Nasolabial Soft Tissue Changes After Le Fort I Advancement

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Purpose: To identify the nasolabial soft tissue changes that occur after Le Fort I advancement.

Materials and Methods: A prospective study of patients who had Le Fort I advancement at the Children's Hospital Boston from 2005 to 2007. The pre- and postoperative anthropometeric nasolabial measurements were recorded by a single examiner.

Results: A total of 37 patients with a mean age of 18.6 years at the time of operation and a mean follow-up of 12.6 months were recruited. Nearly one half of the study sample (16 of 37) had cleft lip/palate. Direct anthropometry showed a reduction of the nasal length by 1.3 mm while the nasal tip protrusion increased by 1.1 mm. The nasofrontal angle decreased by 9.8° and the upper lip moved forward by 4.15 mm, reflecting the advancement in the maxilla. The height of the cutaneous upper lip increased by 0.4 mm. No significant differences were found in the soft tissue response observed between the cleft and noncleft subjects.

Conclusions: Le Fort I advancement produces elevation of the nasal tip, as seen by a reduction in the nasal length, an increase in the nasal tip protrusion, and a concomitant reduction in the nasofrontal angle. Additionally, the cutaneous lip height increased, most likely due to an unfurling of the upper lip.

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A combined surgical orthodontic approach is routinely used to correct significant dentofacial deformities. Surgical movement of the maxilla influences the overlying soft tissue and nasal morphology. Therefore, quantitative data on alterations in the nasolabial region that occur with the skeletal movements need to be considered during treatment planning for patients undergoing Le Fort I advancement.

The published data are replete with studies using lateral cephalometry to document the soft tissue changes that occur with orthognathic surgery. Although this technique permits evaluation of the profile alterations, it does not give information on what occurs in the transverse dimension, which is especially important in assessing the nasolabial changes. Moreover, patients are used to viewing themselves in the mirror as a three-dimensional (3D) object and could find it difficult to relate to information presented solely as profile analysis.

Anthropometry is an objective technique for quantifying facial morphology using a series of linear and angular measurements derived from a set of well-defined landmarks.[1] It permits measurements in all three dimensions and calculation of proportions to evaluate facial harmony.[2] The sagittal and transverse soft tissues measurements obtained with anthropometry can be correlated with the osseous movements and can be incorporated into prediction algorithms. This type of information will potentially provide better predictions of the sagittal and transverse changes that occur with Le Fort I osteotomy. The objectives of the present study were to quantify the nasolabial soft tissue changes that occur with Le Fort I advancement, and to identify the role of gender, the magnitude of surgical movement, and the diagnosis of a cleft lip/palate (CLP) on the nasolabial soft tissue changes that occur with Le Fort I advancement.

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FIGURE 1. Anthropometric landmarks: en, endocanthion; n, nasion; sn, subnasale; al, alare; pr, pronasale; c, highest point of Columella; ls, labiale superius; sto, stomion; cph, crista philtri inferior.

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Materials and Methods

SAMPLE SELECTION

The study cohort consisted of a series of consecutively treated patients who had undergone Le Fort I osteotomy performed by a single surgeon (B.L.P.) at Children's Hospital Boston (Boston, MA) from 2005 to 2007. All subjects who met the following criteria were included in the present study:

1. Single piece Le Fort I osteotomy and advancement with rigid fixation
2. Preoperative and at least 6-month postoperative lateral cephalograms available
3. No concomitant mandibular osteotomy or adjunctive nasal procedures performed within the observation period

The Children's Hospital, Boston, institutional review board approved the present study (protocol no. M08-05-0223).

SURGICAL TECHNIQUE

All patients underwent standard Le Fort I osteotomy with rigid internal fixation. The right and left alar bases were sutured with 3.0 Prolene to a hole surgically created in the anterior nasal spine. The alar base width was narrowed by 2 to 3 mm. The wound was closed with running horizontal mattress suture without V–Y advancement.

