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Original article

Short-term hard and soft tissue changes after mandibular advancement surgery in Class II patients: a retrospective cephalometric study

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Summary

Aim: The aim of this study was to describe hard and soft tissue changes after mandibular advancement surgery and to investigate the possible differences between Class II facial patterns.
Materials and methods: Lateral cephalograms of 109 patients who underwent combined orthodontic treatment and bilateral sagittal split osteotomy (BSSO) were studied. Radiographs were taken within 6 weeks before surgery (T0) and at least 6 months postoperatively (T1). Patients were classified into 3 groups according to the preoperative mandibular plane angle. Hard- and soft-tissue changes were analysed with an x-y cranial base coordinate system. Measurements were evaluated statistically.
Results: Soft and hard tissues of the chin moved forward and downward. The position of the upper lip remained unchanged, while the lower lip moved forward and upward and decreased in thickness. The soft tissue points of the chin follow their corresponding skeletal points almost completely, while the change of the lower lip was only 76 per cent of the movement of the underlying hard tissue. The increase of SNB was more evident in the low-angle group, as well as improvement of the facial convexity. Stomium superius moved more forward in the low- and medium-angle cases. Ratios of hard and soft tissue changes showed no differences for different facial patterns.
Limitations: Limitations derived from the retrospective study design. Only short-term changes could be addressed. The distinction between surgical changes and changes due to skeletal relapse is difficult to assess. Also, the difficulty to reproduce a relaxed lip position during imaging may influence our results.
Conclusion: Class II characteristics improved after mandibular advancement. Soft tissues of the chin follow their skeletal structures almost in a 1:1 relationship, while movement of the lower lip was less predictable. The facial pattern of Class II patients should be considered in treatment planning.

Introduction

Facial appearance is very important in our modern society and plays a crucial role in social interactions (1). Attractive individuals seem to be viewed as more successful at work, having better social skills and appear to have higher self-esteem (2). Nowadays, more and more adults are seeking treatment to improve dental and facial aesthetics. Therefore, combined orthodontic-orthognathic correction has become a common treatment plan. The goal of this treatment procedure is to establish a functional occlusion and correct skeletal relationship, as well as improve facial aesthetics. Since overall patient's satisfaction after orthognathic surgery depends on the position of the soft tissues, it is important to comprehend their response to skeletal repositioning (3). Proper prediction of the postoperative soft tissue profile is necessary for accurate diagnosis and treatment planning in combined surgical-orthodontic treatment. Furthermore, patients expect to obtain detailed information about facial changes after surgery.

Since 1972, several authors studied the hard to soft tissue response after mandibular advancement surgery (4–19). In literature, there seems to be a consensus for the soft tissue chin, varying from 90 to 127 per cent of the advancement of pogonion (12). For the response of the lower lip, results are more divergent, ranging from 35 to 108 per cent (12). Therefore, the postoperative position of the lower lip is still less predictable. Different factors may contribute to the complexity of soft tissue response such as posture, individual morphology, thickness and tonicity of soft tissues (14, 20).

Only few articles address the differences in postoperative soft tissue behaviour among different facial patterns. Until now, the influence of the characteristics of high- and low-angle Class II facial patterns on postoperative soft tissue changes remains unclear.

The aims of this study were to: 1. describe soft tissue changes 6 months after mandibular advancement surgery in Class II patients, 2. investigate to which extent soft tissue changes correlate to the movement of the underlying hard tissue, 3. compare postoperative changes between different Class II facial patterns.

Materials and methods

This study was registered and approved by the medical ethics committee of the University Hospitals Leuven, with the registration number S57380.

