CHAPTER 91

Computerized Three-Dimensional Facial Analysis

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The facial plastic and reconstructive surgeon relies on an acute sense of aesthetics when performing operations that alter a patient's facial contour. With good technical skills, the surgeon's results are only as good as his or her knowledge of what particular contour is aesthetically pleasing. Careful preoperative planning and objective evaluation of postoperative results are essential to the education of the facial plastic surgeon. Maxillofacial surgeons utilize both hard and soft tissue cephalometrics of the maxillary-mandibular relationship to plan surgical procedures and to evaluate their results. Facial plastic surgeons evaluate total facial contour and work primarily from photographs, not x-rays.

Larrabee et al performed profile analysis using cephalometric measurements on lateral photographs of patients.[1] The profile photographs were taken using the natural head position technique.[2] Key cephalometric landmarks were identified and digitalized from photographs using a digitizing pad (DIGI-PAD 5, GTCO Columbia, MD) with a resolution of 0.001. The digitalizing pad was connected to a microcomputer via an RS232 interface. The software allowed evaluation of multiple functions from different cephalometric systems. Two-dimensional facial analysis can be used for preoperative planning and postoperative evaluation of facial plastic surgical procedures. However, the ability to evaluate total facial contour and predict outcome of surgical procedures has been limited, when using two-dimensional facial analysis.[3,4]

Methods of facial analysis that utilize a three-dimensional component include physioprint,[5] telecentric optics,[6] stereophotogrammetry,[7] Moire topography,[8] holography,[9] and morphoanalysis.[10,11] Physioprint, morphoanalysis, and Moire topography all produce uncorrected divergence inaccuracies that are difficult to interpret. Stereophotogrammetry is an accurate and noninvasive technique for three-dimensional facial analysis; however, it requires elaborate and expensive equipment, making it impractical for facial analysis. Holography, although accurate, is expensive and entails safety risks endangering the eyes and skin of both the patient and the examiner.

In this chapter, we introduce a system for three-dimensional analysis of the face that allows the surgeon to define key cephalometric points by visualization and palpation, and that allows the permanent recording of these points in a three-dimensional (xyz-axis) system. These data can then be used to quantitate facial contour, compare pre- and postoperative changes after facial plastic or reconstructive surgical procedures, or follow changes in facial contour over time.

MATERIALS AND METHODS

The three-dimensional facial analysis system is comprised of (1) a three-dimensional coordinate digitalizer (Perceptor); (2) a microcomputer with RS232C port; (3) a three-dimensional graphics design program; (4) a spreadsheet-database program; and (5) customized software for data manipulation.

Three-Dimensional Coordinate Digitalizer

Perceptor (Micro Control Systems, Vernon, CT) is an interactive, three-dimensional position coordinate digitalizer (Fig. 91-1). It is comprised of a 16 × 18 inch rectangular steel base, on which is mounted a precision-machined arm with four joints of rotation and approximately a 21-inch reach. Enclosed within the base is a circuit board that performs the necessary data acquisition functions. The Perceptor interfaces with any microcomputer having a serial port.

The mechanics of the Perceptor include precision potentiometers enclosed within each of its five joints. These potentiometers pass on the electrical input needed to calculate angles of rotation. Given these angles and known lengths of each arm segment, the Perceptor computes the x, y, and z coordinates at the position of the pointer tip. Performance

