Craniofacial Osteotomies: A Photocephalometric Technique for the Prediction and Evaluation of Tissue Changes

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Cephalometric films have been used extensively for the evaluation of skeletal and soft-tissue changes following orthognathic surgery. Much valuable information has been gained from this approach. However, when considering upper-third and middle-third face surgery, standard cephalometric techniques are seriously deficient. There are two main deficiencies: (1) the lateral cephalometric film allows only evaluation of the soft-tissue *profile;* the soft tissues overlying the supraorbital rim, the globe, the zygoma, infraorbital rim, nasolabial fold, and the alar bases cannot be evaluated. (2) The soft tissue relationships and changes in the frontal or full-face aspect cannot be evaluated at all via conventional anteroposterior cephalometric methods. In the standard frontal cephalogram the soft tissues are masked by the cranial and facial skeleton allowing only the lateral soft tissues to be delineated. Many important soft-tissue changes occur in the frontal aspect of the patient following dentofacial and craniofacial surgery.

Alterations in the interpupillary distances, the medial canthal artery and distances, flaring of the alar bases, and changes in soft tissues overlying the mandibular angles or zygomatic eminences occur. In addition, many changes in the vertical dimension of the facial skeleton are reflected by shortening, lengthening, widening, or narrowing of the soft tissue in the frontal view.

It is because of these deficiencies in standard cephalometric techniques that we feel the proposed technique will be of value in treatment planning and the evaluation and prediction of skeletal and soft-tissue changes following dentofacial and craniofacial surgery.

PROFILE ESTHETIC RELATIONS

Riedel[30] studied dentofacial relationships of esthetically pleasing beauty princesses and found that the maxillary incisors were more upright and mandibular incisors were more inclined than those of previous studies. In 50% of the cases the upper lip, lower lip and chin fell on a straight line.

Peck and Peck[26] found that the general public prefers a more protrusive dentofacial pattern than cephalometric standards allow.

Baum[4] studied facial changes in adult patients 19 to 21 years of age who had completed orthodontic treatment at 12 to 16 years of age. Females had not changed significantly following treatment, but males had continued to show growth of chins and noses with the denture becoming more retrusive.

Neger[24] demonstrated that change in soft tissue does not necessarily accompany extensive dental changes and that the straight profile does not necessarily have an underlying normal occlusion.

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Merrifield[23] developed a profile line from soft-tissue chin tangent to the most procumbent lip forming an angle with the Frankfort horizontal called the "Z" angle. In balanced faces the upper lip should fall on the profile line with the lower lip tangent or slightly behind the profile line.

Zimmer[36] established a line from anterior nasal spine to Downs' B point and showed that the nose, upper and lower lips and chin were almost identical in thickness to this plane and that the nose had a ratio of 1.5:1 to any of the other soft-tissue structures.

Ricketts[28] established a line from the tip of the nose to the chin calling this the "esthetic plane." He found in beautiful profiles the upper lip was 2 mm and the lower lip 4 mm posterior to this line, and that the upper lip thickens 1 mm for every 3 mm of retraction.

Steiner established a plane from the middle of the "S" formed by the lower border of the nose and the upper lip to the chin. The lips should fall on this line. (Hambleton[15])

Holdaway suggested a line tangent to the chin and upper lip called the H-line. This line forms an angle with line NB termed the H-angle. If the ANB angle is 1-3 degrees, the H-angle should be 7-9 degrees. An increase or decrease of ANB is accompanied by a proportional change in H-angle for good esthetics. (Hambleton[15])

Anderson et al.[1] in a ten year postretention study demonstrated that orthodontics produced decreased dentofacial protrusion and decreased protrusion of incisors and the lips. Following treatment, the lips continued to retract relative to facial profile. The upper lip thickened during treatment, 1.0 mm thickening for each 1.5 mm retraction. After ten years of postretention a significant increase in thickness remained. Lower lip thickness was unaffected by orthodontic treatment. Soft tissues at A and B points were not affected by orthodontic treatment. Pogonion was not affected by treatment but became more prominent when related to the NB line during and following treatment. Soft tissues were closely related and dependent on dentoskeletal framework. Males showed more growth in nose, base of upper lip, and chin than females. Profiles flattened during and following orthodontic treatment because of relative growth of the nose and chin.

