Original Article

Factors Influencing the Predictability of Soft Tissue Profile Changes Following Mandibular Setback Surgery

Karim A. Mobarak, BDS, MDS[a]; Olaf Krogstad, DDS, PhD[b]; Lisen Espeland, DDS, PhD[c]; Torstein Lyberg, DDS, MD, PhD[d]

Abstract: The objective of this cephalometric study was to assess long-term changes in the soft tissue profile following mandibular setback surgery and investigate the presence of factors that may influence the soft tissue response to skeletal repositioning. The subjects enrolled were 80 consecutive mandibular prognathism patients operated with bilateral sagittal split osteotomy and rigid fixation. Lateral cephalograms were taken at 6 occasions: immediate presurgical, immediate postsurgical, 2 and 6 months postsurgical, and 1 and 3 years postsurgical. The subjects were grouped according to gender and magnitude of setback. Ratios of soft tissue to hard tissue movements were calculated for the subgroups. Females generally demonstrated greater ratios than males with a statistically significant difference for the upper lip and chin ($P < .05$). Postsurgical alterations in the profiles were more predictable in patients with larger setbacks compared to patients with smaller ones. Skeletal relapse had a profound influence on long-term profile changes. Based on these findings, it is proposed that the database used in prediction software be adjusted to account for such factors in an attempt to improve the accuracy of computerized treatment simulations. (*Angle Orthod* 2001;71:216–227.)

Key Words: Computerized predictions; Videoimaging; Orthognathic surgery; Bilateral sagittal split osteotomy; Class III malocclusion

INTRODUCTION

Surgical correction of Class III dentofacial deformities may be accomplished by maxillary advancement, mandibular setback, or bimaxillary procedures. In some instances, the choice between these procedures is not straightforward. While any of these approaches are usually equally effective in correcting the dental malocclusion, each procedure affects the patient's appearance differently, with only 1 resulting in the most esthetically pleasing profile. Computerized prediction programs have greatly enhanced the clinician's ability to quickly evaluate different estimates of the postoperative profile with all possible surgical options. Prediction tracings and videoimages have also simplified communication between doctor and patient and encouraged patients to participate in the decision-making process.[1] The computer algorithms that describe the soft tissue response to skeletal repositioning, which are utilized in generating these predictions, have mainly been derived from follow-up studies on orthognathic surgery patients. Alterations of the soft tissue profile that accompany mandibular setback surgery have been addressed by several studies.[2–19] While there is general agreement on the anticipated average impact of surgery, little is known about the influence of factors such as gender, presurgical facial morphology, soft tissue tonicity, magnitude of surgical repositioning and skeletal relapse on soft tissue response. Knowledge of possible effects of these variables could improve the accuracy of presurgical predictions.

The aims of the present study were to:

1. Describe the soft tissue response following mandibular setback surgery and evaluate the long-term treatment outcome in terms of soft tissue profile.
2. Investigate the relationship between soft tissue and skeletal movements.
3. Examine whether gender, preoperative soft tissue thickness, magnitude of skeletal repositioning, and skeletal

[a] Karim A. Mobarak, Research Fellow, Department of Orthodontics, University of Oslo, Oslo, Norway.

[b] Olaf Krogstad, Professor Emeritus, Department of Orthodontics, University of Oslo, Oslo, Norway.

[c] Lisen Espeland, Associate Professor and Director of Postgraduate Study, Department of Orthodontics, University of Oslo, Oslo, Norway.

[d] Senior Scientist, Department of Maxillofacial Surgery, Ullevaal University Hospital, Oslo, Norway.

Corresponding author: Dr Karim A. Mobarak, Department of Orthodontics, Institute of Clinical Dentistry, University of Oslo, PO Box 1109 Blindern 0317, Oslo, Norway
(e-mail: kmobarak@bigfoot.com).

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TABLE 1. Patient Characteristics[a]

Variable	Whole Sample (n = 80) Mean	SD	Min	Max	Males (n = 46) Mean	SD	Females (n = 34) Mean	SD
Age at surgery (y)	24.8	7.6	17.6	51.0	25.1	7.6	24.5	7.6
SNA (°)	81.7	3.6	73.1	91.8	82.2	3.9	81.0	3.2
SNB (°)	85.4	3.9	77.2	95.5	86.3	4.1	84.2	3.1
A to Nasion perpendicular (mm)	1.0	3.6	−7.1	10.5	0.9	4.2	1.2	2.6
Pg to Nasion perpendicular (mm)	12.0	7.6	−0.8	34.8	12.7	8.8	11.1	5.6
ML/NSL (°)	33.6	5.3	21.0	43.0	32.0	5.7	35.7	3.9
Overjet (mm)	−5.1	2.7	−11.1	−0.5	−5.6	2.5	−4.6	2.7
Overbite (mm)	1.7	1.5	0.1	6.1	1.7	1.5	1.7	1.5
G-Sn-Pg′ (°)	2.7	6.6	−14.1	18.0	2.4	7.0	3.0	5.8
Nasolabial angle (°)	99.9	13.9	63.8	140.5	97.3	14.8	103.4	11.9

[a] n indicates number of patients; SD, standard deviation; Min., minimum; Max., maximum; y, years.

relapse influence the predictability of soft tissue behavior.

MATERIALS AND METHODS

Subjects

The subjects enrolled in this study were 80 consecutive Caucasian patients (46 males and 34 females) with a Class III malocclusion operated with bilateral sagittal split osteotomy. All patients were selected from the files at the Department of Orthodontics, University of Oslo. Surgery was performed at the Department of Maxillofacial Surgery, Ullevaal University Hospital during the period from 1990 to 1996. No patient received any additional orthognathic surgical procedure and all patients received rigid internal fixation. Practicing orthodontists or postgraduate students carried out pre- and postsurgical orthodontic treatment. No surgery was performed until growth was evaluated to have declined to adult levels. A criterion for inclusion in the study was the availability of standardized lateral cephalograms of adequate quality and resolution exposed according to a strict data collection protocol. The subjects' age at surgery and some presurgical craniofacial and occlusal characteristics are presented in Table 1.

Surgical technique

Seven different surgeons performed the operations for the patients studied. After completion of the mandibular split, the teeth were placed in their planned position and stabilized with intermaxillary fixation. The bony segments were fixed using bicortical screws with washer (Salzburg, Howmedica Leibinger; GmbH & Co. KG; Freiburg, Germany) which were placed in the gonial area through a transcutaneous approach. Two screws were placed above the inferior alveolar nerve in the retromolar area and the third screw below the nerve in a more anterior position. After completion of skeletal fixation, the intermaxillary fixation was released and the occlusion and the position of the condyles were checked. Postoperative orthodontic treatment and use of Class III elastics started within 2 to 4 weeks after surgery.

