Computer Imaging Software for Profile Photograph Analysis

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Objectives: To describe a novel calibration technique for photographs of different sizes and to test a new method of chin evaluation in relation to established analysis measurements.

Design: A photograph analysis and medical record review of 14 patients who underwent combined rhinoplasty and chin correction at an academic center. Patients undergoing concurrent orthognathic surgery, rhytidectomy, or submental liposuction were excluded. Preoperative and postoperative digital photographs were analyzed using computer imaging software with a new method, the soft tissue porion to pogonion distance, and with established measurements, including the cervico-mental angle, the mentocervical angle, and the facial convexity angle.

Results: The porion to pogonion distance consistently increased after the chin correction procedure (more in the osseous group). All photograph angle measurements changed toward the established normal range postoperatively.

Conclusions: Surgery for facial disharmony requires artistic judgment and objective evaluation. Although 3-dimensional video analysis of the face seems promising, its clinical use is limited by cost. For surgeons who use computer imaging software, analysis of profile photographs is the most valuable tool. Even when preoperative and postoperative photographs are of different sizes, relative distance comparisons are possible with a new calibration technique using the constant facial landmarks, the porion and the pupil. The porion-pogonion distance is a simple reproducible measurement that can be used along with established soft tissue measurements as a guide for profile facial analysis.

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A ccurate facial analysis is essential for the development of an appropriate treatment plan for each patient undergoing facial plastic surgery. The development of skills in facial analysis can enhance surgical outcomes, especially in patients seeking rhinoplasty and chin correction. Even a well-executed surgery will result in a poor aesthetic result if inaccurate analysis leads to an improper decision (eg, an excessively large chin implant). Balance of the prominent facial structures, such as the chin and nose, in relation to adjacent structures has received considerable attention since Aufricht1 first suggested combining chin surgery with rhinoplasty in 1958. The importance of balanced facial proportions has been studied for centuries by architects, artists, physicians, and dentists. The science of a standardized technique of measuring craniofacial dimensions on radiographs, known as cephalometry, was introduced by B. Holly Broadbent, DDS, in the 1930s and, along with dental occlusion, remains a valuable tool for orthodontics and orthognathic surgical planning.2

The 3 general categories of patients who are candidates for chin correction surgery are those with orthognathic problems, those with an aging face, and those with a chin/nose imbalance. First, patients with a dentofacial malocclusion may be candidates for orthodontics and orthognathic surgery (eg, sagittal split ramus osteotomy or maxillary advancement). Sliding genioplasty can be a useful addition to orthognathic surgery, but some patients defer orthognathic treatment and prefer masking procedures, such as rhinoplasty or chin correction. The second category includes those patients seeking rhytidectomy or submental liposuction. This computer imaging study concentrates on patients in the third category, who underwent concurrent rhinoplasty with chin surgery (either sliding osseous genioplasty or chin implantation with an alloplast).

As the popularity of digital photography and computer imaging increases, surgeons may choose to use the technology for any combination of patient education, presurgical planning, and postoperative photograph analysis. This study tests a new method of chin evaluation (the porion [Po] to pogonion [Pog] distance) in relation to established analysis measurements and de-
scribes a novel calibration technique for photographs of different sizes.

METHODS

COMPUTER IMAGING ANALYSIS

Preoperative and postoperative standardized profile photographs of 14 patients were analyzed by a blinded investigator (T.T.T.) using computer software (Marketwise Hi-Res 7.0 software; United Imaging, Winston-Salem, NC). The measurement variability was not significant when measured 3 separate times. Two study groups were chosen (osseous genioplasty and chin implantation with alloplast) to allow comparison of the photographic measurements.

A standardized background and camera-mounted lighting were used for all profile photographs using a digital camera (Sony D-1; Sony Corp, Tokyo, Japan). Natural head positioning (approximating the Frankfort horizontal plane) was created by asking patients to look straight ahead to a point at eye level on the wall or into the image of their eyes in a mirror at eye level, as described by Moorrees.3

PROFILE PHOTOGRAPH CALIBRATION

Because of slight differences in photograph sizes, preoperative and postoperative photographs could not be measured with absolute distance measurements (in millimeters). Each patient’s preoperative and postoperative photographs were calibrated using the following new technique. The soft tissue equivalent of the Po’ (the superiormost visible external auditory canal) and the anteriormost midpupil were chosen because of the consistency of these 2 points on the profile view, even after genioplasty, rhinoplasty, or other procedures. The distance between the Po’ and the pupil (Pup) was calibrated using the “calibrate” feature on the imaging software (Figure 1). The chosen distance between the points is calibrated to 10 U. (This feature of the software used was developed for the patient to hold a 10-cm ruler on the photograph.) By setting the Po’-Pup distance at 10 U, the Po’-Pog’ distance was measured as a function of the Po’-Pup distance. Therefore, the results are only comparable between the same patient’s preoperative and postoperative photographs.