ANTHROPOMETRIC EVALUATION

Preoperative (T1) and postoperative (T2) standard anthropometeric nasolabial measurements (Fig 1 and Table 1) were recorded using a caliper and nasal angleometer, as described by Farkas.[3] All measurements were performed by a single examiner (B.L.P.) with more than 15 years' experience in direct anthropometric techniques. Proportional indexes were calculated based on the linear measurements (Table 2). For transverse proportional indices, the intercanthal distance was used as a base measurement, because this region was unaffected by the operation.

CEPHALOMETRIC ASSESSMENT

Surgical changes to the craniofacial skeleton were objectively evaluated using routine lateral cephalometric analysis. The pre- and postoperative

Table 1. LINEAR AND ANGULAR ANTHROPOMETRIC MEASUREMENTS

Measurement	Landmarks
Intercanthal distance	en-en
Nasal height	n-sn
Nasal width	al-al
Nasal length	n-prn
Nasal tip protrusion	sn-prn
Columellar length	sn-c
Cutaneous upper labial height	sn-ls
Overall upper labial height	sn-sto
Vermilion height of upper lip	ls-sto
Lower prolabial width	cphi-cphi
Sagittal position of upper lip	t-ls
Maxillary incisor teeth display at rest	incisal show
Nasofrontal angle	Angle between proximal nasal bridge contour and anterior surface of forehead below glabella
Nasal tip angle	Angle formed by lines following general direction of columella and nasal bridge
Nasolabial angle	Angle between surfaces of columella and upper lip skin

Abbreviations: en, endocanthion; n, nasion; sn, subnasale; al, alare; pr, pronasale; c, highest point of columella; ls, labiale superius; st, stomion; cphi, crista philtri inferior.

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lateral cephalograms were scanned and digitized using the Dolphin Imaging Program, premium version 10.5 (Dolphin Imaging and Management Solutions, Chatsworth, CA) by a single examiner (S.V.). The mean enlargement factor was recorded for each radiograph. All linear measurements were transformed by the respective enlargement factors using the imaging software to enable direct comparison. A customized cephalometric analysis using an x and y coordinate system allowed measurement of the linear distances from the horizontal and vertical reference lines. The horizontal reference line was parallel to the Frankfort-Horizontal plane and passed through nasion. The vertical reference line, perpendicular to the horizontal reference line, originated at nasion and extended inferiorly (Fig 2). The horizontal and vertical change in the maxillary position between T1 and T2 was documented using the difference in N-A (HP) in millimeters and N-ANS (perp HP) in millimeters, respectively.

Measurement error for the cephalometric analysis was assessed in 10 randomly selected patients, whose lateral cephalometric radiographs were redigitized and remeasured by the same examiner 1 month later. The coefficient of variation was calculated.

STATISTICAL ANALYSIS

Simple descriptive statistics (mean, standard deviation, and frequency distributions) were used to summarize the data. The initial tests for normality (assessment for skewness, kurtosis, and Shapiro-Wilk) were performed to determine, where appropriate, the parametric and nonparametric univariate analysis testing for the continuous variables (Table 2). Paired t tests and Wilcoxon rank sum tests were used to examine the differences in the anthropometric and cephalometric outcomes between T1 and T2.

To examine the independent association of several factors with changes in the anthropometric measures, multivariate linear regression analyses were used to study the association between the independent and outcome variables. The outcome variables included changes in anthropometric measurements (T2 − T1).[4] The predictor variables were selected on an a priori knowledge of influencing soft tissue change and included gender, the amount of horizontal and vertical maxillary skeletal change, and the presence of a CLP. All regression models were built using the ordinary least squares approach. R-square values were computed to examine the amount of variance explained by the predictor variables.

Corrections were made for multiplicity using a modified Bonferonni method to reduce the likelihood of type I errors; an α threshold for statistical significance for multiple comparisons was set at 0.01. Univariate analyses were performed using SAS, version 9.2 (SAS Institute, Cary, NC), and multivariate linear regression analyses were performed using SPSS for Windows, version 16 (SPSS, Chicago, IL).