Cephalometric assessment

All lateral cephalograms were taken in the same cephalostat with the teeth in centric occlusion and the lips in relaxed position. Magnification for linear measurements was 5.6%, which was not corrected. The cephalograms were taken at the following occasions: within 1 week before surgery (T1), within 1 week after surgery (T2), 2 months after surgery (T3), 6 months after surgery (T4), 1 year after surgery (T5), and 3 years after surgery (T6). The 2-month radiograph was missing in 3 patients, and the 6-month and 1-year radiographs were missing in 4 patients.

All radiographs were hand-traced on acetate paper by the same examiner. The clearest radiograph in each patient's series was selected and the details of the cranial base structures were drawn. A x-y cranial base coordinate system was constructed on this radiograph through Sella with the x-axis drawn 7° to the Sella-Nasion line and the y-axis passing through Sella perpendicular to the x-axis. The tracings of the different stages were superimposed on the first radiograph and the reference lines were transferred to the tracing of each consecutive cephalogram. During superimposition particular attention was given to fitting the tracing of the cribriform plate and the anterior wall of the sella turcica, areas that undergo minimal remodeling.[20] The x and y coordinates for the landmarks were registered by digitization to the Dentofacial Planner computer program (Dentofacial Software Inc, Toronto, Canada). The skeletal and soft tissue landmarks identified and the reference lines used are shown in Figure 1. Cephalometric landmark and some measurement definitions are presented in Table 2.

Error of the method and statistical analysis

Twenty-five radiographs chosen at random were traced and digitized by the same investigator on 2 separate occa-

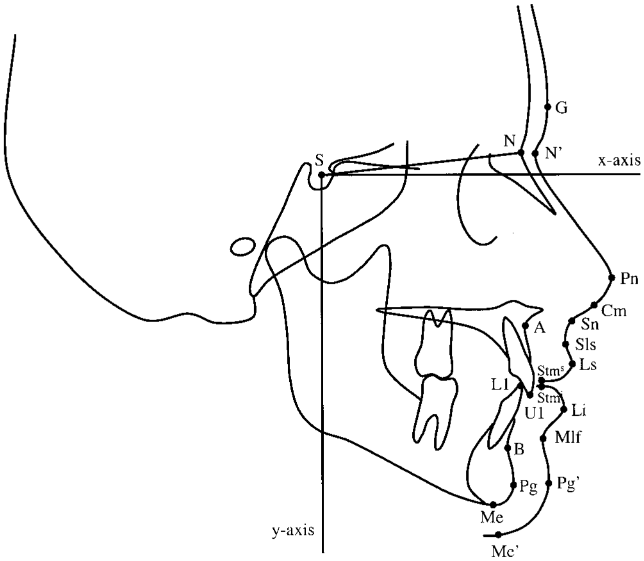

FIGURE 1. Skeletal, soft-tissue, and dental landmarks used in the cephalometric analysis. Definitions are given in Table 2.

sions at least 2 weeks apart. Dahlberg's method[21] was used to determine the error between the duplicate determinations and the coefficient of reliability was also calculated.[22] Systematic error was assessed by a paired *t*-test at the 10% level as recommended by Houston[22] (Table 3).

To test for statistical significance of changes in cephalometric variables between the different stages, Student's *t*-test for paired data was performed. Pearson's coefficients of correlation were calculated to examine relationships between soft tissue and hard tissue changes. The sample was subdivided according to gender and magnitude of surgical setback. *T*-tests for independent samples and analysis of variance (ANOVA) were used to compare soft to hard tissue ratios in these subgroups.

A surgical splint was present in the immediate postsurgical radiographs of 3 patients. Due to the increase in anterior facial height caused by the splints and the resulting influence on soft tissue landmark position, all data based on the immediate postoperative cephalogram (T2) for these 3 patients were excluded.

RESULTS

Mean changes in the various cephalometric parameters for the 80 mandibular setback patients as the immediate result of surgery and in the subsequent observation periods are given in Tables 4 and 5. The amount, timing, and direction of postoperative changes of some soft tissue landmarks are shown in Figure 2.

TABLE 2. Cephalometric Landmark and Some Measurement Definitions

Landmark	Definition
A	The innermost point on the contour of the maxilla between anterior nasal spine and the incisor tooth
B	The innermost point on the contour of the mandible between the incisor tooth and the bony chin
U1	Incision superior; the midpoint of the incisal edge of the most prominent maxillary central incisor
L1	Incision inferior; the midpoint of the incisal edge of the most prominent mandibular central incisor
Me	Menton: the most inferior midline point on the mandibular symphesis
Pg	Pogonion: the most anterior point on the osseous contour of the chin
S	Sella: the center of sella turcica
G	Glabella: the most anterior point on the forehead in the region of the supra-orbital ridges
N	Nasion: the most anterior point of the frontonasal suture
N′	Soft tissue nasion: the deepest point in the soft tissue concavity overlying the naso-frontal suture
Cm	Columella point: the midpoint of the columella of the nose
Pn	Pronasale: the most anterior and prominent point of the nose (tip of the nose)
Sn	Subnasale: the point at which the columella (nasal septum) merges with the upper lip in the midsagittal plane
Sls	Superior labial sulcus: the point of greatest concavity in the middle of the upper lip between subnasale and labrale superius
Ls	Labrale superius: the most anterior point of the upper lip
Stm^s	Stomion superius: the lowermost point on the vermilion of the upper lip
Stm^i	Stomion inferius: the uppermost point on the vermilion of the upper lip
Li	Labrale inferius: the most anterior point of the lower lip
Mlf	Mentolabial fold: the point of greatest concavity in the midline of the lower lip between labrale inferius and soft tissue pogonion
Pg′	Soft tissue pogonion: the most prominent or anterior point on the chin in the midsaggital plane
Me′	Soft tissue menton: the lowest point on the contour of the soft tissue chin
Upper lip inclination	The angle made by the intersection of the line connecting points Ls and Sn and the x-axis
Lower lip inclination	The angle made by the intersection of the line connecting points Mlf and Li and the x-axis
Nasolabial angle	The angle made by the points Cm-Sn-Ls
Mlf depth	Mentolabial fold depth: the distance from point Mlf to a line connecting Li and Pg′
Facial convexity	The angle made by the points G-Sn-Pg′
El	Esthetic line: a line connecting Pn and Pg′