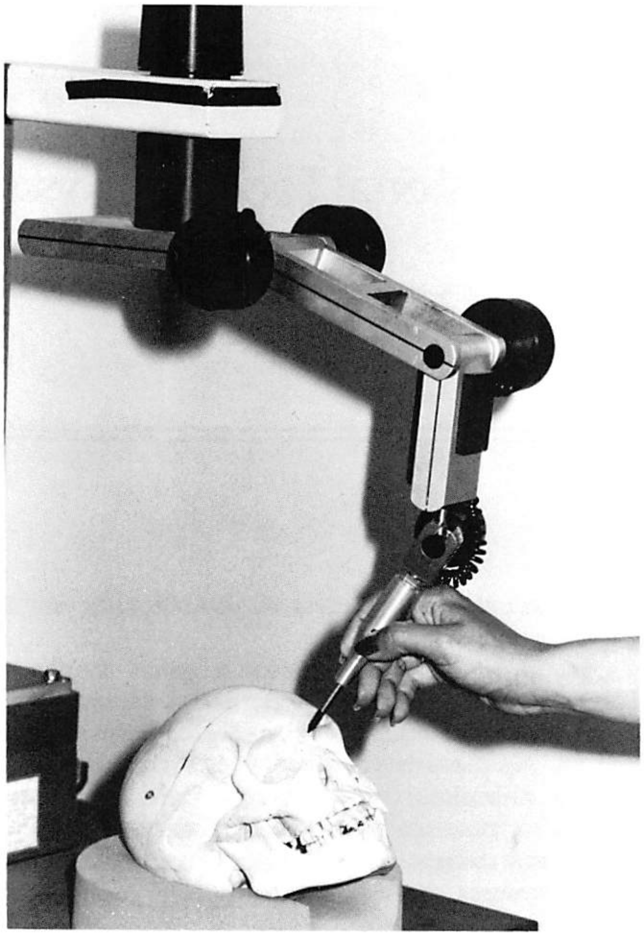

Figure 91–1. Perceptor three-dimensional position coordinate digitalizer. The tip of the instrument is positioned at a cephalometric landmark and that point is recorded as an x, y, and z coordinate.

specifications of Perceptor include accuracy of 0.007 to 0.020 inch (0.018 to 0.051 cm) and speed of measurements up to 4.6 x, y, and z coordinates per second.

Microcomputer

The microcomputer must be an IBM PC or equal (IBM AT) with 256 kilobytes (K) of memory, DOS 2.0 or greater operating system, dual disk drives (320K), or a single disk drive with hard disk, graphics adapter card, monitor, and RS232C port.

Three-Dimensional Graphics Design Program

Advanced Space Graphics 2.0 (Micro Control Systems, Vernon, CT) provides the x, y, and z coordinates of a contour and allows for the creation of three-dimensional "wireframe" drawings.

Spreadsheet-Database Program

Microsoft Excel (Microsoft Corp., Redmond, WA) was used to store data in the form of a spreadsheet and perform cephalometric calculations.

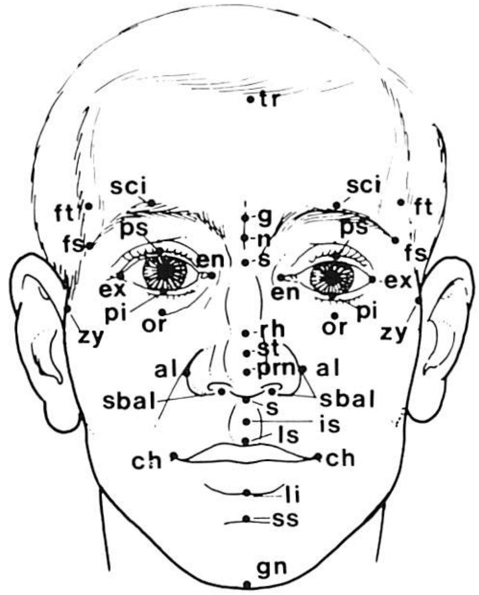

Figure 91–2. Cephalometric landmarks: Frontal view. tr = trichion, sci = superciliare,* ft = frontotemporale,* g = glabella, ps = palpebrale superius,* fs = frontosupraorbitale, n = nasion, s = sellion, en = endocanthion,* ex = exocanthion,* pi = palpebrale inferius,* or = orbitale,* zy = zygion,* st = supratip, al = alare, prn = pronasale, sbal = subalare, is = inferior sulcus, ls = labiale superiorus, ch = chelion, li = labiale inferiorus, ss = superior sulcus, gn = gnathion/menton. (*Denotes right- and left-sided points.)