Results

A total of 37 patients (19 males and 18 females), who had a Le Fort I advancement at Children's Hospital Boston, from 2005 and 2007, with a mean age of 18.6 years (range 13.9 to 41.6), were included in the present study. This sample included 16 patients with CLP, equally distributed between unilateral (n = 8) and bilateral (n = 8). Of the 37 patients, 13 underwent maxillary sagittal advancement only, 10 simultaneous inferior repositioning, and 14 superior repositioning. Malar augmentation with Medpore implants was performed in 22 (59%) of all 37 patients and in 13 (80%) of the 16 patients with CLP. The postoperative (T2) lateral cephalograms and anthropometric measurements were taken more than 6 months after Le Fort I advancement (mean 12.6 months, range 7.6 to 20).

Table 2. CHANGES IN ANTHROPOMETRIC MEASURES FROM T1 TO T2 (n = 37)

Anthropometric Parameter	T1	T2	ΔT2-T1	95% CI	*P* Value
Linear measurements					
Intercanthal distance (en-en)	31.61 ± 3.4	31.75 ± 3.3	0.29 ± 0.71	0.04, 0.53	.023*
Nasal height (n-sn)	50.61 ± 4.2	50.44 ± 4.0	−0.17 ± 1.22	−0.59, 0.25	.413
Nasal width (al-al)	32.08 ± 2.7	32.82 ± 2.9	0.79 ± 2.26	0.01, 1.56	.047*
Nasal length (n-prn)	43.75 ± 4.1	42.36 ± 3.7	−1.26 ± 1.54	−1.79, −0.73	< .001†
Nasal tip protrusion (sn-prn)	21.22 ± 3.4	22.25 ± 3.1	1.14 ± 1.88	0.50, 1.79	.001†
Columellar length (sn-c)	10.49 ± 2.0	10.50 ± 1.7	0.01 ± 0.79	−0.26, 0.29	.916
Cutaneous height of upper lip (sn-ls)	14.32 ± 3.4	14.76 ± 3.3	0.40 ± 0.88	0.10, 0.70	.011‡
Overall upper lip height (sn-sto)	20.28 ± 3.6	20.58 ± 4.2	0.20 ± 2.13	−0.53, 0.93	.581
Vermilion height of upper lip (ls-sto)	7.03 ± 2.9	7.21 ± 2.9	0.13 ± 1.09	−0.25, 0.50	.492
Lower prolabial width (cphi-cphi)	11.19 ± 2.0	11.61 ± 2.2	0.40 ± 1.42	−0.09, 0.89	.104
Maxillary incisor display	2.93 ± 3.0	3.53 ± 2.1	0.73 ± 1.86	0.09, 1.37	.026*
Right tragion to labiale superious distance (t-ls)	128.44 ± 6.8	132.45 ± 5.9	4.15 ± 3.57	2.89, 5.42	< .001†
Angular measurements					
Nasofrontal angle (°)	147.82 ± 7.1	137.30 ± 19.8	−9.76 ± 20.12	−17.41, −2.11	.014‡
Nasal tip angle (°)	97.6 ± 12.2	99.10 ± 11.5	1.45 ± 6.80	−1.14, 4.03	.261
Nasolabial angle (°)	89.06 ± 20.1	92.10 ± 17.1	3.10 ± 13.82	−2.15, 8.36	.237
Proportional indexes					
Nasal index (al-al/n-sn × 100)	63.91 ± 8.1	65.59 ± 7.8	−1.68 ± 4.7	−3.31, 0.52	.043*
Nasal bridge index (n-prn/n-sn × 100)	86.39 ± 5	84.19 ± 5.1	−2.2 ± 3.5	−3.42, 0.98	.001‡
Nasal tip protrusion-width index (sn-prn/al-al × 100)	66.46 ± 12.4	68.46 ± 12.73	−1.99 ± 7.8	−4.69, 0.7	.142
al-al/en-en × 100	101.13 ± 8.2	103.66 ± 9.5	−2.53 ± 6.99	−4.93, −0.13	.04*
chpi-chpi/en-en × 100	35.86 ± 6.9	36.87 ± 8.0	−1.01 ± 4.9	−2.69, 0.67	.355

Abbreviations: CI, confidence interval; en, endocanthion; n, nasion; sn, subnasale; al, alare; pr, pronasale; c, highest point of columella; ls, labiale superius; st, stomion; cphi, crista philtri inferior.