Burstone[11] studied lip posture and its natural, horizontal and angular relationships to the facial profile. The importance of relaxed lip posture and its reproducibility were established. The effects of lip incompetence and other inherent factors were shown to affect profile changes.

Profile Skeletal vs. Soft Tissue Changes

Fromm and Lundberg[13] made an investigation of the soft-tissue profile changes following surgical correction of mandibular protrusion. Comparisons between preoperative and postoperative patients in respect to height and thickness of upper and lower lips, chin and soft "B" point thickness, facial height and lower face height, and the angle of the nasal tip were evaluated. The height of the upper lip increased as well as the thickness. The length and thickness of the lower lip remained unchanged, while soft tissue "B" point became more concave.

Bell and Dann[5] showed the stability and the predictability of soft-tissue changes following anterior maxillary and anterior mandibular osteotomies as well as chin-augmentation procedures. Maxillary lip procumbency was reduced by a ratio of 0.7 ± 0.1 for each unit of upper incisor retraction. A soft-tissue change of 0.6 ± 0.1 for each unit of hard-tissue chin advancement was demonstrated.

Hershey and Smith[18] established pre-

dictive values for soft-tissue changes following surgical correction of the prognathic mandible. The soft-tissue chin retracted 0.9 mm for each 1.0 mm of skeletal retraction. The lower lip retracted 0.6 mm for each 1.0 mm of retraction at pogonion. The lower lip moved posteriorly 0.2 mm for each 1.0 mm posterior movement at pogonion. A "flattening" of the upper lip appeared clinically and the lower lip prominence increased about twice that of the upper lip "flattening." The pretreatment thickness of the lips was not a significant factor in response to surgery. The soft-tissue response did not vary greatly between small and large surgical movements.

Dann, Fonseca and Bell[12] assessed the soft-tissue changes following maxillary advancement procedures. The horizontal change of the upper incisor to upper lip vermilion border is represented by 0.5 ± 0.1 while vertical changes were represented by 0.3 ± 0.15. Change of nasolabial angle with respect to upper incisor was 1.2 ± 0.3 for each unit of incisor retraction.

Lines and Steinhauser[21] indicated that the soft-tissue chin followed the hard-tissue chin 1:1 when the mandible is repositioned posteriorly. In maxillary posterior movement the lip moves posteriorly in a ratio of 2:1 hard to soft tissue. The maximum change is at the vermilion border while zero change occurred at the base of the nose. Mandibular advancements appeared to increase the soft tissue in a 1:1 ratio at the chin and a 4.3 ratio at lower incisors to lower lip. If the mandibular anterior alveolus is advanced, the soft tissue of the lower lip advances in a 3:2 ratio, teeth to soft tissue.

Method

The following study was undertaken to expand these previous contributions. Prior to lateral and frontal cephalograms, three or four radiopaque metallic markers (4 mm × 4 mm), each with a small hole, are fixed to the patient's skin in specified areas using colloidin as an adhesive (Fig. 1). Standard lateral and frontal cephalometric head films are taken in a cephalostat with the patient in natural head position and with the lips relaxed.

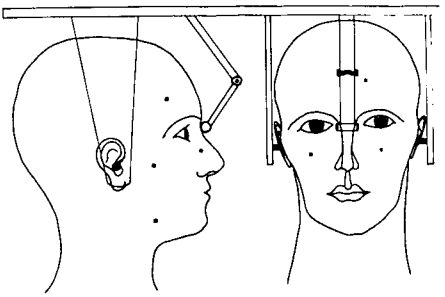

Fig. 1 Location of radiopaque metallic markers.

Lateral and frontal photographs are next taken while maintaining the same head position (Fig. 2).