TABLE 3. Error of the Method Assessed From Duplicate Tracings of 25 Radiographs

	Variable	Dahlberg's Calculation	Houston's Coefficient of Reliability	Systematic Error: *t* Test (*P* Value)
Hard tissue				
Horizontal (mm)	B	0.20	99.9	0.261
	Pg	0.25	100.0	0.243
	U1	0.21	99.9	0.509
	L1	0.18	99.9	0.021[a]
Vertical (mm)	Me	0.20	99.9	0.007[a]
Soft tissue				
Horizontal (mm)	Sn	0.53	99.2	0.163
	Sls	0.35	99.7	0.017[a]
	Ls	0.32	99.8	0.241
	Li	0.24	99.9	0.730
	Mlf	0.18	99.9	0.709
	Pg′	0.14	100.0	0.100
	Ls to El	0.56	96.8	0.153
	Li to El	0.23	99.4	0.770
Vertical (mm)	Sn	0.46	99.0	0.654
	Sls	1.01	94.3	0.011[a]
	Ls	0.86	96.1	0.358
	Stm^s	0.37	99.3	0.328
	Stm^i	0.28	99.6	0.809
	Li	0.54	98.8	0.561
	Mlf	0.46	99.2	0.320
	Pg′	0.58	99.1	0.705
	Me′	0.37	99.7	0.018[a]
Thickness (mm)	Sn to A	0.52	95.0	0.056[a]
	Sls to A	0.48	96.0	0.021[a]
	Ls to U1	0.33	99.0	0.084[a]
	Li to Ll	0.3	98.0	0.187
	Mlf to B	0.21	98.0	0.162
	Pg to Pg′	0.23	98.5	0.860
Angular (°)	Nasolabial angle	2.37	96.6	0.581
	Upper lip inclination	2.12	94.0	0.550
	Lower lip inclination	1.50	97.0	0.131
Facial convexity		1.14	97.0	0.008[a]

[a] Significant at the 10 percent level ($P < .1$).

Amount, direction, and time course of soft tissue changes

Upper lip. A posterior repositioning of the upper lip landmarks Sn, Sls, and Ls as an immediate result of mandibular setback was observed. This immediate backward movement was most pronounced at Ls (0.7 ± 1.6 mm; $P < .001$) and gradually decreased in the more superior lip points. Posterior movement of Ls and Sls continued during the postoperative period. At the end of the observation period, the net posterior movement of Ls was 1.6 ± 1.6 mm ($P < .001$). Although the decrease in the distance from Ls to the esthetic line as a result of surgery was 2.0 ± 1.5 mm, only 0.6 ± 1.5 mm ($P < .001$) of this change was maintained at the end of follow-up. Along with the posterior movement of the upper lip landmarks, an accompanying inferior movement could be observed. As an immediate response to surgery, point Stm^s moved down (1.0 mm ± 1.7 mm) and continued to move in an inferior direction throughout the postoperative period to reach a net inferior position of 1.9 ± 1.6 mm ($P < .001$) (Table 5). A straightening of the upper lip as evidenced by the 6.3 ± 5.3° ($P < .001$) decrease in upper lip inclination and the 6.1 ± 6.1° ($P < .001$) increase in the nasolabial angle was also observed. The upper lip thickness decreased, the decrease being most pronounced in the measurement Ls to U1 (2.2 ± 1.9 mm; $P < .001$), but also obvious in measurements Sls to A and Sn to A.

Lower lip and chin. As an immediate effect of mandibular setback, all soft tissue landmarks were relocated in a posterior direction. The greatest change was observed at point Mlf (6.5 ± 3.4 mm; $P < .001$), followed by Pg' (6.0 ± 3.9 mm; $P < .001$) and finally by Li (5.4 ± 3.1 mm; $P < .001$) (Figure 2). During the first 2 months postoperatively, Li moved more posteriorly than Mlf, whereas Pg' did not follow this movement. In the subsequent postoperative intervals the lower lip remained more or less stationary, whereas a reversal in direction of movement at Mlf and Pg' could be seen. Statistically significant anterior movement of Mlf and Pg' then continued throughout the rest of the observation period. Thus, at the end of the follow-up period, point Li demonstrated the greatest amount of posterior relocation (6.5 ± 2.8 mm; $P < .001$) compared to Mlf and Pg' which were relocated 5.9 ± 3.0 mm and 4.5 ± 3.7 mm ($P < .001$), respectively. The distance from Li to the esthetic line showed a net increase of 2.2 ± 2.4 mm ($P < .001$). In the vertical plane, as a direct effect of surgery, points Li and Stm^i showed an inferior movement of 2.3 ± 3.6 mm and 1.8 ± 2.6 mm ($P < .001$), respectively. Postoperatively, Li moved in a superior direction (1.5 ± 2.4 mm $P < .001$) approaching its original preoperative vertical position, whereas Stm^i maintained a net inferior position of 1.5 ± 2.3 mm ($P < .001$). Mean surgical changes in the vertical position of landmarks Mlf, Pg' and Me' were minimal and statistically insignificant. At the end of the observation period, only Me' demonstrated a net superior movement (0.8 ± 1.9 mm $P < .001$).

A change in lower lip inclination (7.7 ± 9.5° $P < .001$) was noted at the time of surgery with the lower lip becoming more procumbent. This initial change then gradually diminished so that, by the end of the observation period, the lower lip had more or less regained its presurgical inclination. An increase in mentolabial fold depth of 0.9 ± 1.3 mm ($P < .001$) was also observed as a result of surgery. At the end of follow-up only 0.4 ± 1.1 mm ($P < .001$) of this deepening was maintained. A slight net decrease in soft tissue thickness at the mentolabial fold region (Mlf-B) (0.3 ± 0.8 mm; $P < .01$) was evident (initial increase followed by a greater decrease). An initial increase in lower lip thickness (Li-L1),

TABLE 4. Changes in Skeletal and Dental Variables Among 80 Mandibular Setback Patients During the Various Time Intervals[a]