Sample selection

This retrospective cephalometric study consisted of 109 patients (77 females and 32 males) with a Class II malocclusion, who underwent combined orthodontics and bilateral sagittal split osteotomy (BSSO) advancement between 2009 and 2015. All patients were surgically treated by the same surgeon. In all cases, similar surgical techniques were used and rigid internal fixation according to Tulasne (21) was applied. The mean surgical advancement at B-point was 4.88 mm (IQR 3.32–6.19 mm). Only patients with standardized lateral cephalograms of sufficient quality and resolution were included. Patients with congenital malformations and patients who underwent additional orthognathic and facial surgery such as maxillary osteotomy, genioplasty and rhinoplasty were excluded. The sample size was thus determined by the number of patients meeting the inclusion criteria during the considered time period. The mean age of the patients was 26.6 years (range 14.6–56.2 years). The subjects were categorized into 3 groups according to the preoperative mandibular plane angle of Steiner's analysis (22). 24 patients represented the low-angle group (SnGoGn ≤27 degrees), 63 patients the medium-angle group (27 degrees < SnGoGn > 37 degrees) and 22 patients the high-angle group (SnGoGn ≥37 degrees). Presurgical patient characteristics for the different facial patterns are presented in Table 1.

Selection of radiographs

Lateral cephalograms were obtained before surgery after presurgical orthodontic decompensation (mean 1.3 months; IQR 25–40 days) at T0 and at T1 at least 6 months after surgery (mean 6.2 months; IQR 6.0–6.3 months) with brackets in situ. All lateral cephalograms were taken with the subject standing upright, with teeth in centric occlusion and the lips in relaxed position. Radiographs were only selected in case of adequate quality, and standardization and all landmarks had to be readily identifiable.

Preoperative lateral cephalograms were taken after presurgical orthodontic decompensation to minimize the effect of orthodontic treatment on the soft tissues. Postsurgical radiographs at least 6 months after surgery were used to eliminate the effects of transient soft tissue edema. Patients who had completed orthodontic treatment at T1 were excluded to rule out the effect of the bracket removal on the lips.

Of the original data collection of 232 subjects, 9 patients were rejected due to poor radiograph image quality, 79 patients were excluded due to completion of orthodontic treatment at 6 months after surgery and 35 patients were ruled out because follow-up radiographs were lacking.

Radiographs of patients treated between 2009 and 2012 were taken with an Orthophos XG (Sirona Group, Bensheim, Germany). A Veraviewepocs 2D (J. Morita Co., Kyoto, Japan) was employed between 2013 and 2014. Since 2015, lateral cephalograms were obtained with a Planmeca ProMax® 2D (Planmeca Inc., Helsinki,

Table 1. Presurgical characteristics of the different Class II facial patterns.

Variable at T0	Low-angle SnGoGn ≤27°		Medium-angle 27° < SnGoGn > 37°		High-angle SnGoGn ≥37°		*P*
	Mean	SD	Mean	SD	Mean	SD	
Gender							0.141
Male	11/24		16/63		5/22		
Female	13/24		47/63		17/22		
Age (years)	26.60	12.51	26.50	11.90	26.80	11.49	0.884
SNA (°)	83.90	2.88	80.40	3.73	79.00	4.15	<0.001*
SNB (°)	78.40	2.84	74.60	3.19	71.80	3.72	<0.001*
ANB (°)	5.50	1.92	5.80	1.89	7.10	2.64	0.069
SNGoGn (°)	22.70	3.08	32.10	2.79	41.90	4.52	<0.001*
Overbite (mm)	3.30	1.52	3.20	1.88	2.40	2.23	0.100
Overjet (mm)	8.30	1.92	6.90	1.96	7.10	2.59	0.032
Mlf depth (mm)	7.20	1.89	8.20	1.76	9.10	2.21	0.015
Gl'-Sn-Pog' (°)	–17.90	6.81	–18.6	5.04	–20.00	6.13	0.706
Nasolabial angle (°)	108.80	11.39	110.00	8.77	107.20	12.67	0.713

**P* values smaller than 0.01 are considered significant.

Finland). Magnification for linear measurements was 1.13 for Planmeca Promax® 2D and 1.10 for both Orthophos XG and Veraviewepocs 2D. Magnification was accounted for by calibration of the cephalograms with an embedded ruler.