The 35 mm panatomic-x photographic negatives are enlarged allowing the photographic images of the metal markers to be superimposed upon the radiopaque images on the cephalogram (Fig. 3). The projection of the enlarged negative is put onto an 8″ × 11″ sheet of plus-x pan photographic film (#4147) which produces a transparent photograph which can be superimposed over the cephalometric film. This permits a direct measurement between skeletal and soft tissue landmarks. By superimposing the cephalograph and photograph the line from nasion to pogonion can be drawn onto the photograph so that soft-tissue measurements can be made directly in vertical and horizontal directions.

Case 1

A 32 year-old Caucasian female, is the first subject evaluated for a dentofacial deformity (Fig. 4). Her frontal and

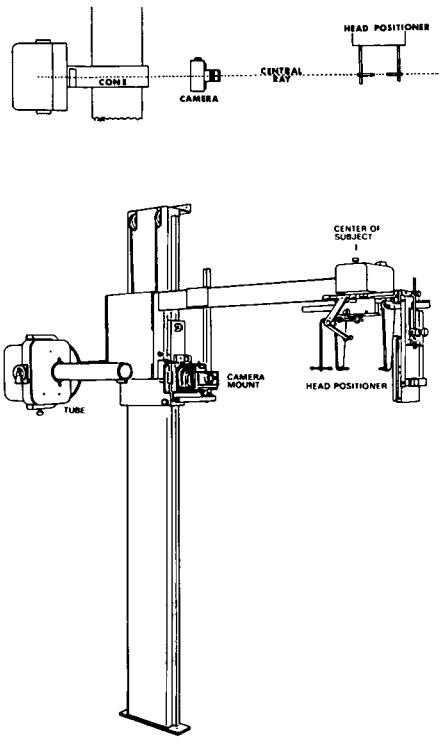

Fig. 2 Standard cephalometric radiographic unit which allows photographic camera and X-ray tube to be aligned along the central ray.

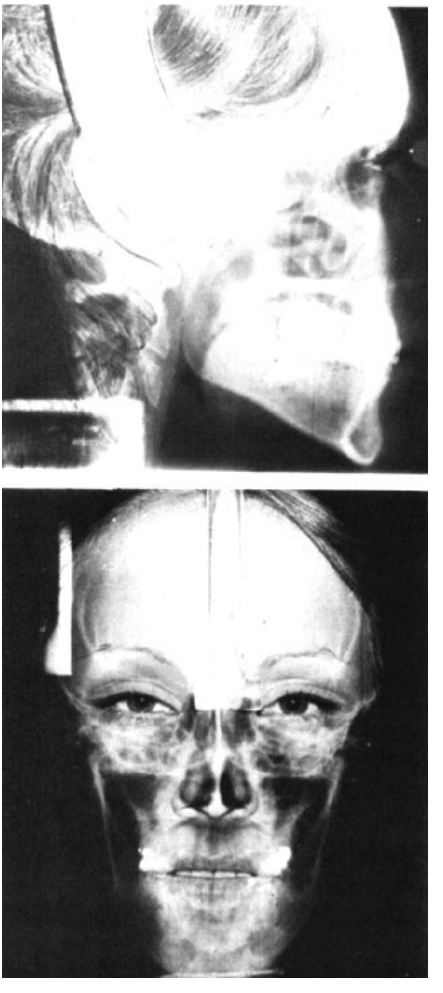

Fig. 3 Superimposition of the lateral and frontal cephalograms and the enlarged lateral and frontal photographs.

profile photographs demonstrate a long lower third of face, lip incompetence of approximately 8 mm, a downward curving oral commissure, a slight dorsal nasal hump, an acute nasolabial angle, and a protrusive upper lip.

Cephalometric evaluation depicts vertical maxillary excess, an open bite and maxillary dento-alveolar protrusion. According to her occlusal analysis she possesses a Class II malocclusion with an open bite. The dental arches are symmetrical with minimal crowding and no missing teeth.

The surgical procedure consisted of a combined anterior and posterior osteotomy. The superior movements of the maxillary segments allowed the autorotation of the mandible so that pogonion moved anteriorly and superiorly.

The postoperative results can be illustrated by observing the photocephalometric data. By superimposing the frontal transparent photographic films of preoperative and postoperative films, we can compare the soft-tissue relationships (Fig. 4, bottom row).

