

A high contrast black and white contour photograph (20cm x 25cm.) was centred on the digitising pad and the vertical contour lines were traced with a cross hair puck. Initially, the most anterior point of the face was located as the zero and each vertical plane provided the X and Y co-ordinates for each vertical plane as the operator moved posteriorly.

These X and Y co-ordinates were fed into the IBM graphics work station *(Figure 4)* and CATIA was used to determine the third dimension, or Z coordinate, by means of the known increment between each contour as it projects onto the side of the face.

Using the three dimensional coordinates stored in the computer, a wire frame image of the face was drawn on the high resolution screen. An eight dial image control unit was used to rotate or tilt the full face image to any perspective at the operator's request. Once the desired view is displayed on the screen, the image may be transferred to a plotter to provide a "hard copy" of the image.

CATIA has the ability of displaying multiple images at any one time by dividing the screen into sections, for example, four half face views are displayed showing various perspectives of the same patient from a single full face photograph *(Figure 5)*.

DISCUSSION

Visualisation plays a particularly important role in the preparation of facial reconstructive surgery. Before any alteration of underlying bony structures can take place, there must be a pre-operative definition of the particular skeletal deformity in question. The clinician must be able to visualise these structures both qualitatively and quantitatively in three dimensions.

Over two thirds of all patients consulting for maxillo-facial deformities, do so for cosmetic reasons. Therefore the clinician must respond to the wishes of the patient in treating facial deformities as well as respecting occlusal criteria. (Guillaubey and Achard, 1984). Even those patients who initially state that improved function is their primary reason for seeking treatment, expectations are likely to focus more on changes in appearance post-operatively than altered functional relationships. (Laufer et al. 1976).

Body Image

Body image may be defined as "the mental picture that each individual has of his/her own appearance. (Tripodakis 1987). This may be divided into four categories. (1) what the person sees in the mirror (2) what is seen in photographs (3) what they see in their own minds (4) the way they look to others (Gorney and Harries, 1974).

In the field of facial reconstructive surgery, it is of utmost importance to define the needs of the patient, not only to provide post operative satisfaction, but to assess the patient's expectation of change. Improvement in appearance is by far the most important motivating factor in patients seeking orthognathic surgery. (Heldt et al. 1982).

Unlike orthodontic treatment which produces gradual change in facial appearance, orthognathic surgery produces sudden, often dramatic modification. During orthodontic treatment, the patient unconsciously adapts to physiognomic changes and slowly integrates these changes into his/her self concept. Orthognathic surgery however, requires a rapid integration of one's own facial features into self concept, thereby placing immediate demands on that persons adaptation skills. (Kiyak et al. 1982).

Favourable body changes are generally greeted with enthusiasm by the patient, because they expect the removal of the facial deformity to produce an improvement in personality and interpersonal relationships. When these improvements do not occur, depression sets in and problem of adjustment arise.