ANGLE MEASUREMENTS

Three facial angles were measured on matched preoperative and postoperative profile photographs. Soft tissue points are illustrated in Figure 2A. Their definitions are as follows: (1) glabella, most prominent anterior point of the forehead; (2) orbitale, lowest point on the inferior orbital rim; (3) menton, lowest point on the chin; (4) Pog’, most prominent point on the chin; (5) Po’, superiormost external auditory canal; (6) pronasale; anteriormost point of the nose (tip); (7) subcervicale, innermost point between the submentum and the neck; and (8) subnasale, point at which the columella meets the upper lip. The menton, Pog’, Po’, and subnasale were the soft tissue counterparts to cephalometric points.

By using the measurement feature of the software, first the distal point of the angle is chosen and, while holding the right click button down, a line is drawn to the midpoint of the angle where the mouse button is released. The second line is drawn by moving the mouse to the third point, and the angle measurement appears on the screen. The cervicomental angle (CMA) is formed by a line tangent to the submentum and the neck tangent intersecting at the subcervicale, the innermost point between the submental area and the neck (Figure 2B).4 The mentocervical angle (MCA) is defined by a line from the pronasal nasal tip to the Pog’ as it intersects with the submental tangent (Figure 2C).5 The facial convexity angle (FCA) is defined as the intersection of a line from the glabella to the subnasale, with a line from the subnasale to the Pog’ (Figure 2D).6

This study was approved by the University of California, Davis, institutional review board. Statistical analysis was performed using SAS statistical software (SAS Institute Inc, Cary, NC), by the University of California, Davis, Statistical Laboratory using paired 2-tailed t tests on the preoperative and postoperative results and analysis of variance to test differences in the study groups. Results were considered significant if P<.05.

RESULTS

MEDICAL RECORD REVIEW

Fourteen patients who underwent concurrent rhinoplasty and chin correction surgery by one of us (J.M.S.) between November 9, 1999, and February 16, 2004, were identified. The 2 study groups included 6 patients in the implant group and 8 in the osseous group (Table). The mean age was 32 years (range, 14-49 years), with 12 females and 2 males. The mean follow-up was 9 months (range, 3-37 months). No complications, such as infection, mentalis dysfunction, tooth damage, or implant extrusion, were identified.

Technical aspects of the procedures were reviewed for chin correction methods. Osseous genioplasty was per-
formed in the standard intraoral fashion with bone fixa-
tion using a titanium plate and screws (Paulus; Stryker Leib-
ing Inc, Kalamazoo, Mich), as previously described.7 The
mean plate size (horizontal advancement) was 6 mm
(range, 4-8 mm). The mean horizontal advancement was
4.8 mm (range, 3-8 mm). The mean vertical shortening
(mean±SD, from 2-6 mm). The mean vertical shortening
(n=4) was 3 mm (range, 1-7 mm), while the mean verti-
ental lengthening (n=4) was 3.6 mm (range, 2-6 mm).

A standard submental approach was used to place ana-
tomical chin implants (Implantech Associates Inc, Ventura,
Calif). Three patients underwent implantation with a me-
dium implant (8 mm of anterior projection×1.2×5.2 mm). Three patients had small implants (6.0×1.2×5.1 mm), and
no large implants (10.0×1.2×5.3 mm) were used.

PHOTOGRAPH ANALYSIS

The preoperative findings for each measurement in the
2 study groups were not significantly different (P>.05).
If the angles were different at the outset, then a greater
or lesser change may have been identified, not because
of the difference in the operations, but because of an
 inadvertent selection bias of using 1 procedure for a dif-
ferent subset of patients.

PO’ TO POG’ DISTANCE

In all patients (N=14), the ratio of the Po’-Pog’ distance–
Po’-Pup distance increased (mean±SD, from 1.28±0.06
preoperatively to 1.33±0.07 postoperatively; P<.01)
(Figure 3A). In the implant group, the mean±SD Po’-
Pog’ distance increased from 1.27±0.08 to 1.30±0.08
(P<.02). The mean±SD Po’-Pog’ distance in the slid-
ing osseous group increased from 1.28±0.05 to 1.35±0.05
(P<.01). The postoperative change was greater for the
osseous genioplasty group (P=.03) (Figure 3B).