The changes in the nose are visualized nicely. The alar bases are wider postoperatively and the columella has moved slightly inferiorly. The upper lip

Fig. 4

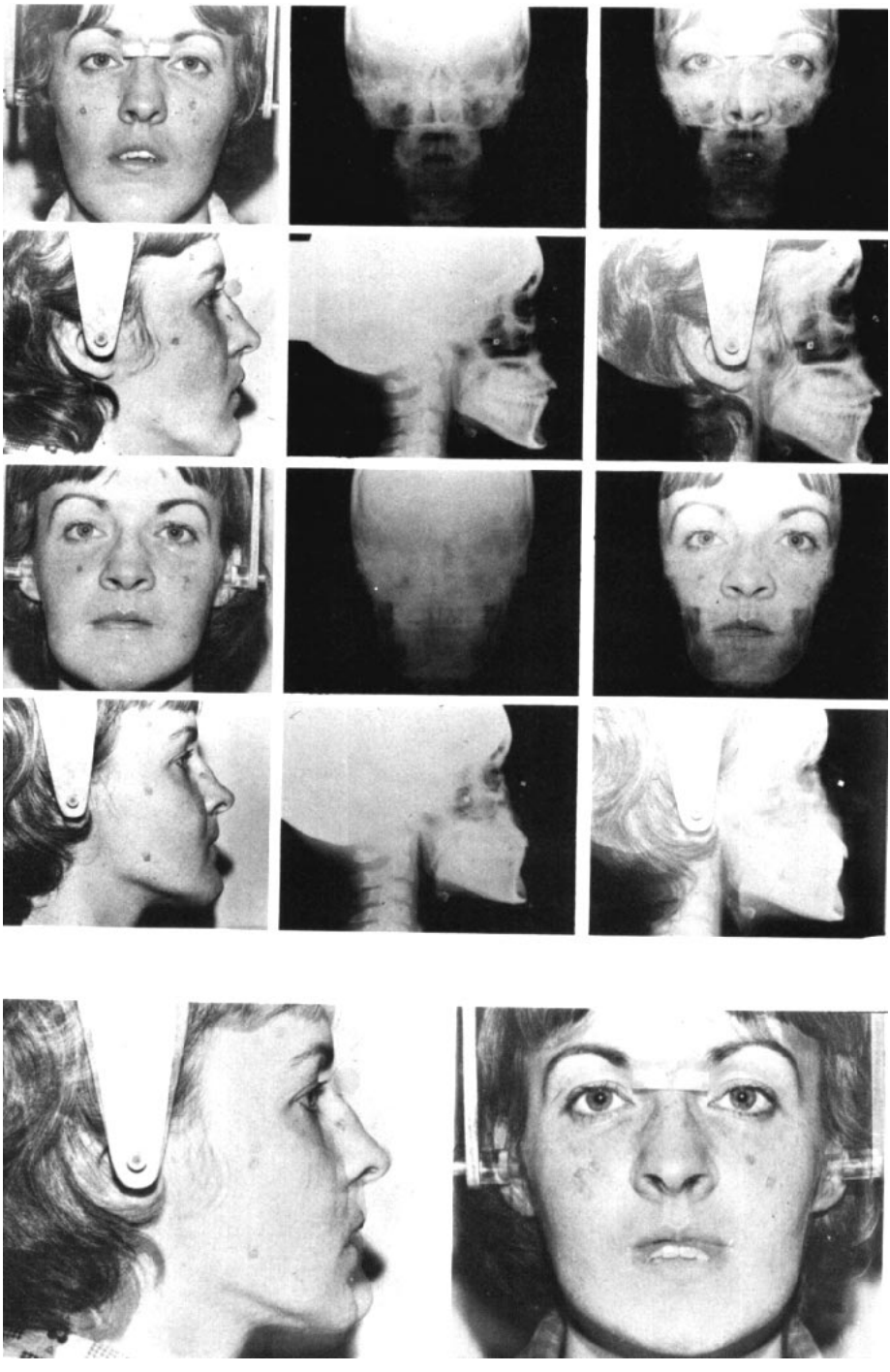

Fig. 5

at the midpoint has moved slightly superiorly, but the commissures of the mouth have markedly moved superiorly with a straighter oral commissure and elimination of lip incompetence.