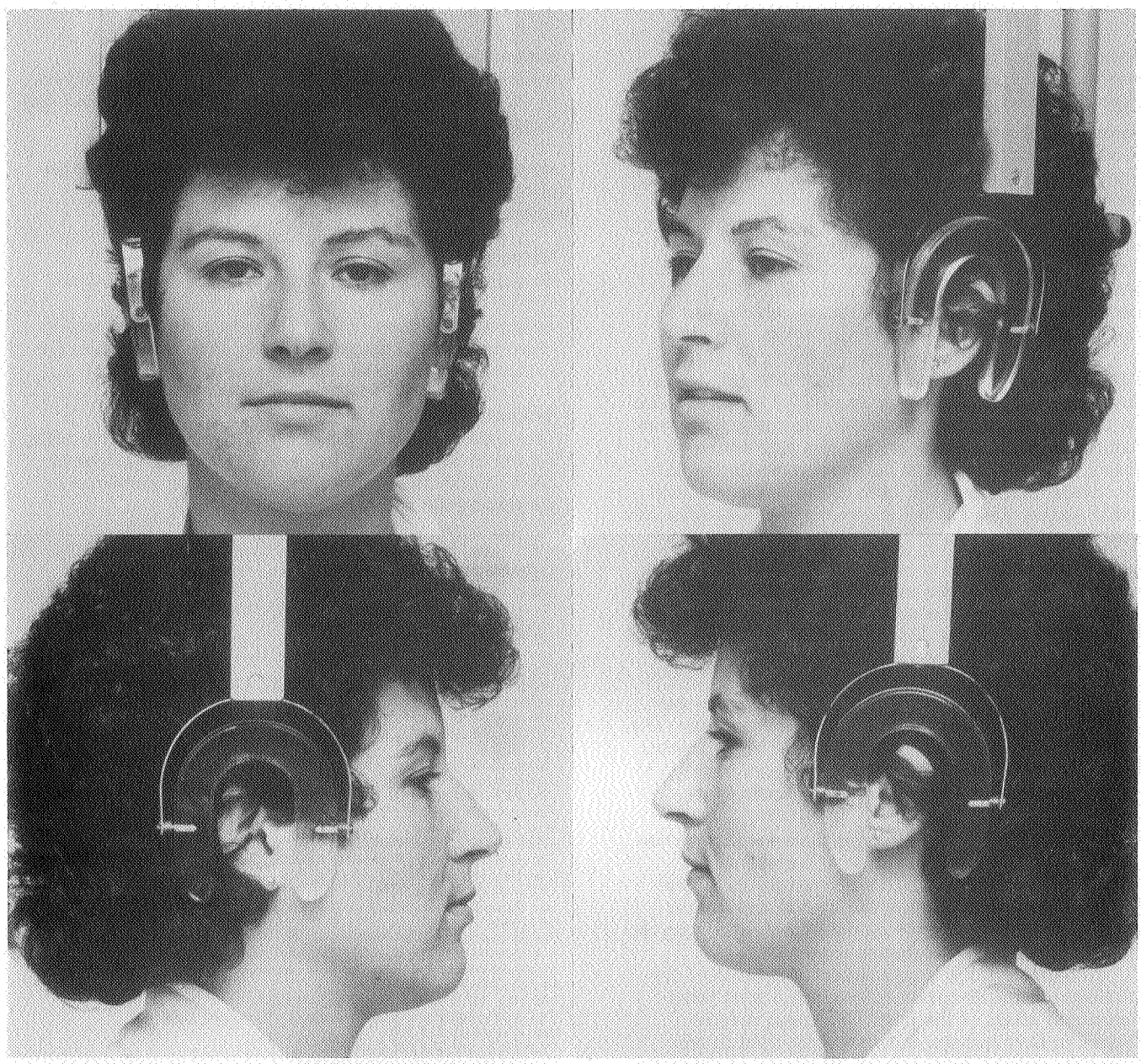

Figure 3. Full face, 3/4 and profile views with subject positioned in the natural head position

Figure 4. IBM™* Work Station
(a) digitising pad
(b) high resolution screen
(c) image control unit

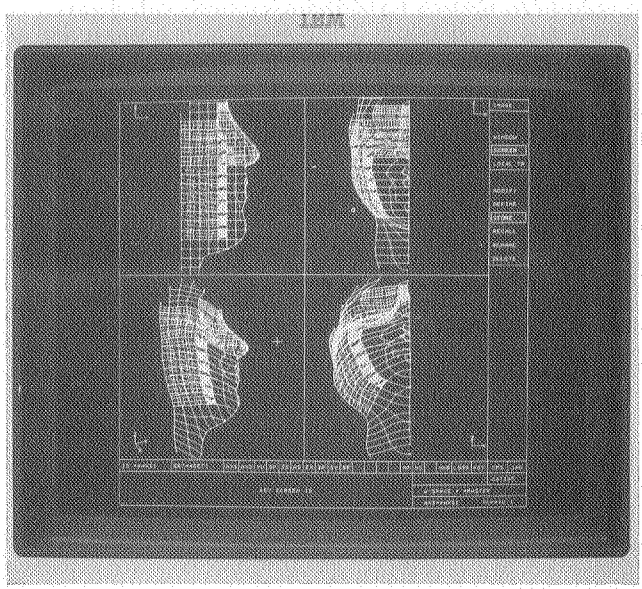

Figure 5. Half face wire frame images showing four different perspectives digitised from a single contour photograph