Data presented as mean ± standard deviation.

*$P < .05$.

†$P < .001$.

‡$P < .01$.

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ANTHROPOMETRIC MEASUREMENTS

After Le Fort I maxillary advancement, a number of statistically significant nasolabial anthropometric changes were observed (Table 2). The nasal length decreased by 1.3 mm (two-sided $P < .0001$, 95% confidence interval −1.79 to −0.73), and the nasal tip protrusion increased by 1.1 mm (two-sided $P < .001$, 95% confidence interval 0.5 to 1.79). No statistically significant differences were observed for the changes in nasal height, alar base width, nasal tip angle, nasolabial angle, or columellar length. Among the proportional indices, the nasal bridge index showed a statistically significant reduction of 2% (two-sided $P < .001$, 95% confidence interval −3.42 to 0.98). The height of the cutaneous upper lip increased by 0.4 mm (two-sided $P = .01$, 95% confidence interval 0.1 to 0.7 mm), and the upper lip had advanced forward by 4.15 mm (two-sided $P < .01$, 95% confidence interval 2.89 to 5.42), as evident from the change in the linear distance from the right tragion to labiale superius (t-ls). No significant differences were observed for changes in vermillion height, philtrum width, or maxillary incisal tooth display at rest. Patients with CLP had a wider nose ($P < .01$) at baseline (Table 3). No statistically significant differences were found in the anthropometric changes that occurred with Le Fort I advancement between the non-CLP and CLP groups at an α level of 0.01. Subgroup analysis among the 3 types of maxillary movements (ie, pure advancement, advancement with superior repositioning, and advancement with inferior repositioning) did not result in statistically significant differences with respect to the soft tissue changes at an α level of 0.01.

CEPHALOMETRIC MEASUREMENTS

A number of statistically significant changes were found in the cephalometric measures that reflected the sagittal advancement of the maxilla [SNA, ANB, WITS, N-A (HP), midface length, and palatal length; Table 4]. Concomitant improvement was found in patient profile, with an increase in facial convexity of approximately 5°. Measurement error was assessed by the coefficient of variation, which was less than 5% for all the cephalometric variables on repeated measures in a random subset of patients.

FIGURE 2. Cephalometric planes used for assessing maxillary advancement.

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MULTIVARIATE LINEAR REGRESSION ANALYSES

The multivariate linear regression analysis suggested that the horizontal change in maxillary position, gender, and the diagnosis of CLP were significant predictors of changes in a number of nasolabial anthropometric measurements (Table 5).

Nasal Height (n-sn)

A marginal association was found between male gender and the changes observed in nasal height. A 1-mm increase occurred in nasal height in the males compared with the females, at an α level of 0.051. The independent predictors accounted for 31.8% of the variance observed in the changes in nasal height resulting from Le Fort I maxillary osteotomy.

Change in Maxillary Incisal Display at Rest (U1)

The change observed in the maxillary incisal tooth display at rest (in millimeters) was significantly associated with the diagnosis of CLP. After controlling for surgical movements and baseline measurements, the patients with CLP had 1.3 mm less incisal display than the non-CLP subjects. The independent predictors accounted for 68.3% of the variance observed in the changes in maxillary in-

Table 3. PREOPERATIVE ANTHROPOMETRIC PARAMETERS (T1) AND AMOUNT OF CHANGE (ΔT) STRATIFIED ACCORDING TO PRESENCE OR ABSENCE OF CLEFT LIP/PALATE