The chin has moved superiorly but shows no change in the lateral direction.

By superimposing the lateral transparent photographs, we can compare the lateral esthetic changes. The postoperative outline demonstrates a nasal tip elevation of approximately 2 mm starting at the inferior one fourth of the nasal dorsum. The columella is more convex in an inferior direction.

The upper lip shows less concavity at A point and appears to be nearly the same vertical length, but is positioned more anteriorly at the labium superioris point. An increase in the fullness or anterior position of the cheek (lateral nasal) area is obvious as well.

Evaluation of the lower third facial changes reveals that the lower lip is moved superiorly and anteriorly, as well as the chin. The chin assumes a more anterior position than the labium inferioris point.

This technique allows assessment of the esthetic changes in the frontal aspect of a patient with marked vertical abnormalities. Important frontal soft-tissue changes have taken place which can be documented. These sometimes subtle, sometimes dramatic, changes can be anticipated with this type of surgery.

Case 2

Our second patient is a 26 year-old Caucasian female (Fig. 5). The frontal soft-tissue photograph shows her with ptosis upper eyelids, asymmetrical alae (important), mild lip incompetence, canted oral commissure, and asymmetrical or deviated lower facial third. From her profile soft-tissue picture can be seen a slight nasal hump, deficient upper lip support and deficient lateral nasal area, excessive lower lip support, an acute nasolabial angle, a protrusive chin and a long lower third facial height.

Cephalometric evaluation demonstrates an anteroposterior maxillary deficiency with deviate prognathism of the mandible. An occlusal analysis centers on a Class III condition and the posterior crossbite with symmetrical arches but no crowded or missing teeth.

The treatment plan for this patient was a total maxillary osteotomy with advancement and bilateral sagittal osteotomies with asymmetrical set-back.

The maxilla was advanced 8 mm and canted to parallel the interpupillary line by a total maxillary osteotomy with "down-fracture." After the maxilla was advanced, secured with infraorbital suspension wires bilaterally, the bilateral sagittal osteotomies were completed.

The maxilla and mandible were placed in an acrylic interocclusal splint and intermaxillary fixation was accomplished by stainless steel ligatures. The sagittal fragments were fixed with transosseous wires and incisions were closed intraorally.

The frontal superimposition of preoperative and postoperative photos shows some interesting soft-tissue changes (Fig. 5, bottom row).

The alae are more symmetrical postoperatively by a unilateral lateral movement of the ala on the side of the mandibular hyperplasia. The opposite ala remained in approximately the same position.

The canting of the oral commissure is not markedly changed even though the occlusal plane has been reoriented to parallel the interpupillary line. The soft-tissue lower third of the face has shifted to a more symmetrical position as evidenced by a movement of the soft chin toward the sagittal midline and the increase in soft tissue overlying the hyperplastic mandibular angle.

The lateral superimposition of preoperative and postoperative transparent photographs demonstrates many soft-tissue changes.

The nasal tip was elevated approximately 2 mm, increasingly from the lower third of the nasal dorsum to the nasal tip. The columella is more convex and moved inferiorly.

The upper lip is more anterior and less concave than before surgery. Very little vertical change is apparent.

The lateral paranasal areas exhibit considerable increase in support with marked anterior movement postoperatively. The lower lip is less prominent and shows superior movement with approximately 4 mm decrease in the lip incompetence. The labiomental fold is less concave postoperatively and the chin is obviously less protrusive.

The frontal esthetic changes following correction of facial asymmetries have not been previously documented. This procedure is capable of measuring such changes which will help obtain predictable soft-tissue response to skeletal movements.

Case 3

A 14 year-old Mexican-American male was next evaluated (Fig. 6). According to his frontal and profile photos he has a deficient nasal bridge with nasal projection, moderate exorbitism, a deficient infraorbital rim and lateral nasal support, an acute nasolabial angle, deficient upper-lip support, mild lip incompetence in relaxed lip posture and relative lower-third protrusion of lower lip and chin.