(Stricker et al. 1979). Liasion with mental health workers is therefore of general value and may prove crucial to the achievement of the maximum physical and social rehabilitation, most specifically for those with facial deformities. (Ball and Paoletti, 1986)

Natural head position

"Lorsqu'un homme est debout et que son axe visuel est horizontal, il est dans l'attitude naturelle".(Broca 1862). This frame of reference (the visual axis) has been adapted from the physical anthropologists, for orthodontic studies. Mooreess and Kean (1958) showed it to be a reliable reference plane in cephalometric studies while Solow and Tallgren (1971 and 1976), used the natural head positioning in their studies on the relationship of head posutre and craniofacial morphology.

In cases of facial deformity a frame of reference outside the cranium is recommended for both radiographic and photographic imaging of the head. Use of a cephalostat to locate the head, via ear rods, cannot produce meaningful pre-operative and post-operative records, as the patient must be positioned into the ear rods. Since these are fixed, both in the horizontal and vertical planes, they cannot accommodate cases of severe asymmetry.

Computer graphics

Computer graphics is the creation and manipulation of pictures with the aid of a computer. These may be non interactive or interactive. Titles shown on television, where the observer has no control over the image, are examples of non interactive computer graphics.

Interactive computer graphics involves two way communication between the computer and the user. The computer upon receiving a signal from an input device, such as the lever of a table tennis game, can modify the displayed picture appropriately. (Newman and Sproull, 1981).

Many computer graphics applications involve the display of three dimensional objects. For example, computer aided design (CAD) systems used in aircraft design and architecture, allow the user to manipulate models. Similar principles of model manipulation may be applied to planning orthognathic surgery.

The technology is now available to build on the grid image on the computer to produce a solid three dimensional image of the face. This image may be coloured to flesh tonings and rotated or tilted to any perspective desired. Furthermore, by means of interactive computergraphics, one may produce a series of "what ifs". The orthodontist and surgeon may plan the ideal procedures to achieve facial harmony using soft tissues analysis in three dimensions. An image of the predicted post operative result may be shown to the patient and assessed in three dimensions. In this way, the expectations of the patient are better judged and the task of the psychological counsellor is lightened.

Once the treatment objective has been determined, the three dimensional co-ordinates of the post-operative result may be compared to the pre-operative co-ordinates. The soft tissue changes required may then provide the surgeon with a prescription for the hard tissue remodelling based on ratios derived from studies of soft tissue following orthognathic surgery (Lines and Steinhauser, 1974, Engel et al. 1979, Radney and Jacobs, 1981, and Hunt and Rudge, 1984).

A three dimensional analysis using a combined photographic - computergraphic technique has the advantage over CAT scanning techniques, in that the photographic technique is both non invasive and far less expensive. Exposure to radiation is avoided while still providing the operator with details of facial topography.

SUMMARY

Diagnostic imaging of the face is described using a standardised, reproducible technique. By means of bilateral projection of grids to the face, contour lines of facial topography may be recorded on a single two dimensional photograph. With computergraphic techniques now available, three dimensional co-ordinates of the face may be determined from this two dimensional image.

Once the three dimensional co-ordinates are stored in the computer, the operator may create images of the face to plan orthognathic and reconstructive surgery.

Further work is being carried out at the School of Mechanical Engineering, Regency College of TAFE, to develop the interactive computer graphic capability of CATIA thus providing three dimensional surgical treatment objectives (STO). These may be transferred to video tape and used at the time of consultation with the patient to describe suggested treatment.

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