Variable	T1–T2[b]		T2–T3[b]		T3–T4		T4–T5		T5–T6	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Skeletal horizontal (mm)[c]										
A	−0.04	0.32	0.07	0.33	0.02	0.30	−0.06	0.26	0.03	0.30
B	−7.00***	3.35	0.35***	0.81	0.53***	0.58	0.20***	0.47	0.27***	0.55
Pg	−6.36***	3.92	0.40***	0.94	0.77***	0.71	0.22**	0.60	0.31***	0.62
Skeletal vertical (mm)[c]										
B	1.08***	1.83	0.46***	0.81	0.30***	0.75	−0.07	0.62	−0.19***	0.48
Pg	1.17***	1.97	0.54***	0.79	0.24*	0.81	0.00	0.68	−0.24***	0.47
Me	1.08***	1.73	0.45***	0.73	0.27***	0.69	−0.03	0.60	−0.22***	0.48
Dental horizontal (mm)[c]										
U1	0.12	0.57	0.30***	0.65	0.23**	0.66	0.01	0.45	0.04	0.58
L1	−7.70***	2.70	0.33***	1.02	0.34***	0.74	0.19**	0.58	0.27***	0.56
Overjet	7.87***	2.62	0.01	1.06	−0.17*	0.70	−0.18**	0.58	−0.22***	0.53
Dental vertical (mm)[c]										
U1	0.04	0.60	0.16**	0.49	0.12	0.54	−0.07	0.43	−0.06	0.39
L1	1.32***	1.90	0.47***	0.87	0.33***	0.74	−0.11	0.65	−0.27***	0.53
Overbite	0.09	1.76	−0.27**	0.87	−0.19*	0.63	0.03	0.69	0.19***	0.48
Dental angular (degrees)[c]										
U1 inclination	0.20	2.54	0.84**	2.37	0.87**	2.61	−0.07	1.94	0.38	2.40
L1 inclination	−0.20	2.54	−0.64*	2.67	−0.71*	2.91	−0.12	2.08	0.26	2.25

[a] T1 indicates within 1 week before surgery; T2, within 1 week after surgery; T3, 2 months after surgery; T4, 6 months after surgery; T5, 1 year after surgery; T6, 3 years after surgery; and SD, standard deviation.

[b] Number of patients equals 77; the 3 patients with the splint in the immediate postoperative radiograph (T2) have been excluded.

[c] Horizontal changes: positive value indicates posterior movement; negative value indicates anterior movement. Vertical changes: positive value indicates superior movement; negative value indicates inferior movement. Dimensional changes: positive value indicates an increase; negative value indicates a decrease.

which gradually decreased again to reach its preoperative dimension, was also observed. Soft tissue thickness at the chin (Pg'-Pg) similarly remained mostly unchanged.

As a result of surgery, facial convexity (G-Sn-Pg') was increased ($5.9 \pm 3.4°$; $P < .001$). About two-thirds of this improvement was maintained at the end of the follow-up period. Composite tracings demonstrating the average profile of the 80 patients before and 3 years after surgery are shown in Figure 3. Values for some of the measurements describing the average soft tissue profile for males and females at the end of follow-up are given in Table 6.

Relation between soft tissue and hard tissue movements

Correlations. Changes in all soft tissue landmarks were found to correlate with movement of their corresponding hard tissue structures. Strongest correlations were generally observed between Pg'-Pg and Mlf-B, followed by Me'-Me and Li-L1. Correlations coefficients between the magnitude of surgical (T1-T2) and net (T1-T6) skeletal change on one hand, and the net (T1-T6) effects on the soft tissue, on the other hand, were calculated and are presented in Table 7. Correlations between the net soft tissue change and the net skeletal change were higher than with the immediate skeletal change. A weak, but significant correlation ($r = 0.33$; $P < .01$) was also found between magnitude of skeletal setback at Pg and horizontal change in upper lip position. In the vertical plane, correlations between soft tissue and hard tissue movements for the chin and mentolabial fold (in the range of 0.4 to 0.5; $P < .001$) were lower than those in the sagittal plane. Correlation coefficients of 0.55 and 0.50 ($P < .001$) were observed between setback at Pg and the vertical change at Stm^s and Stm^i, respectively. Weaker correlations were found between the change in anterior facial height (vertical movement of Me) and these measurements.

No associations were found between skeletal repositioning in the horizontal or vertical plane and the change in soft tissue thickness at the chin, mentolabial fold, the lower lip, or the change in mentolabial fold depth. A weak, but significant correlation was, however, found between the magnitude of setback and the net decrease in upper lip thickness (Ls to U1) ($r = 0.47$; $P < .001$).

Preoperative thickness of both the upper and lower lip was significantly correlated with the net change in their thickness ($r = 0.54$ and $r = 0.36$; $P < .001$, respectively). No similar associations were found for preoperative soft tissue thickness of the mentolabial fold or chin. A significant correlation was, however, found between the preoperative mentolabial fold depth and the net change in its depth ($r = 0.57$; $P < .001$).

Influence of skeletal relapse on postoperative soft tissue changes. Percentages of the net change (T1-T6) of some

TABLE 4. Extended

T2–T6[b]		T1–T6	
Mean	SD	Mean	SD
0.07*	0.29	0.03	0.32
1.25***	0.96	−5.66***	2.99
1.62***	1.20	−4.65***	3.61
0.51***	1.07	1.59***	1.67
0.54***	1.20	1.71***	1.86
0.44***	1.14	1.52***	1.61
0.46***	1.02	0.58***	1.07
1.01***	1.24	−6.61***	2.49
−0.56***	1.26	7.23***	2.76
0.14	0.63	0.16	0.85
0.41**	1.14	1.72***	1.86
−0.25*	1.11	−0.20	1.86
1.55***	3.85	1.74***	4.11
−1.49**	4.07	−1.72***	4.44

soft tissue landmarks and both the net (T1-T6) and surgical movement (T1-T2) of the underlying hard tissue landmarks were calculated (Table 8). Due to the large standard deviations encountered, the 5% trimmed mean is also presented. Percentages of the net soft tissue change to the net skeletal change were generally higher compared to those of the net soft tissue change to the surgical skeletal change.

A paired *t*-test was used to analyze whether the magnitude of postoperative soft tissue changes differed significantly from the amount of relapse of the underlying skeletal landmarks. No statistically significant differences existed between relapse at Pg and Pg' or Me and Me'. Statistically significant differences were found between changes at Mlf and point B, the skeletal landmark moving more anteriorly (0.7 ± 1.1 mm; $P < .001$) than its soft tissue counterpart. Whereas Li showed a postoperative posterior movement, L1 demonstrated an anterior movement resulting in a difference of 2.3 ± 1.7 mm ($P < .001$).

Effect of magnitude of surgical setback on soft tissue changes. The 80 mandibular setback patients were divided into 4 subgroups according to the amount of surgical repositioning at Pg. Patients with setbacks smaller than 3.0 mm formed the small setback group (S), setbacks between 3.0 and 6.0 mm formed the moderately small setback group (MS), setbacks between 6.0 and 9.0 mm the moderately large setback group (ML) and setbacks greater than 9.0 mm the large setback group (L). Ratios of net soft tissue (T1-T6) to net hard tissue (T1-T6) movement for the 4 subgroups were calculated and are presented in Table 9. Group (S) showed the largest variance in soft tissue percentages. Since such ratios with large standard deviations are not clinically useful, this group was excluded from further statistical analysis. Standard deviations for the upper lip, mentolabial fold, and chin in group (L) were smaller compared to groups (ML) and (MS). Standard deviations of the percentages for the upper lip decreased with increasing magnitude of setback. A trend for the percentages of the lower lip and soft tissue chin to decrease from group (L) to group (MS) could also be observed. Statistical comparison (ANOVA) between the 3 subgroups revealed statistically significant differences in the percentages for the lower lip and soft tissue chin only ($P < .05$).