A nasal-malar-maxillary deficiency is noted in the cephalometric radiographs. His dental condition is a Class III malocclusion with moderate maxillary crowding, good arch symmetry and all teeth present.

His treatment plan specified nasal-malar-maxillary middle-third facial advancement to be followed by postsurgical orthodontics.

A middle-third facial osteotomy was performed to advance the midface approximately 10 mm. The osteotomies were accomplished through bilateral infraorbital incisions and one inverted "U" incision over the glabellar area. In addition, two intraoral horizontal incisions in the posterior maxillary areas were utilized. The osteotomies were carried just below the frontal-nasal suture and anterior to the lacrimal apparatus.

The osteotomy extended laterally and superiorly to just inferior to the frontal-zygomatic suture. This operation divided the frontal process of the zygoma mediolaterally and extended inferiorly to the junction of the zygomatic buttress and maxilla. Here the osteotomy extended at a LeFort I level posteriorly to the pterygoid plates. The midfacial skeletal component was mobilized and intermaxillary fixation accomplished with an acrylic splint and stainless steel ligatures. Lyophilized bone grafts and transosseous wires were used to stabilize the midfacial skeleton. In addition, frontal suspension wires were used.

The superimposition of preoperative and postoperative frontal photographs shows the medial canthal distance slightly increased (approximately 1.5 mm). The nasal tip and alar bases and columella were elevated slightly (Fig. 6, bottom row).

The exorbitism has been decreased so that the lower eyelid is tangential to the iris postoperatively when compared with the preoperative distance between the margin of the lower lid and iris. This is a decrease in the palpebral width.

Lip incompetence has been eliminated and there is no apparent increased mentalis activity. The upper lip appears longer postoperatively from the nasolabial angle to the labium superioris.