Cephalometric assessment

All lateral cephalograms were digitally analysed with the OnyxCeph3TM software (Image Instruments, Chemnitz, Germany). An x-y cranial base coordinate system was constructed on the radiographs through nasion. The x-axis was drawn 7 degrees to the sella-nasion line, the y-axis passing through nasion perpendicular to the x-axis. The postoperative tracing was imposed on the first radiograph by structural superimposition on the cribriform plate and the anterior wall of the sella tursica. Figure 1 shows the skeletal, soft tissue and dental landmarks and reference lines used in the cephalometric analysis. Definitions of landmarks and measurements are presented in Table 2. X and Y coordinates for the landmarks and conventional cephalometric variables were established by the OnyxCeph3TM software (Image Instruments, Chemnitz, Germany).

Error of the method and statistical analysis

To determine reproducibility of the measurements, 20 subjects were randomly selected and digitized by the same investigator at least 1 month apart. Inter-observer reliability was also evaluated on 20 random subjects, digitized by another investigator at least 1 month apart. The ICC(A,1) following McGraw KO and Wong SP (1996) has been used.

Changes of measurements between presurgical and postsurgical situation were evaluated with the Signed rank test. Note that differences were calculated as postsurgical value (T1) minus presurgical value (T0). Kruskal Wallis tests were used to compare changes between groups. Associations amongst ordinal/continuous variables were verified with Spearman correlations. The slope (and 95% CI) from a linear regression model was reported to verify if the changes (T1–T0) in hard and soft tissue were of similar magnitude.

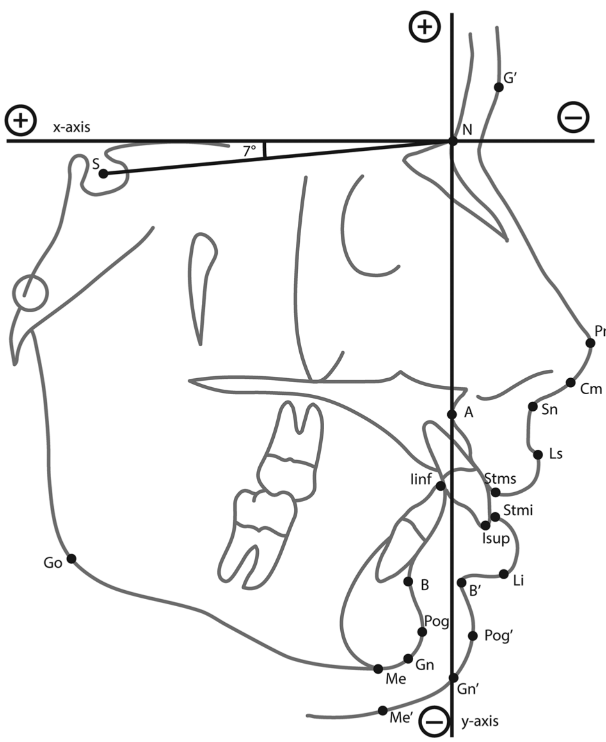


Figure 1. Landmarks and reference planes used in cephalometric analysis.

Given the large number of verified relations, P values were only considered significant if smaller than 0.01 (instead of the classical 0.05) to reduce the probability of false positive results. (23) Still, a single significant P value should be interpreted with caution.

All analyses have been performed using SAS software, version 9.4 of the SAS System for Windows.

Results

Inter- and intra-observer reliability is presented in Table 3 and Table 4. Mean pre- and postsurgical coordinates and surgical changes of hard and soft tissue landmarks are presented in Table 5. Concerning the mean surgical changes, negative values indicate a forward movement and positive values a backward movement of the landmarks in the horizontal plane. In the vertical direction, negative values indicate a downward movement and positive values an

Table 2. Definition of cephalometric landmarks and measurements.