Customized Software for Data Collection

Customized software permits collection of data in a structured form using defined cephalometric points. The points are broken down into three groups: profile, paired, and nasal group. These data are in a form that can be read by Microsoft Excel.

Cephalometric Landmarks

When collecting data, measuring points or landmarks are defined as precisely as possible. In this study, classic landmarks[12] and some new measuring points were used (Figs. 91-2 through 91-5 and Tables 91-1 through 91-3).[1,13] Specialized nasal landmarks were used to allow detailed analysis of the geography of the nose.[13,14] Once all the landmarks are identified, standard cephalometric indices can be tabulated. Powell and Humphries introduced landmarks of facial contour that provide an excellent evaluation of both hard- and soft-tissue measurements of the aesthetic face.[14] They also proposed the concept of the *aesthetic triangle*, which is an excellent screen for facial aesthetics. The major aesthetic masses of the face include the forehead, nose, lips, chin, and neck.[14] Facial harmony and balance between these major masses of the face can be assessed by studying relationships between the soft-tissue angles (nasofrontal, nasofacial, nasomental, and mentocervical) and lines (nasomental) of the aesthetic triangle. The angle between a line connecting the

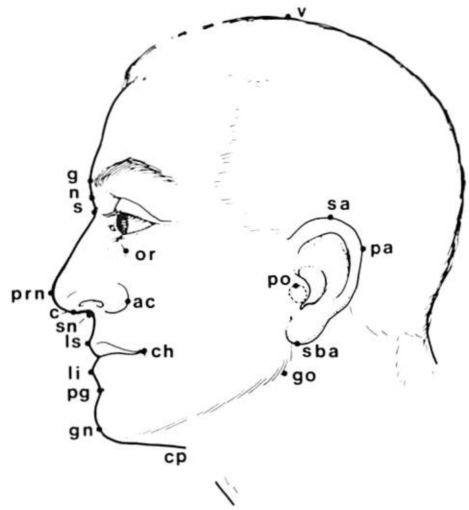

Figure 91–3. Cephalometric landmarks: Lateral view. g = glabella, n = nasion, s = sellion, or = orbitale,* sa = superaurale,* pa = postaurale,* po = porion, prn = pronasale, ac = alar curvature point,* c = midpoint columella, sn = subnasale, ls = labiale superiorus, ch = chelion,* sba = subaurale,* li = labiale inferiorus, go = gonion, pg = pogonion, gn = gnathion/menton, cp = cervical point. (*Denotes right- and left-sided points.)

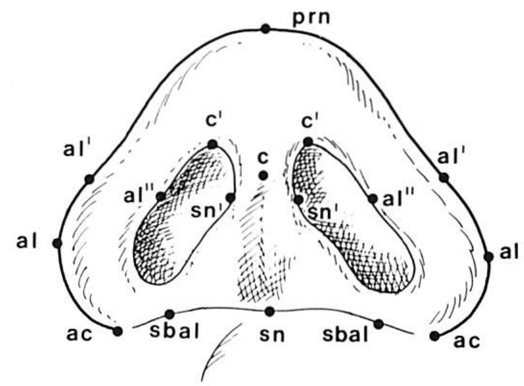

Figure 91–5. Cephalometric landmarks: Nasal points (basal view). prn = pronasale, al' = lateral ala,* c' = high point of columella,* c = mid-point columella, al'' = medial ala,* sn' = width of columella, al = alare,* ac = alar curvature point,* sbal = subalare,* sn = subnasale. (*Denotes right- and left-sided points.)

glabella and the nasion and the tip creates the *nasofrontal angle*. The angle between the nasal-tip line and a line connecting the glabella and pogonion is the *nasofacial angle*. The *nasomental angle* is formed by a line connecting the nasal tip and nasion and a line drawn from the nasal tip to the pogonion. The *mentocervical angle* is defined as the angle between a vertical line from glabella to pogonion and a horizontal line from the menton to the cervical point.