Effect of gender on soft tissue response. Following exclusion of group (S) due to its considerable variability, the remaining 62 patients were divided into male and female subgroups. No statistically significant differences were found between the 2 subgroups in magnitude of setback at Pg, vertical surgical changes at Me, or skeletal relapse. Ratios of net soft tissue (T1-T6) to net hard tissue (T1-T6) movement for the 2 subgroups were calculated and are presented in Table 10. Females generally demonstrated higher percentages of soft tissue movement than males, but the differences were statistically significant for the ratios of Ls: Pg and Pg': Pg ($P < .05$) only.

DISCUSSION

The focus of the present study was to evaluate long-term changes in the soft tissue profile following mandibular setback surgery and investigate the relationship between soft tissue and hard tissue movements. Assessment of the long-term outcome demonstrated considerable facial changes and improvements. Class III patients typically have a concave profile characterized by an upper lip with a turned-up contour that is too far behind the esthetic line, a small nasolabial angle, a protrusive and full lower lip, and a poorly defined mentolabial fold. As a result of treatment, the soft tissue profile was straightened and the lip relationships improved (Figure 4). The patients, however, tended to maintain a somewhat more prognathic profile when compared to untreated adults norms.[23]

In agreement with several other investigators, the mandibular setback surgery resulted in a straightening of the upper lip with a concomitant increase in the nasolabial angle. Upper lip thickness and the distance to the esthetic line also decreased. Gjørup and Athanasiou[15] explained that the upper lip, because of the abnormal incisal relationship before surgery, is kept in a pseudoposition as a form of adaptation and compensation. The achievement of a normal incisal relationship influences the soft tissue overlying the incisors and leads to better lip competence and posture. Techalertpaisarn and Kuroda,[24] utilizing a 3-dimensional digitizing system, found changes in the central portion of the upper lip to be less than at the periphery. They attributed this finding to the support in the central area by the unaltered maxillary bone and teeth, whereas the peripheral

TABLE 5. Changes in Soft Tissue Variables Among 80 Mandibular Setback Patients During the Various Time Intervals[a]

Variable	T1–T2[b]		T2–T3[b]		T3–T4	
	Mean	SD	Mean	SD	Mean	SD
Horizontal (mm)[c]						
Sn	−0.12	0.84	−0.16	0.86	0.00	0.81
Sls	−0.29*	1.19	−0.12	1.05	−0.16	0.98
Ls	−0.68***	1.60	−0.31*	1.17	−0.21	1.25
Li	−5.44***	3.05	−1.05***	1.57	−0.04	1.19
Mlf	−6.52***	3.38	−0.54***	1.39	0.57***	0.85
Pg′	−5.98***	3.87	−0.01	1.16	0.66***	0.94
Ls to El	−2.03***	1.52	0.27*	1.07	0.43***	1.09
Li to El	0.37*	1.60	0.60***	1.50	0.61***	1.10
Mlf depth	0.90***	1.28	0.01	1.00	−0.29**	0.78
Vertical (mm)[c]						
Sn	0.10	0.74	−0.40***	0.85	−0.05	0.79
Sls	−0.16	1.84	−0.72***	1.76	−0.02	1.41
Ls	−0.39	1.80	−0.45**	1.34	−0.48***	1.24
Stm^s	−0.96***	1.72	−0.21	1.10	−0.14	0.90
Stm^i	−1.78***	2.57	0.69***	1.73	−0.04	1.19
Li	−2.26***	3.59	1.23***	2.46	0.63**	1.68
Mlf	0.02	2.80	0.86***	1.88	0.22	1.43
Pg′	0.21	2.80	0.26	1.94	−0.03	1.48
Me′	0.42	1.93	0.82***	1.11	0.11	0.92
Thickness (mm)[c]						
Sn to A	−0.07	0.88	−0.23*	0.86	−0.02	0.82
Sls to A	−0.26	1.21	−0.20	1.03	−0.18	0.99
Ls to U1	−0.80***	1.71	−0.60***	1.24	−0.43**	1.28
Li to L1	2.21***	3.22	−1.40***	1.51	−0.39*	1.33
Mlf to B	0.48***	1.07	−0.88***	1.08	0.04	0.67
Pg′ to Pg	0.38***	0.90	−0.41***	0.89	−0.11	0.69
Angular (degrees)[c]						
Nasolabial angle	2.56***	5.92	1.39*	5.10	0.53	4.71
Upper lip inclination	−2.45***	5.93	−0.79	4.51	−0.82	4.12
Lower lip inclination	−7.68***	9.54	2.41**	7.24	3.06***	5.23
G-Sn-Pg′	5.86***	3.39	−0.47*	1.66	−0.64***	1.55

[a] T1 indicates within 1 week before surgery; T2, within 1 week after surgery; T3, 2 months after surgery; T4, 6 months after surgery; T5, 1 year after surgery; T6, 3 years after surgery; and SD, standard deviation.
[b] Number of patients equals 77; the 3 patients with the splint in the immediate postoperative radiograph (T2) have been excluded.
[c] Horizontal changes: positive value indicates posterior movement; negative value indicates anterior movement. Vertical changes: positive value indicates superior movement; negative value indicates inferior movement. Dimensional changes: positive value indicates an increase; negative value indicates a decrease.
* $P < .05$.
** $P < .01$.
*** $P < .001$.

portions were more influenced by the mandibular setback. The observation in the present study of an increase in upper lip length of approximately 2 mm, with subsequent reduction in maxillary incisor exposure, delineates the need for careful treatment planning especially in patients who have a starting low lip line.

The increase in inclination and curvature of the lower lip, frequently described by other authors,[3–5,11,15] was not supported by the findings of the present study. The initial increase in lower lip inclination was not maintained due to the lesser posterior movement of point Li compared to Mlf and Pg’ at surgery and the original inclination was regained 1 year postoperatively (probably related to resolution of edema). In contrast to the mentolabial fold and chin, where anterior movement in response to skeletal relapse of the underlying skeletal structures was observed, the lower lip reached a state of equilibrium within the first 6 months after surgery (Figure 2). Why the lower lip was not similarly affected by skeletal changes could be partly explained by the retroclination of the lower incisors as a compensation for skeletal relapse. The increase in distance of the lower lip to the esthetic line and the deepening of the mentolabial fold observed in the present study are in agreement with several other reports. The increase in mentolabial fold depth is most probably related to the decrease in soft tissue thickness in that area.