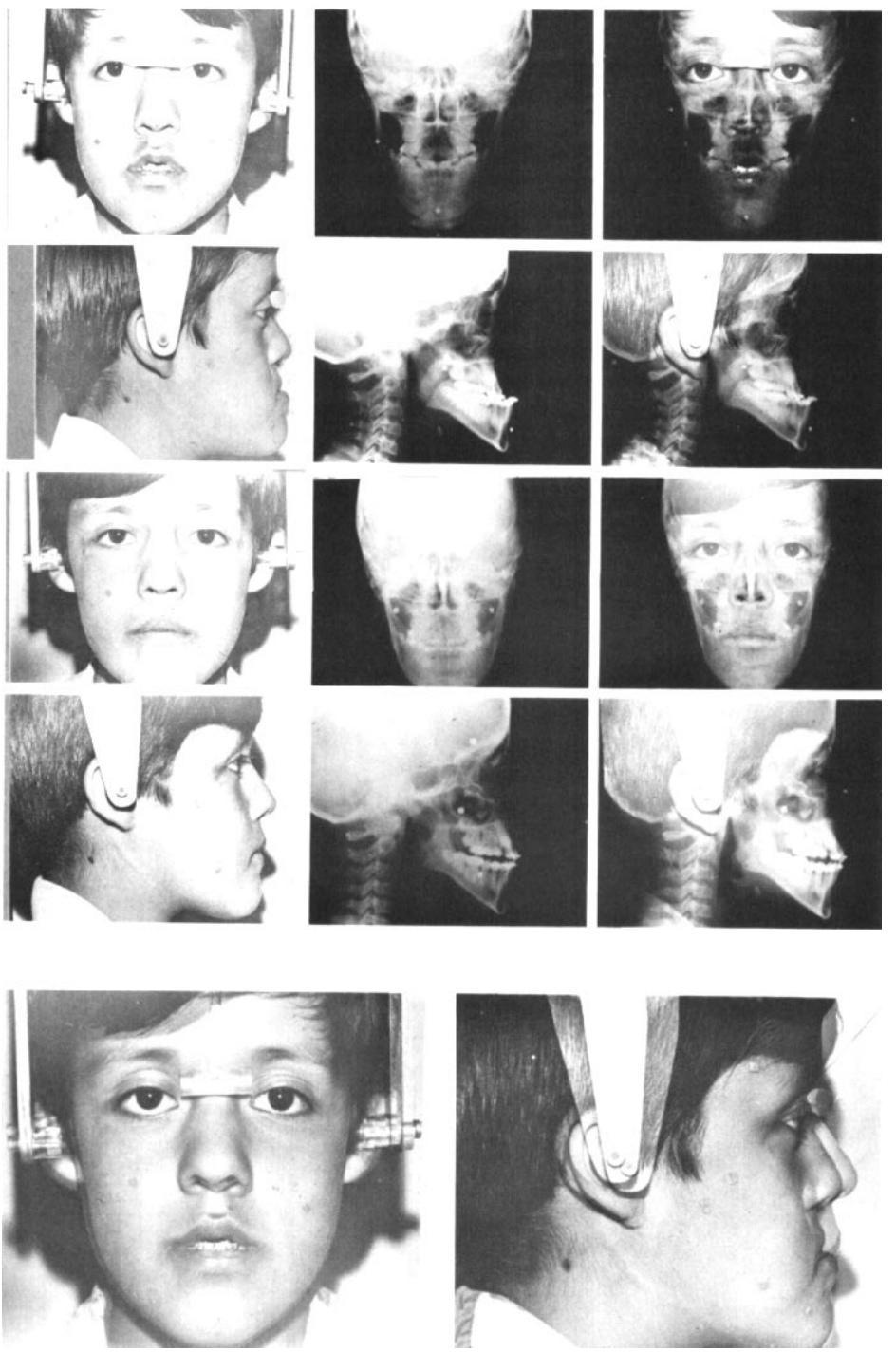

Fig. 6

The commissure of the mouth is less downslanting and more horizontal. The contour of the lower third of the face shows very little change.

The lateral soft-tissue esthetics were assessed by preoperative and postoperative superimposition of lateral transparent photographs.

The entire midfacial component shows uniform anterior movement. The nasal bridge and nasal projection are increased markedly from their preoperative position.

The nasolabial angle is increased and the upper lip is less concave than before surgery. In addition, the upper lip is longer from the nasolabial angle to the labium superioris point and is projected more anteriorly so that the relative lower lip protrusion has been eliminated.

It is also interesting that the exorbitism has been corrected by the anterior movement of the infraorbital rims but, in addition, the globe demonstrated a posterior movement of approximately 2 mm.

The lateral nasal area (cheek) shows a marked anterior movement with increased cheek support.

The soft-tissue response to significant middle-third facial osteotomy is varied and sometimes subtle in nature. The present technique can evaluate drifting of the medial canthal, changes in widths of alar bases and interpupillary widths; measurements for hypertelorism surgery can also be monitored very nicely.

Discussion

This is a preliminary study of a technique developed by the authors to obtain more information concerning soft-tissue responses to craniofacial and dentofacial surgery. It offers many advantages over previously described procedures. It allows more detailed soft-tissue analysis in the lateral projection which is difficult to obtain by standard cephalometric techniques. In addition, valuable information can be obtained in the frontal view that cannot be secured from standard frontal cephalograms.

We are currently measuring the various sources of error inherent in this technique. We have developed a method of closely reapproximating the patients' head position in the cephalostat for serial radiography. We are measuring the accuracy and reproducibility of head position and will present this in subsequent papers. Further, we are measuring the magnification and distortion error inherent in the X-ray beam and the optical distortion from the photographic lens. Measurement of these sources of error will enable us to correct for these with computerization. The accurate measurement of soft-tissue changes must be delayed until the above sources of error are accurately determined.

Conclusions

1. A technique is presented that allows the production of lateral and frontal transparent photographic films to be accurately superimposed over the corresponding lateral and frontal cephalograms.

2. The photographs are standardized to the cephalometric radiographs allowing the preoperative and postoperative photographs to be superimposed for correlative measurements.

3. Subtle changes in frontal soft tissues can be compared before and following surgery or for serial growth studies.

4. This technique is adaptable to any standard cephalostat now in operation with only minor modifications.

5. Further sources of optical distortion and magnification errors as well as patient repositioning errors are currently being evaluated.

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