Landmark	Definition
S	Sella: center of sella tursica
N	Nasion: most anterior point of frontonasal suture
A	Innermost point on contour of maxilla between anterior nasal spine and incisor tooth
B	Innermost point on contour of mandibula between incisor tooth and bony chin
Pog	Pogonion: most anterior point on osseous contour of chin
Me	Menton: most inferior midline point on mandibular symphysis
Gn	Gnathion: most inferior anterior point on the outline of the bony chin
Go	Gonion: point at the angle of the mandible
Isup	Incision superior: midpoint of incisal edge of most prominent maxillary central incisor
Iinf	Incision inferior: midpoint of incisal edge of most prominent mandibular central incisor
Pn	Pronasale: most anterior and prominent point of nose (tip of nose)
Cm	Columella point: midpoint of columella of nose
Sn	Subnasale: point at which columella (nasal septum) merges with upper lip in midsagittal plane
Ls	Labrale superius: most anterior point of upper lip
Li	Labrale inferius: most anterior point of lower lip
Stms	Stomion superius: most inferior point of upper lip
Stmi	Stomion inferius: most upper point of lower lip
B’	Soft tissue B point: point of greatest concavity in midline of lower lip between labrale inferius and soft tissue pogonion
Pog’	Soft tissue pogonion: most prominent or anterior point on chin in midsagittal plane
Me’	Soft tissue menton: lowest point on contour of soft tissue chin
Gn’	Soft tissue gnathion: most inferior anterior point of the soft tissue chin
Max1-NF	U1 angle: upper central incisor to palatal plane angle
Mand1-MP	L1 angle: lower incisor to mandibular plane angle
II	Interincisal angle
G’-Sn-Pog’	Facial convexity: angle between soft tissue glabella, subnasale and soft tissue pogonion
Cm-Sn-Ls	Nasolabial angle: angle between columella and labrale superius
Mlf depth	Mentolabial fold depth: horizontal distance from B’ to Li

Table 3. Inter-observer reliability based on 20 subjects.

	Inter-observer reliability		
Measurement	ICC	SEM	RC
Pog(x)	0.932	2.239	6.201
B(x)	0.921	2.100	5.818
A(x)	0.910	1.278	3.541
Isup(x)	0.910	1.669	4.623
Ls(x)	0.903	1.658	4.592
Pog'(x)	0.917	2.498	6.921
N(y)	–0.494	0.344	0.953
Pog(y)	0.966	1.523	4.219
B(y)	0.775	3.322	9.201
A(y)	0.783	1.956	5.419
Isup(y)	0.949	1.123	3.111
Ls(y)	0.920	1.316	3.646
Pog'(y)	0.932	2.072	5.740
II(°)	0.858	3.200	8.863

ICC, intra-class correlation; SEM, Standard error of measurement; RC, Reproducibility coefficient (calculated as 2.77*SEM) which expresses the range of plausible differences between two repeated measures (i.e. the half width of the 95%CI for differences between two repeated measurements).

upward movement. Mean changes for the high-angle, medium-angle and low-angle group are given in Table 6.

Changes of landmarks after mandibular advancement surgery

Skeletal changes

Horizontal

The anterior movement of the bony chin was significant and similar for all landmarks ($P < 0.0001$). The mean advancement (T1–T0) was 5.01 mm at pogonion, 5.06 mm at gnathion, 5.11 mm at menton, and 4.88 mm at B-point. The position of A-point showed no significant changes.

Vertical

The skeletal landmarks of the chin also showed an even absolute downward movement: 2.16 mm at pogonion, 2.18 mm at gnathion, 2.30 mm at menton, and 2.23 mm at B-point. ($P < 0.0001$) Again, there was no significant change at A-point.

For horizontal and vertical changes, there were no significant differences found between high- and low-angle subjects.