Anthropometric Parameter	T1 Non-CLP	T1 CLP	T1 *P* Value	ΔT = T2 − T1 Non-CLP	ΔT = T2 − T1 CLP	ΔT *P* Value
Linear measurements						
Intercanthal distance (en-en)	30.4 ± 2.2	33.3 ± 4.1	.060	0.24 ± 0.7	0.36 ± 0.74	.797
Nasal height (n-sn)	50.5 ± 4.8	50.7 ± 3.5	.786	−0.38 ± 1.32	0.14 ± 1.0	.063
Nasal width (al-al)	30.8 ± 1.8	33.9 ± 2.9	.001	0.64 ± 2.4	2.07 ± −0.4	.758
Nasal length (n-prn)	43.8 ± 4.8	43.7 ± 3.0	.860	−1.33 ± 1.39	−1.14 ± 1.8	.772
Nasal tip protrusion (sn-prn)	21.5 ± 3.1	20.9 ± 3.8	.483	1.29 ± 0.8	0.93 ± 2.9	.052*
Columellar length (sn-c)	10.5 ± 2.3	10.5 ± 1.5	.819	0 ± 0.7	0.04 ± 0.9	.783
Cutaneous upper labial height (sn-ls)	15.3 ± 3.8	13 ± 2.4	.046	0.19 ± 0.9	0.71 ± 0.8	.091
Overall upper labial height (sn-sto)	20.4 ± 4.4	20.1 ± 2.3	.664	−0.33 ± 2.4	1 ± 1.4	.050*
Vermilion height of upper lip (ls-sto)	6.8 ± 3.4	7.4 ± 2	.132	−0.05 ± 0.9	0.39 ± 1.4	.432
Lower prolabial width (cphi-cphi)	10.8 ± 1	11.8 ± 2.8	.522	0.48 ± 1.8	0.29 ± 0.5	.331
Maxillary incisor display	3.5 ± 2.9	2.1 ± 3	.108	0.95 ± 1.8	0.39 ± 1.9	.262
Right tragus-ls	128.6 ± 7	128.3 ± 6.9	.876	3.5 ± 3.8	5.15 ± 3.1	.230
Angular measurements						
Nasofrontal angle (°)	145.6 ± 6.1	150.7 ± 7.4	.062	−10.66 ± 25.1	−8.27 ± 7.6	.352
Nasal tip angle (°)	102.3 ± 11.6	97.1 ± 14.4	.275	0.333 ± 4.7	3.27 ± 9.3	.822
Nasolabial angle (°)	91.6 ± 18.9	85.8 ± 21.7	.214	4.16 ± 16.1	1.36 ± 9.3	.823
Proportional indexes						
Nasal index (al-al/n-sn × 100)	61.59 ± 7.7	68.45 ± 9.0	.051	1.63 ± 4.68	1.25 ± 6.6	.871
Nasal bridge index (n-prn/n-sn × 100)	86.75 ± 5.3	89.01 ± 3.9	.281	−2.07 ± 3.6	−2.9 ± 3.7	.600
Nasal tip protrusion-width index (sn-prn/al-al × 100)	70 ± 11.4	58.92 ± 13.4	.033	3.04 ± 6.0	1.58 ± 14.4	.237
al-al/en-en × 100	100.91 ± 6.9	102.1 ± 10.4	.731	2.15 ± 7.8	3.3 ± 8.1	.741
chpi-chpi/en-en × 100	35.67 ± 4.9	38.58 ± 7.8	.238	1.36 ± 6.3	0.05 ± 1	.294

Abbreviations: T1, baseline; T2, postoperative; ΔT; change from T1 to T2; CLP, cleft lip/palate; en, endocanthion; n, nasion; sn, subnasale; al, alare; pr, pronasale; c, highest point of columella; ls, labiale superius; st, stomion; cphi, crista philtri inferior.
*$P < .05$.

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cisal display at rest (in millimeters) resulting from Le Fort I maxillary advancement.

Change in Nasolabial Angle

The changes observed in the nasolabial angle were significantly associated with the baseline measurement and horizontal skeletal change. When all other factors (eg, cleft type, gender, vertical changes) were controlled, for every 1-mm advancement, a 1.35° increase was found in the nasolabial angle. The independent predictors accounted for 61.7% of variance observed in the changes in the nasolabial angle resulting from Le Fort I maxillary advancement.