TABLE 5. Extended

T4–T5		T5–T6		T2–T6[b]		T1–T6	
Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.04	0.66	−0.01	0.68	−0.15	0.84	−0.25**	0.81
−0.08	0.82	0.07	1.01	−0.42**	1.29	−0.64***	1.14
−0.26*	0.92	−0.14	1.09	−1.01***	1.37	−1.63***	1.56
−0.20	1.01	0.11	0.97	−1.21***	1.74	−6.54***	2.77
0.25**	0.77	0.33***	0.69	0.49**	1.60	−5.94***	3.00
0.30**	0.79	0.57***	0.88	1.37***	1.58	−4.51***	3.76
0.33**	0.88	0.34**	1.08	1.41***	1.21	−0.63***	1.51
0.34***	0.87	0.34***	0.91	1.89***	1.92	2.20***	2.38
−0.26***	0.62	0.02	0.55	−0.80***	0.84	0.43***	1.10
0.09	0.73	−0.35***	0.67	−0.63***	0.70	−0.54***	0.76
−0.30	1.46	−0.16	1.08	−1.06***	1.59	−1.21***	1.54
−0.17	1.31	−0.82***	1.34	−1.76***	1.39	−2.15***	1.74
−0.11	0.90	−0.43***	0.74	−0.90***	1.19	−1.85***	1.63
−0.03	1.21	−0.30**	0.91	0.33	1.91	−1.48***	2.33
0.04	1.50	−0.21	1.32	1.52***	2.41	−0.79*	3.02
0.00	1.59	−0.51**	1.47	0.58*	2.13	0.55	2.60
0.10	1.71	−0.81***	1.78	−0.43*	1.90	−0.24	2.69
0.04	0.87	−0.58***	0.77	0.38*	1.33	0.77***	1.89
0.10	0.70	−0.04	0.73	−0.23*	0.89	−0.27**	0.81
−0.01	0.84	0.03	1.01	−0.51***	1.30	−0.69***	1.18
−0.26*	0.93	−0.17	1.19	−1.46***	1.52	−2.20***	1.88
−0.38***	0.92	−0.16	1.09	−2.17***	3.52	0.07	1.68
0.06	0.66	0.06	0.59	−0.76***	1.15	−0.28**	0.79
0.07	0.64	0.26**	0.77	−0.24	1.10	0.15	0.96
0.56	4.16	0.99*	4.28	3.53***	5.29	6.10***	6.07
−1.25**	3.58	−0.71	3.40	−3.93***	4.30	−6.31***	5.33
1.91***	4.56	1.25**	3.88	8.07***	6.72	0.40	8.07
−0.27	1.27	−0.64***	1.39	−1.91***	1.66	3.92***	3.37

Ratios of soft tissue to hard tissue movements

An accurate prediction of the postoperative facial profile is an essential step of the treatment planning process for combined surgical orthodontic therapy. As computers become more powerful and software more intuitive, computerized prediction tracings and videoimaging procedures for planning orthognathic surgery are increasing in popularity. The database upon which commercially available surgical prediction software packages are based has been derived from studies that have either reported mean ratios of soft tissue to hard tissue movements or provided linear regression equations. Ratios generated for the present sample of 80 patients are generally comparable to those described by other authors (Table 11). Due to the high individual variability encountered, it was considered appropriate to report the 5% trimmed mean rather than the absolute mean value for the total sample to discount for the effect of some of the outliers and to provide clinically useful data. Percentages for the upper lip (25%), lower lip (100%), and mentolabial fold (106%) are somewhat higher than figures previously reported. The percentage for the chin (94%) is intermediate between values reported in other studies.

While experience and research[25,26] have shown the use of software based on such data to be clinically helpful, it is important to realize that the computerized prediction of soft tissue profile changes following orthognathic surgery is not a precise science and that treatment forecasts are likely to be only as accurate as the database utilized. Arguments against the accuracy of such predictions include: (1) large individual variability in soft tissue response (eg, soft-tissue thickness, tonicity, posture, muscle pull, etc); (2) differences in skeletal stability among patients operated with the same procedure; (3) difficulty in executing the surgical procedure exactly as planned; and (4) inaccuracies inherent in the cephalometric method itself used to generate the predictions. Realizing these shortcomings while acknowledging the clinical usefulness of treatment simulations, there clearly is room for further improvement and refinement of the currently available database. The large number of patients followed in the present study permitted dividing the

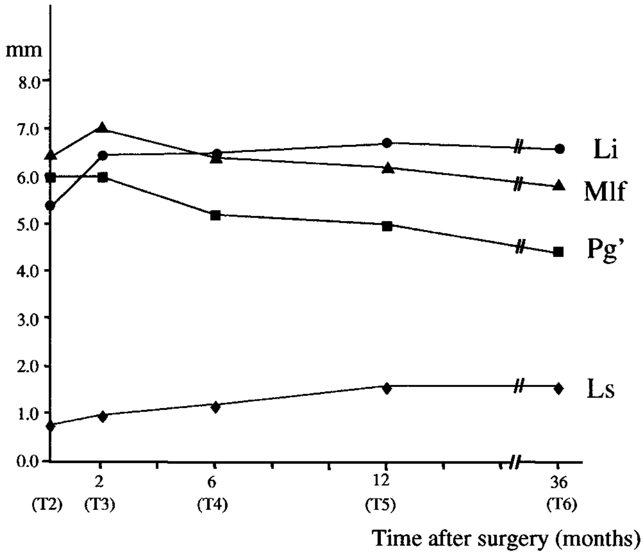

FIGURE 2. Postsurgical horizontal changes at soft tissue Pogonion (Pg'), Mentolabial fold (Mlf), Labrale inferius (Li), and Labrale superius (Ls) among the 80 mandibular setback patients expressed as a function of time. The zero point on the horizontal axis represents the immediate response to surgery measured within 1 week after surgery (T2).