Angular

After surgery, the skeletal distal relationship significantly improved. The mean ANB-angle changed from 6.01 degrees to 2.98 degrees due to forward movement of the mandible, of which the position (SNB) improved from 74.88 degrees to 77.81 degrees ($P < 0.0001$). Increase of the SNB-angle was more evident ($P = 0.007$) in the low-angle group with on average 3.50 degrees ± 1.07, while high- angle patients showed a lower increase of 2.7 degrees ± 1.52 ($P = 0.015$). Also, ANB decreased more in the low-angle group with 3.60 degrees ± 0.99 ($P = 0.019$). The mandibular plane angle (SN-GoGn) showed a mean significant increase of 1.21 degrees ± 1.89 ($P < 0.0001$).

Dental changes

Horizontal

Incision inferior translated forward by 4.49 mm ($P < 0.0001$). The mean overjet changed from 7.27 mm to 3.01 mm, with a mean decrease of 4.23 mm ($P < 0.0001$). Also, incision superior moved slightly forward by 0.41 mm ($P < 0.001$). Incision superior moved slightly forward in the low-angle group, while it moved backward in the high-angle cases ($P = 0.01$). However, changes for incision superior were very small and clinically irrelevant.

Table 4. Intra-observer reliability based on 20 subjects.

	Intra-observer reliability		
Measurement	*ICC*	*SEM*	*RC*
N(x)	0.308	0.456	1.262
Me(x)	0.987	1.033	2.861
Pog(x)	0.987	0.991	2.746
Gn(x)	0.987	1.032	2.860
B(x)	0.984	0.959	2.656
A(x)	0.973	0.709	1.964
Isup(x)	0.976	0.865	2.397
Iinf(x)	0.955	1.250	3.463
Sn(x)	0.963	0.891	2.468
Ls(x)	0.974	0.871	2.413
Stm-s(x)	0.964	1.023	2.835
Stm-i(x)	0.970	0.988	2.737
Li(x)	0.980	0.910	2.520
B'(x)	0.984	0.922	2.555
Pog'(x)	0.987	0.985	2.729
Gn'(x)	0.978	1.417	3.924
Me'(x)	0.974	1.542	4.270
N(y)	0.099	0.378	1.048
Me(y)	0.988	0.871	2.412
Pog(y)	0.954	1.781	4.934
Gn(y)	0.986	0.969	2.685
B(y)	0.974	1.110	3.074
A(y)	0.964	0.792	2.193
Isup(y)	0.976	0.769	2.131
Iinf(y)	0.978	0.777	2.152
Sn(y)	0.966	0.730	2.021
Ls(y)	0.970	0.800	2.215
Stm-s(y)	0.969	0.782	2.166
Stm-i(y)	0.979	0.727	2.014
Li(y)	0.981	0.829	2.298
B'(y)	0.984	0.810	2.245
Pog'(y)	0.947	1.829	5.066
Gn'(y)	0.978	1.187	3.288
Me'(y)	0.984	1.013	2.806
SNA(°)	0.982	0.544	1.506
SNB(°)	0.988	0.467	1.293
ANB(°)	0.983	0.337	0.934
OB(mm)	0.875	0.599	1.659
OJ(mm)	0.990	0.270	0.749
Max1-NF(°)	0.965	1.391	3.853
Mand1-MP(°)	0.940	1.822	5.048
II(°)	0.962	1.645	4.557
Gl'SnPog'(°)	0.969	1.108	3.068
CotgSnLs(°)	0.943	2.429	6.729
SNGoGn(°)	0.969	1.258	3.485
[Sn-A]	0.915	0.749	2.075
[Ls-Isup]	0.994	0.187	0.519
[Li-Iinf]	0.988	0.243	0.672
[B-B']	0.981	0.284	0.788
[Pog-Pog']	0.827	1.110	3.074

ICC, intra-class correlation; SEM, Standard error of measurement; RC, Reproducibility coefficient (calculated as 2.77 × SEM) which expresses the range of plausible differences between two repeated measures (i.e. the half width of the 95%CI for differences between two repeated measurements).

Vertical

A significant downward movement of 1.94 mm was seen for incision inferior ($P < 0.0001$). Overbite decreased with 1.46 mm, from 3.03 mm at T0 to 1.57 mm at T1 ($P < 0.0001$). Changes for incision superior were not significant.