Table 4. CEPHALOMETRIC MEASURES AT T1, T2, AND ΔT = T2 − T1 (N = 37)

Variable	T1	T2	ΔT = T2 − T1	95% CI	*P* Value
Horizontal skeletal					
SNA (°)	76.83 ± 5.8	81.88 ± 5.3	5.04 ± 3.7	0.8, 6.27	< .001*
ANB (°)	−1.11 ± 4.7	3.32 ± 2.8	4.42 ± 3.9	3.13, 5.72	< .001*
Wits (FOP) (mm)	−5.69 ± 6.0	0.20 ± 4.9	5.89 ± 5.7	3.98, 7.81	< .001*
N-A (HP) (mm)	−6.71 ± 6.3	−1.64 ± 5.8	5.06 ± 4.0	3.74, 6.39	< .001*
Vertical skeletal					
N-ANS (Perp HP) (mm)	52.85 ± 6.5	54.24 ± 6.2	1.39 ± 4.5	−0.1, 2.90	.069
U1-NF (Perp NF) (mm)	28.24 ± 4.2	28.48 ± 4.4	0.24 ± 2.5	−0.60, 1.08	.570
U6-NF (Perp NF) (mm)	24.99 ± 3.4	25.28 ± 3.8	0.29 ± 1.9	−0.34, 0.92	.356
Overjet (mm)	−2.15 ± 4.3	2.78 ± 1.0	4.93 ± 4.2	3.55, 6.32	< .001*
Overbite (mm)	−1.24 ± 2.6	0.95 ± 1.3	2.19 ± 2.9	1.23, 3.16	< .001*

Abbreviations: T1, baseline; T2, postoperative; ΔT; change from T1 to T2; CI, confidence interval; NF, nasion Frankfort perpendicular.
*$P < .001$.

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Table 5. PREDICTORS OF NASOLABIAL SOFT TISSUE CHANGE

Parameter	Predictor	R^2	Regression Equation
Nasal height (mm)	Baseline variable, gender	0.318	Change in nasal height (n-sn) = 6.67 − [0.152 × (n-sn at T1)] + 1.01 (male) − 0.086 (CLP) + 0.054 (horizontal advancement) + 0.054 (vertical change)
Maxillary incisor display at rest (mm)	Baseline variable, CLP	0.683	Change in maxillary incisal display at rest (U1) = 2.581 − [0.461 × (U1 at T1)] − 0.312 (male) − 1.288 (CLP) + 0.007 (horizontal advancement) + 0.065 (vertical change)
Nasolabial angle (°)	Baseline variable, horizontal change	0.617	Change in nasolabial angle = 39.245 − [0.421 × (nasolabial angle at T1)] − 6.961 (male) − 6.17 (CLP) + 1.35 (horizontal advancement) + 0.636 (vertical change)

Abbreviations: n, nasion; sn, subnasale.

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Discussion

The 3D nature of the skeletal alignment and the variation in the characteristics of the overlying soft tissues confound the esthetic outcomes after orthognathic surgery. Skeletal maneuvers can not only change the soft tissue morphology in the immediate vicinity, but also that in distant regions owing to the 3D composite anatomy of the craniofacial region. These changes affect the overall esthetic balance of the face. Thus, maxillofacial surgeons must pay due attention to alterations in the facial form before performing orthognathic surgery. Although plain radiography and computed tomography provide excellent hard tissue images, the information that can be extracted pertaining to the soft tissue counterparts and their surface anatomy is limited.

The response of the facial soft tissues to Le Fort I advancement was assessed in the present study using direct anthropometric measurements. This permitted evaluation of the frontal, as well as the profile, changes. The linear distance from the right tragus to the labiale superius increased after maxillary advancement. This might have resulted from the forward movement of the upper lip, as well as from the increase in the transverse dimension of the facial middle third owing to the new soft tissue support being given by the maxillary advancement. The nasal length (n-prn) and nasofrontal angle decreased with a concomitant increase in the nasal tip protrusion (sn-prn), indicating an elevation of the nasal tip. Similar changes in the nasal tip have been reported in studies using lateral cephalograms.[5,6] The cutaneous lip height also increased, most likely from an unfurling of the upper lip.