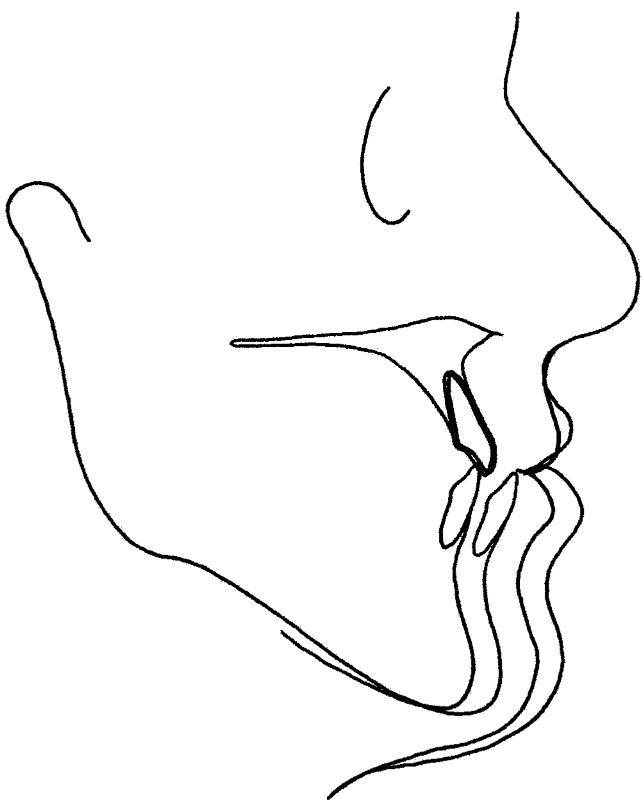

FIGURE 3. Composite tracings illustrating soft tissue profiles before treatment and 3 years after surgery for the 80 mandibular setback patients.

TABLE 6. Mean Values and One Standard Deviation Describing the Soft Tissue Profiles for Male and Female Setback Patients 3 Years After Surgery[a]

	Males (n = 46)		Females (n = 34)	
Variable	Mean	SD	Mean	SD
Facial convexity (G-Sn-Pg′) (degrees)	6.8	6.9	6.3	5.6
Nasolabial angle (degrees)	103.1	13.3	109.9	9.7
Upper lip to esthetic-line (mm)	7.6	2.7	7.8	2.0
Lower lip to esthetic-line (mm)	4.6	2.7	5.1	2.7

[a] n indicates number of patients; SD, standard deviation.

TABLE 7. Pearson Correlation Coefficients Between Hard Tissue Movement and Soft Tissue Changes[a,b]

Soft Tissue	Hard Tissue	HT (T1–T6) vs ST (T1–T6) (n = 80)	HT (T1–T2) vs ST (T1–T6) (n = 77)
Ls	Pg	0.44**	0.33*
Li	Ll	0.80**	0.78**
Li	Pg	0.82**	0.78**
Mlf	B	0.97**	0.92**
Mlf	Pg	0.93**	0.89**
Pg′	Pg	0.97**	0.92**
Me′	Me	0.88**	0.78**

[a] HT indicates hard tissue; vs, versus; ST, soft tissue; T1–T6, net changes; and T1–T2, surgical changes.
[b] All changes are in the horizontal plane with the exception of Me′-Me.
* $P < .01$.
** $P < .001$.

TABLE 8. Percentages of Soft Tissue Changes to Hard Tissue Movement[a]

	ST (T1–T6) : HT (T1–T6) (n = 80)			ST (T1–T6) : HT (T1–T2) (n = 77)		
	Mean	SD	5% Trimmed Mean	Mean	SD	5% Trimmed Mean
Ls : Pg	63.8	369.3	25.2	34.5	133.8	26.6
Li : Ll	102.1	32.7	99.9	87.9	26.5	87.1
Mlf : B	108.8	30.5	106.4	62.2	243.2	85.8
Pg′ : Pg	104.1	130.6	94.0	70.2	58.1	67.9

[a] ST indicates soft tissue; T1–T6, net changes; HT, hard tissue movement; and T1–T2, surgical changes. n, number of patients; and SD, standard deviation.

sample according to gender and magnitude of surgical repositioning and investigating the impact of skeletal relapse. Analyzing these variables revealed influences in postsurgical soft tissue response with possible clinical implications.

Are soft tissue changes accompanying a large mandibular setback as predictable as those with a small setback? Con-

TABLE 9. Percentages of Net (T1–T6) Soft to Hard Tissue Movement Among Setback Patients[a]

		Large Setbacks (>9 mm) n = 20		Moderately Large Setbacks (6–9 mm) n = 22		Moderately Small Setbacks (3–6 mm) n = 20		Small Setbacks (<3 mm) n = 18	
ST	HT	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ls	Pg	31.1	16.7	18.4	25.8	32.4	53.8	206.5	817.1
Li	Ll	107.9	25.7	101.0	25.8	85.6	24.4	117.0	51.2
Mlf	B	101.8	9.9	106.0	13.6	103.9	16.9	127.7	59.5
Pg′	Pg	100.6	9.5	98.6	16.2	81.7	37.3	144.2	287.8

[a] n indicates number of patients; ST, soft tissue; HT, hard tissue; and SD, standard deviation.

TABLE 10. Percentages of Net (T1–T6) to Hard Tissue Movement Among Male and Female Setback Patients Following Exclusion of Patients with the Smallest Setbacks

		Males (n eq 39)		Females (n = 23)	
ST	HT	Mean	SD	Mean	SD
Ls	Pg	19.3	28.8	39.9	42.2
Li	Ll	96.9	27.4	100.4	21.4
Mlf	B	101.7	13.6	107.7	13.3
Pg′	Pg	88.7	23.2	102.4	25.9

[a] n indicates number of patients; ST, soft tissue; HT, hard tissue; and SD, standard deviation.

FIGURE 4. Pre- and post-treatment photographs of a mandibular setback patient.

trary to what may be expected, the results of the present study indicate that soft tissue changes following small setbacks are less predictable compared to large setbacks. This is clearly reflected by the large standard deviations of the percentages for the small setback group (Table 9). The reason for the poor predictability with small setbacks may be related to the fact that there usually is a relatively greater rotation of the distal segment with a greater component of vertical repositioning in such cases. Results of the present study indicate that changes in the vertical dimension are less predictable than in the horizontal plane. The influence of the correction of the anterior crossbite and normalization of incisal relationship may also be more influential than the setback per se. Such findings imply extra skepticism when using computerized predictions in cases to receive small mandibular setbacks. Statistical analysis also indicates that soft-tissue to hard-tissue ratios for the lower lip and chin gradually decreased with decreasing magnitude of setback ($P < .05$).

The other question is related to the effect of gender on soft tissue changes. The use of ratios rather than absolute measurements in the present study has eliminated the effect of size differences between males and females. Our findings indicate that soft tissue movement in response to skeletal repositioning is somewhat greater in females than in males (statistically significant for the upper lip and chin, $P < .05$). The issue of gender difference has previously been addressed by a study on a Chinese sample.[18] Interestingly, the authors found statistically significant differences ($P < .05$) between the sexes in soft-to-hard tissue change ratios for the lower lip and the chin, with females demonstrating higher ratios than males (12% and 11% difference for the soft tissue chin and lower lip, respectively). The authors attributed these differences to the greater soft tissue thickness in males compared to females. What is the clinical relevance of these findings? Higher ratios for females compared to males observed in the present study (20% and 14% difference for the upper lip and soft tissue chin, respectively) indicate that utilization of separate prediction data based on gender would probably be a step forward towards a more accurate prediction.