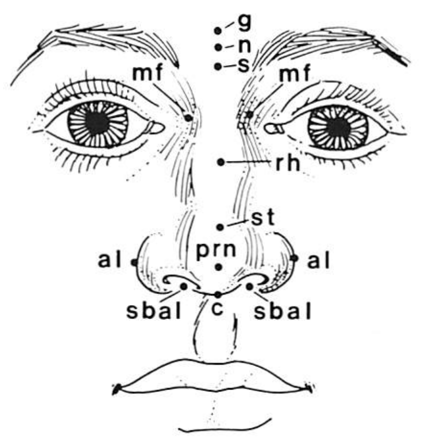

Figure 91–4. Cephalometric landmarks: Nasal points (frontal view). g = glabella, n = nasion, s = sellion, mf = maxillofrontale,* rh = rhinion, st = supratip, al = alare,* prn = pronasale, sbal = subalar,* c = midpoint columella. (*Denotes right- and left-sided points.)

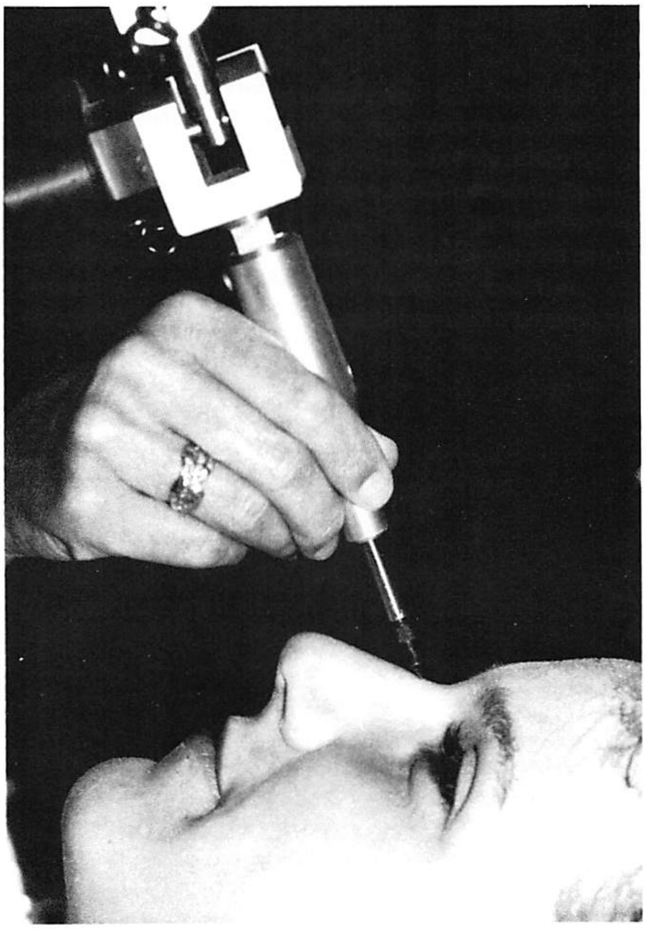

Figure 91–6. Patients are relaxed with their head mobilized on a headrest during data acquisition.

Table 91–1. Cephalometric Landmarks — Midline Points

Origin — s — sellion
v — vertex
tr — trichion
g — glabella
n — nasion
s — sellion
rh — rhinion
st — supratip
prn — pronasale
sn — subnasale
is — inferior sulcus
ls — labiale superiorus
li — labiale inferiorus
ss — superior sulcus
gn — gnathion/menton
cp — cervical point

Collection of Data

To perform standardized cephalometric measurements, the patient is seated comfortably with the head stabilized in a molded headrest on the platform of the digitalizer. Patients are instructed to relax their lips and to keep their teeth in light occlusion during data acquisition (Fig. 91-6).

Once the instrumentation is activated, localization of landmarks and collection of data begins with the profile points (see Table 91-1). Then, all of the paired landmarks are identified (see Table 91-2), returning to a designated point of origin with each new pair of points to correct for any head movement. Finally, nasal landmarks (see Table 91-3) are localized to complete the process of data collection.