Apart from lateral cephalometry, two-dimensional photogrammetry and nasal casts have been used to assess nasolabial soft tissue changes after Le Fort I advancement. The poor definition and superimposition of the midline and lateral soft tissue outlines are some of the main drawbacks of lateral cephalometry. Although linear measurements can be performed on two-dimensional frontal photographs, they are not appropriate for assessing changes in facial depth. Betts et al[7] used 31 nasal casts constructed from impressions taken with custom-made trays to evaluate soft tissue response to Le Fort I osteotomy. They observed a widening of the nasal base (average 9%) in all patients, irrespective of the vector of maxillary movement. Nasal tip protrusion and the nasolabial angle decreased in 65% of the patients. However, it was not possible to draw conclusions on the significance of these changes, because the investigators did not perform a statistical analysis to compare the pre- and postoperative outcomes. In addition to the discomfort and potential for soft tissue compression during impression taking, nasal cast analysis can also be confounded by the errors induced from the dimensional changes of the impression and cast materials.

Yamada et al[8] evaluated the soft tissue changes occurring after Le Fort I osteotomy using a 3D laser scanner. They reported a statistically significant increase in the nasal width (al-al) and nasal tip protrusion (n-prn). Recently, Rauso et al[9] also reported on the nasolabial changes using direct anthropometry, with a general trend toward widening of the alar base and a concomitant shortening of the columellar length even after performing the alar c-inch and a midline V-Y extension. They did not observe such a trend in relation to the upper lip.

In addition to the direct transverse measurements, we calculated proportion indices for a better understanding of the relative soft tissue changes that occur with maxillary advancement. The intercanthal distance was selected as the base measure, because no surgical intervention was performed in this region. Although an increase in the nasal width has been reported to occur after Le Fort I advancement,[10] we did not observe a statistically significant increase in the transverse nasal measurements or their proportional indices in our sample. This might be because meticulous attention was given to narrowing the alar base width 2 to 3 mm by suturing the right and left alar bases to the anterior nasal spine in all patients at the time of maxillary advancement. Apart from the nasal bridge index (n-prn/n-sn × 100), other proportional indices did not reach the $P < .01$ level of statistical significance. The increase in the nasal bridge index is a result of the forward and upward movement of the nasal tip with maxillary advancement.

Although a simple hard/soft tissue movement ratio that fits all patients would be desirable, such ratios do not exist. Considerable individual variation among patients would confound the predictions given by such simple ratios. The use of multiple regression equations could be a possible solution, because these consider some of the other factors that affect the esthetic outcomes. In the present study, we have generated some regression equations that could be used in the prediction of certain soft tissue parameters (Table 5).

Patients with CLP had nasolabial repair as infants, and although scar tissue is present in the area, the established anthropometric landmarks are used in this patient population.[11] In addition, the paired *t* test was used to compare the CLP and non-CLP groups. In respect to the baseline values (T1), only the nasal width was significantly larger in the CLP group. However, the net soft tissue change (ΔT) before (T1) and after (T2) surgery was not significantly different between the 2 groups at an α level of 0.01 ($\Delta T = T2 - T1$; Table 3).

Many patients who require Le Fort I osteotomy have maxillary hypoplasia that extends to the infraorbital rims. A standard Le Fort I advancement does not change the deficiency in the superior aspect of the middle third of the face.[12] Therefore, malar augmentation with implants in the infraorbital region that extend to the zygomatic arch were placed in several patients at the time of Le Fort I to improve the projection of the upper midface. However, it was not possible to quantify the changes in the malar complex with conventional anthropometric techniques. With the availability of stereophotography, it will be possible to monitor the alterations in the malar region using 3D color maps.[13,14] In addition, stereophotography will facilitate the collection of anthropometric measurements.

Le Fort I advancement produces elevation of the nasal tip, as evident by the reduction in the nasal length and nasofrontal angle, along with an increase in the nasal tip protrusion. Additionally, the cutaneous lip height is observed to be increased, most likely from an unfurling of the upper lip.

A lack of understanding of the 3D nature of the soft tissue response to orthognathic surgery can result in undesirable esthetic outcomes. A thorough soft tissue examination must be a part of the preoperative evaluation. It is important to appreciate the nasolabial changes that occur with maxillary advancement and to include these in the treatment plan.

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