CERVICOMENTAL ANGLE

All patients had a decrease in the CMA (mean±SD,
from 116°±5° preoperatively to 110°±4° postoper-
atively; P<.01), as shown in Figure 4. Separately, the
mean±SD CMA decreased in the implant group (n=6)
(mean±SD, from 132°±15° preoperatively to 127°±15°
postoperatively; P<.01) and the osseous group (n=8)
(mean±SD, from 124°±13° preoperatively to 121°±11°
postoperatively; P<.03). There was no significant dif-
ference in the postoperative CMA change between the 2
groups (P=.41).

MENTOCERVICAL ANGLE

In all patients, the MCA decreased (mean±SD, from
120°±9° preoperatively to 111°±9° postoperatively;
P<.01) (Figure 5). The mean±SD MCA decreased in the
implant group (from 125°±10° preoperatively to 119°±9°
postoperatively; P<.01) and the osseous group
(from 116°±5° preoperatively to 106°±4° postopera-

Table. Distribution of Patients*

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</table>

Abbreviation: NA, data not applicable.

*The mean implant size was 7.3 mm, the mean titanium plate size was 5.8
mm, and the horizontal bony advancement was 5.3 mm after bending
the plate for the vertical component.

Figure 2. Illustration of the soft tissue equivalents of cephalometric landmarks (A); the cervicomental angle is formed by a line tangent to the submentum (from the menton [Me] to the subcervical [SC]) and a line tangent to the neck intersecting at the SC (the innermost point between the submental area and the neck) (B); the mentocervical angle is defined by a line from the pronasale (Pn) or nasal tip to the soft tissue pogonion (Pog’) intersecting with the submental tangent (Me to SC) (C); and the facial convexity angle is defined as the intersection of a line from the glabella (G) to the subnasale (Sn) with a line from the Sn to the Pog’ (D). Po’′ indicates porion.
In all patients, the FCA increased (mean±SD, from 167°±5° preoperatively to 172°±4° postoperatively; \( P < .01 \)) (Figure 6). The mean±SD FCA increased in the implant group (n=6) (from 164°±2° preoperatively to 170°±3° postoperatively) and the osseous group (n=8) (from 169°±5° preoperatively to 174°±3° postoperatively) \( P < .01 \) for both groups). The change in the FCA was not different \( (P = .55) \) between the 2 groups.

**COMMENT**

In this study, changes in profile photographs after concurrent rhinoplasty and chin surgery are represented by positional changes in the soft tissue landmarks that are measured by a variety of angles and distances. No facial feature can be properly analyzed without considering the relationship of the surrounding structures. The complex concept of balanced facial proportions is similar to the words of Epstein, \(^7\) “to be established by comparisons, by shifting shades of difference, turned over and teased out, and after all that what one comes up with might still not feel altogether right and precise.” That feeling is the artistic aspect that should be considered, even after the objective analysis is completed.

Profile photograph analysis has many limitations. A favorable profile view can be seen after genioplasty, but the chin, when viewed from the front, may seem unnaturally narrow. Dynamic changes after surgery, such as lip position with smiling or mentalis dysfunction, are also not readily identifiable on static photographs. Although this study deals with 2-dimensional analysis and the limitations therein, the future of facial analysis using 3-dimensional photography and videography will allow the surgeon to quantify changes by adjusting the viewpoint. \(^8\) The major drawback of this technology for an individual surgeon’s practice remains costly (approximate price, $68 000). \(^9\)

Adherence to the principles of standardized photography is essential to accurate analysis. \(^10\) One of the major limitations of the photographs in this study was size differences between the preoperative and postoperative images. Photographs taken with a ruler next to the chin (Figure 6K) or life-size photographs are ideal for a comparative study; however, when this is not used, the Po’-Pog distance calibration is introduced as a method to allow relative comparisons between preoperative and postoperative images. The Po’-Pog distance was chosen because of the constant position of the ear canal and Pup regardless of surgery. By using computer imaging software, the photograph size is made equal based on the Po’-Pog distance on preoperative and postoperative views. The relative values of change, such as the Po’-Pog distance, can then be measured. One limitation of this technique is that this new value, Po’-Pog’, must be compared with other patients as a ratio of Po’-Pog/Po’-Pog. Therefore, the Po’-Pog distance cannot be compared with the millimeters of chin advance...
The results of this study support the concept that chin augmentation procedures can create aesthetic improvement in the CMA. The normal CMA has been described by Sporri et al\textsuperscript{11} for use in measuring nasal tip projection. Absolute measurements of the Po’-Pog’ distance can be obtained using this constant in future studies.