Table 91–2. Cephalometric Landmarks — Paired Landmarks (Right and Left)

Origin — s — sellion
ft — frontotemporale*
zy — zygion*
en — endocanthion*
ex — exocanthion*
or — orbitale*
po — porion*
sa — superaurale*
sba — subaurale*
pa — postaurale*
ps — palpebrale superius*
pi — palpebrale inferius*
sci — superciliare*
fs — frontosupraorbitale
mf — maxillofrontale*
al — alare
sbal — subalare*
ac — alar curvature point*
ch — chelion*

*Denotes right- and left-sided points

Table 91–3. Cephalometric Landmarks — Nasal Group

Origin — s — sellion
prn — pronasale
sn — subnasale
al — alare*
c′ — high point of columella*
al′ — lateral ala*
al″ — medial ala*
sbal — subalare*
ac — alar curvature point*
sn′ — width of columella*
c — midpoint columella

*Denotes right- and left-sided points

Certain cephalometric landmarks may be difficult to localize and reproducibility of data depends on the clinician's ability to identify these points accurately. In some cases, the landmarks are in a general area (e.g., supratip, glabella). Some landmarks can be either "bony" or "osseous" when located on the skeletal surface (e.g. nasion), or "soft" when located on the skin surface (e.g., sellion).

Cephalometric Measurements and Indices

When all of the landmark points have been recorded in a file, cephalometric measurements and indices are calculated by the customized software. These data can be compared against normal values obtained from a large population of patients, or they may be used to compare pre- and postoperative results.

CONCLUSION

Three-dimensional facial analysis has many possible applications for the facial plastic and reconstructive surgeon. The system can be used to evaluate the facial contour of any population of patients, and may be used to compare pre- and postoperative results as well as other aesthetic variables.

Most clinical studies in facial plastic and reconstructive surgery lack precise quantitative long-term evaluation of results. Using three-dimensional facial analysis, the clinician can accurately quantitate changes in aesthetic contour noted during the postoperative period. Long-term follow-up of different implants (e.g., demineralized bone, irradiated cartilage) can be evaluated for resorption in precise quantitative terms. Objective analysis of these studies will allow the data to be readily interpreted and communicated to other investigators. Furthermore, the system provides a method of education and self-assessment for the surgeon.

REFERENCES

1. Larrabee WF Jr, Maupin G, Sutton D. Profile analysis in facial plastic surgery. Arch Otolaryngol 1985; 111:682–687.
2. Bean LR, Kramer JR, Khouw FE. A simplified method of taking radiographs for cephalometric analysis. J Oral Surg 1970; 28:675–678.
3. Henderson D. The assessment and management of bony deformities of the middle and lower face. Br J Plast Surg 1974; 27:287–296.

4. Fanibunda K. Photoradiography of facial structures. Br J Oral Surg 1986; 21:256-258.
5. Sassouni V. Palato print, physioprint, and roentgenographic cephalometry as new methods in human identification. J Forensic Sci 1957; 2:429-443.
6. Lovesey EJ. A simple photographic technique for recording three-dimensional head shape. Med Biol Illus 1973; 23:210-213.
7. Beard LFH, Burke PH. Evolution of a system of stereophotogrammetry for the study of facial morphology. Med Biol Illus 1967; 17:20-25.
8. Takasaki H. Moire topography. Appl Optics 1970; 9:1467-1472.
9. Ansley DA. Techniques for pulsed laser holography of people. Appl Optics 1970; 9:815-821.
10. Rabey GP. Craniofacial analysis. Proc R Soc Med 1971; 64:103-111.
11. Rabey GP. Current principles of morphoanalysis and their implications in the oral surgery practice. Br J Surg 1977; 15:97-134.
12. Farkas LG. Anthropometry of the head and face in medicine. New York: Elsevier, 1980:3.
13. Farkas LG, Kolar JC, Munro IR. Geography of the nose: A morphometric study. Aesthetic Plast Surg 1986; 10:191-223.
14. Powell N, Humphries B. Proportions of the aesthetic face. New York: Thieme-Stratton, 1984:15.

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