Angular

Angulation of the upper incisor (Max1-NF) and the interincisal angle (II) showed no significant changes after surgery. Angulation of the lower incisor (Mand1-MP) decreased significantly with 2.42° ($P < 0.0001$).

For vertical and angular changes, there were no significant differences found between high- and low-angle patients.

Soft tissue changes

Horizontal

No significant changes were observed for labrale superius. However, there were differences between the growth patterns ($P = 0.009$) for stomium superius, which moved more forward in the low- and medium-angle subjects ($P = 0.018$ and $P = 0.003$, respectively) Concerning the lower lip, labrale inferius showed a very significant forward movement of 3.76 mm ($P < 0.0001$). All soft tissue landmarks of the chin moved forward: 4.81 mm at soft tissue pogonion, 4.92 mm at soft tissue gnathion, 4.94 mm at soft tissue menton, and 4.75 mm at soft tissue B-point ($P < 0.0001$). For the changes of the lower lip and soft tissue chin, no differences were found between the different facial patterns.

Vertical

No significant postsurgical changes were noticed for the upper lip. Regarding the lower lip, labrale inferius and stomium inferius moved upward by 1.17 mm ($P < 0.0001$) and 0.58 mm ($P = 0.0003$) correspondingly. Soft tissue landmarks of the chin were relocated downward after mandibular advancement ($P < 0.0001$). Soft tissue pogonion moved downward by 1.59 mm, soft tissue gnathion by 1.85 mm, soft tissue menton by 2.03 mm, and soft tissue B-point by 1.87 mm.

Thickness

Soft tissue thickness of the upper lip at Ls-Isup showed no significant change. Decrease of thickness of the lower lip by 1.89 mm was evident ($P < 0.0001$). Also, depth of the mentolabial fold decreased by 0.99 mm ($P < 0.0001$). Concerning soft tissue thickness of the chin, the only significant change was a decrease of Me-Me' by 0.34 mm ($P = 0.0011$).

Angular

There was no important change in nasolabial angle after surgery. On the other hand, reduction of facial convexity was highly significant (5.29 degrees ± 2.76; $P < 0.0001$). $P =$ Facial convexity had a tendency to improve more in the low-angle group (6.70 degrees ± 2.57) than in high-angle cases (5.60 degrees ± 3.21) ($P = 0.011$).

Relationship between landmarks

Correlations

Spearman correlation coefficients between hard and soft tissue changes are presented in Table 7. There was a strong correlation of the horizontal change of Li, B', Pog', Gn', and Me' with the horizontal change of pogonion. Landmarks closer to pogonion showed a stronger correlation. For these points there was also a good correlation in vertical direction, although correlation of Li was somewhat weaker.

Furthermore, changes of all soft tissue points of the mandible showed a significant positive correlation with the movement of their corresponding skeletal structures. In horizontal direction, correlation was highly significant for Pog-Pog', followed by B-B', Me-Me', and Iinf-Li. Vertically, correlation was strongest for Me-Me', Pog-Pog', B-B', and Iinf-Li, respectively.

A weak negative correlation was found between presurgical thickness of the lip and postsurgical vertical change of soft tissue B-point. This implies a more downward movement of soft tissue B-point when the presurgical thickness of the lower lip is higher. No significant correlation was found for the horizontal change of soft tissue B-point and vertical and horizontal change of Li with the presurgical thickness of the lip.

No significant correlation was found for the presurgical thickness of the soft tissue chin at Me-Me' and Pog-Pog' and changes of soft tissue pogonion and soft tissue menton landmarks.