All patients in this study exhibited a change in the measured angles toward the established normal ranges. The only significantly different postoperative change between the implant and osseous groups was in the increased Po’-Pog’ distance. Several aspects could account for the difference. The soft tissue response to a chin implant is reported as only 60% (1.0:0.6), while an osseous genioplasty can result in a 1:1 advancement for up to 8 mm of bone movement.\textsuperscript{4,12} The reason for this disparity is likely related to the contraction of the soft tissue capsule that surrounds a polymeric silicone (Silastic) implant and resorption of up to 5 mm of mandible.\textsuperscript{13} The following will relate how the change in measurements correlates to changes in soft tissue landmarks after either chin implantation with an alloplast or osseous genioplasty.

**CERVICOMENTAL ANGLE**

The results of this study support the concept that chin augmentation procedures can create aesthetic improvement in the CMA. The normal CMA has been described for males (121°) and females (126°).\textsuperscript{14} After surgery, all patients in this study showed improvement (less obtuse) in the CMA. Although Guyuron and Raszewski\textsuperscript{15,16} have reported that “the cervicomental angle improved more for osteoplastic genioplasty” when compared with chin implantation in a series of 76 patients, there was no difference in the 2 groups in this study. Obviously, the most improvement in neck contour is seen when chin surgery is combined with rhytidectomy or submental liposuction.

**MENTOCERVICAL ANGLE**

The MCA has been defined in 2 different ways. Powell and Humphreys\textsuperscript{10} defined the MCA as the junction of a line from the glabella to the Pog’ with the submental tangent (menton to subcervicale). The MCA is useful in soft tissue analysis because it integrates features of the nasal tip projection (pronasale), neck position (submental tangent), and chin projection (Pog’).\textsuperscript{17} Although changes in tip projection were not measured in this study, the MCA will be increased with increasing nasal tip projection and decreased with deprojection. One notable difference between the 2 groups is that most of the implant group (5 of 6 patients) were within the MCA’s normal range (110°-120°) postoperatively, while only 2 patients in the osseous group remained in the normal range (Figure 7). As anticipated, the 3 largest decreases in the MCA (15°, 15°, and 17°) were observed in patients who underwent the largest movements during osseous genioplasty.

Although the ultimate surgical change is at the discretion of the surgeon’s aesthetic judgment, several standard proportions of the soft tissue profile view have been suggested for preoperative assessment. One of the lines of the MCA is the “E line” (esthetic plane) that extends from the pronasale and the Pog’ (Figure 5B). By using this line as a reference, Ricketts\textsuperscript{18} suggested that the upper lip should be 4 mm posterior, while the lower lip is 2 mm posterior to this line; however, he recognized that considerable variation exists for lip positioning. The Gonzales-Ulloa “zero-meridian line” can be created by drawing a line from the nasion that is perpendicular to the Frankfort horizontal plane on a profile photograph. The anteriormost chin point (soft tissue Pog’) is suggested to ideally touch this line;\textsuperscript{17} however, some researchers believe that this represents chin overprojection (Figure 7). Others’ suggest that the Pog’ should be 4 (±2) mm posterior to a line that is perpendicular to the Frankfort horizontal plane that extends down through the subnasale.
FACIAL CONVEXITY ANGLE

Downs described the FCA by using bony landmarks on cephalograms. The soft tissue equivalent of this angle has a reported normal mean±SD of 168°±4°. Because nasal tip projection is not represented in this angle, the effect of genioplasty on chin projection, irrespective of nasal tip surgery, can be evaluated with the FCA. An FCA that is closer to 180° suggests an overprojected chin, but could involve dentofacial malocclusion or maxillary retru-
Figure 7. Illustration of a profile view showing the increase in the porion to pogonion distance after chin augmentation with alloplast or osseous genioplasty.

sion. On the other hand, an FCA that is less than normal could suggest a horizontally deficient chin and/or maxillary protrusion. Excellent aesthetic results in both groups were reflected by increased FCAs. The postoperative FCAs in the osseous group were outside the reported normal range in 6 of the 8 patients (Figure 6). Aesthetic judgment must include avoidance of chin overprojection. Too much osseous advancement, or an improperly selected implant, can result in masculinization of the female profile.

In conclusion, computer imaging software is a simple and reliable tool that is useful for analyzing photographs in patient education, surgical planning, and postoperative review. Each facial measurement and angle should be used as a guide in combination with other analysis tools and clinical judgment. As 3-dimensional photographic analysis becomes more affordable and available, comparison of preoperative and postoperative results will include spatial relationships and dynamic components of facial structures.