Another factor investigated was soft tissue thickness and preoperative morphology. Results of the present study reveal associations between the preoperative thickness of both the upper and lower lip and the net change in thickness (r = 0.54 and 0.36 $P < .001$, respectively) in the sense that the greater the preoperative soft tissue thickness, the greater the expected change. A significant correlation was also found between the preoperative mentolabial fold depth and the net change in its depth (r = 0.57 $P < .001$). Even for the areas where a relationship between preoperative morphology and soft tissue thickness apparently exists, correlation coefficients are probably too weak to provide clinically useful predictions. This is in agreement with the conclusions of Gjørup and Athanasiou[15] and Chunmaneechote and Friede[17] who found low regression coefficients when testing if the soft tissue thickness at lip and chin regions

TABLE 11. Literature Review of Soft Tissue to Hard Tissue Ratios Following Mandibular Setback Surgery[a]

Study	Surgical Procedure	Number of Patients	Follow-Up Period
Bjork et al, 1971[6]	Transverse ramus osteotomy	22 (10)	1 y and (11 y)
Robinson et al, 1972[7]	Subcondylar osteotomy or BSSO	10	
Hershey and Smith, 1974[8]	Oblique sliding osteotomy	24	>6 m
Lines and Steinhäuser, 1974[9]	VRO	8	>6 m
Suckiel and Kohn, 1978[10]	Unspecified	50	3–6 m
Kajikawa, 1979[11]	Curved oblique (20) and body osteotomy (13)	33	Unspecified
Willmot, 1981[12]	Several varieties of setback surgery	26	1 y
Fanibunda, 1989[13]	VRO	33	9 m–7 y
Lew et al, 1990[14]	VRO or BSSO	25	12–26 m
Gjørup and Athanasiou, 1991[15]	VRO (extraoral)	50	5–22 m
Ingervall et al, 1995[16]	BSSO with RIF	29	14 m
Chunmaneechote and Friede, 1999[17]	VRO	23	>5.4 m
Hu et al, 1999[18]	Intraoral oblique or VRO	25 females 18 males	6–12 m
Gaggl et al, 1999[19]	BSSO	60	3–4 m
Present study	BSSO with RIF	80	3 y

[a] y indicates years; m, months; BSSO, bilateral sagittal split osteotomy; VRO, vertical ramus osteotomy; and RIF, rigid internal fixation.

could act as predictors of the ratios of soft to hard tissue changes.

An additional factor to consider when predicting long-term profile changes following orthognathic surgery is the effect of skeletal relapse. Previous studies providing prediction data for mandibular setback surgery have calculated the ratios between the amount of change in hard and soft tissues over the same interval (net soft tissue change to net skeletal setback) and stated that the soft tissue chin and mentolabial fold generally follow their corresponding bony structures in an almost 1:1 relation.[6–19] When calculated in the same way, our data also demonstrate a ratio close to 1:1. In the present study we attempted to provide, besides the soft to hard tissue ratios calculated over the same interval, alternative ratios that incorporate the effect of mean long-term skeletal relapse (Table 8). When relapse was accounted for, ratios for all mandibular structures dropped, the drop gradually increasing from the lower lip (12%) to the mentolabial fold (20%) to the soft tissue chin (27%). By expressing the long-term soft tissue changes as a percentage of surgical skeletal setback, rather than as a percentage of the long-term skeletal change, prediction ratios are obtained that are likely to generate a more realistic estimate and one that is more appropriate to demonstrate to the patient.

Despite several sources of inaccuracy, a profile prediction for mandibular setback surgery continues to be a valuable tool as it still can provide a useful estimate that facilitates communication and treatment planning. Taking the various factors investigated in the present study in consideration, different soft to hard tissue algorithms may be created for various situations. Thus different values may for example be applied for a female with a large setback as compared to a male where a small setback is planned. If in addition, average relapse is also accounted for, it is likely that an even more realistic long-term prediction is obtained. Since the newer versions of computerized prediction software allow the user to modify the soft to hard tissue ratios, it is recommended that these data should be adjusted, based on gender, magnitude of skeletal repositioning and each team's own long-term stability data for mandibular setback surgery. A future study designed to compare computerized predictions based on these modifications with the actual postoperative patient profiles should be undertaken to confirm the usefulness of the present findings.

CONCLUSIONS

The main effects of mandibular setback surgery on the soft tissue profile included an increase in facial convexity, straightening and lengthening of the upper lip with a concomitant increase in nasolabial angle, and deepening of the mentolabial fold.

Changes in the soft tissue profile following small setbacks were less predictable compared to large setbacks. Females demonstrated greater soft tissue movement in response to skeletal repositioning compared to males (statistically significant for the upper lip and chin; $P < .05$).

Correlations of preoperative soft tissue thickness and the net change in soft tissue thickness as a result of mandibular setback surgery were too weak to provide clinically useful predictions.

Changes in facial esthetics following orthognathic surgery are highly dependent on skeletal stability of the surgical procedure. If a more realistic long-term estimate of the resulting profile is desirable, it is proposed that mean relapse be accounted for.

A modification of the database utilized in commercially available prediction software that accounts for gender, magnitude of skeletal repositioning, and each team's own long-term stability data for mandibular setback surgery is likely

TABLE 11. Extended

Amount of Setback	Upper Lip	Lower Lip	Mentolabial Fold	Chin
	16% to Pg	100% to Ll		100% to Pg
			100% to B	100% to Pg
	20% to Pg	60% to Pg	80% to Pg	90% to Pg
	20% of setback	75% to Ll		100% to Pg
		67% to Pg	95% to B	96% to Pg
		83% to Ll		
7.4 and 8.4 mm	15% and 25% to Pg	66% and 75% to Ll	92% and 112% to B	80% and 104% to Pg
	10% to Pg	80% to Ll	87% to B	92% to Pg
	44% to Ll	74% to Ll	107% to B	94% to Pg
	(−11%)–20% to Pg	67% to Ll	89% to B	95% to Pg
	15% to Pg	82% to Pg	93% to Pg, 103% to B	91% to Pg
6 mm at Pg	23% to Pg	88% to Ll	106%	107%
7.7 mm at Pg	15% to Pg	84% to Pg	96% to Pg, 97% to B	96% to Pg
7.6 mm at B	34% to B	82% to Ll	92% to B	106% to Pg
8.1 mm at B	26% to B	71% to Ll	90% to B	94% to Pg
7.1 mm at Pg	32% to Pg	83% to Ll		84%
6.3 mm at Pg	25% to Pg	100% to Ll	106% to B	94% to Pg

to improve the accuracy of computerized treatment simulations.

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