Ratio of hard and soft tissue changes

To evaluate if hard and soft tissue changes were equal in magnitude, changes of some soft tissue landmarks and their underlying hard tissue structures are presented in Figure 2 as scatterplots. If for every subject the changes of hard and soft tissue points are equal, all points would fall on the identity line. The slope from the linear regression is reported to show the average value, i.e. equal to 1 if changes in hard and soft tissues are on average equal in magnitude. The slope (95% CI) was found to be 0.981 for Pog':Pog, 0.928 for B':B, Me':Me 0.923, and lowest for Li:Iinf with 0.756. All changes are in the horizontal plane with exception of Me':Me. The soft tissue landmarks of the chin follow the change of the corresponding hard tissue points almost completely (>90 per cent). On the other hand, change in soft tissue of the lower lip is only 75.6 per cent of the change in hard tissue. No significant differences were found between between low-angle and high-angle subjects.

Discussion

In our study, we evaluated short-term hard and soft tissue changes after mandibular advancement surgery in 109 patients. Our sample consisted of more than twice as many females than males, which implies that mostly females are seeking treatment. This was also found in previous studies (11, 12, 24).

Postsurgical lateral cephalograms of at least 6 months after surgery were selected to rule out the effect of soft tissue edema immediately after surgery. According to literature, postoperative swelling is fully resolved after 6 months (10). Another criterion for X-ray selection was that brackets still had to be *in situ* to eliminate positional changes on upper and lower lip due to bracket removal. As a result of these strict selection criteria, we were only able to evaluate short-term changes in a range of 6 to 8.5 months after mandibular advancement surgery.

Concerning dental changes, we found a very small but statistical significant forward movement of incision superior of 0.41 mm. This change is probably due to the finishing phase of orthodontic treatment. However, this small movement is clinically irrelevant. We also noticed a mean decrease in angulation of the lower incisor of 2.42 degrees. This finding might be a result of establishing frontal contact between lower and upper incisors by mandibular advancement surgery and orthodontic finishing.

Our results suggest no significant effect of surgery on the position of the upper lip in vertical and horizontal direction. This seems to be in agreement with previous authors, who either found no effect (5, 7) or only clinically irrelevant changes (11, 24, 25). In literature, an initial anterior movement of the upper lip was reported immediately after surgery due to postoperative swelling, which gradually faded (7, 11, 12, 24). In the long-term, a posterior relocation of labrale superius has been reported especially in low-angle patients (24).

Table 5. Pre- and postsurgical coordinates (T0 and T1) and surgical changes (T1-T0) of hard and soft tissue landmarks.

Landmark	Coordinate at T0		Coordinate at T1		Change T1-T0		*P*
	Mean	SD	Mean	SD	Mean	SD	
Skeletal							
Horizontal (mm)							
Me(x)	16.93	8.69	11.82	8.70	−5.11	2.40	<0.0001*
Pog(x)	11.98	8.20	6.97	8.27	−5.01	2.23	<0.0001*
Gn(x)	13.48	8.56	8.42	8.60	−5.06*	2.30	<0.0001*
B(x)	13.10	7.11	8.22	7.24	−4.88*	1.99	<0.0001*
A(x)	1.86	4.28	1.82	4.32	−0.04	0.65	0.9964
Vertical (mm)							
Me(y)	−112	7.70	−114	7.96	−2.30	2.02	<0.0001*
Pog(y)	−106	8.06	−108	8.37	−2.16	2.29	<0.0001*
Gn(y)	−110	7.92	−112	8.18	−2.18	2.10	<0.0001*
B(y)	−94.4	6.73	−96.7	7.05	−2.23	2.67	<0.0001*
A(y)	−57.1	4.19	−57.3	4.24	−0.15	0.67	0.0274
Angular (°)							
SNA	80.89	4.00	80.79	4.09	−0.09	0.60	0.1148
SNB	74.88	3.87	77.81	4.01	2.93	1.18	<0.0001*
ANB	6.01	2.13	2.98	2.04	−3.03	1.21	<0.0001*
SN-GoGn	31.88	7.17	33.09	6.90	1.21	1.89	<0.0001*
Dental							
Horizontal (mm)							
Isup(x)	−1.08	5.59	−1.49	5.60	−0.41	1.24	0.0010*
Iinf(x)	5.94	5.36	1.45	5.42	−4.49	2.12	<0.0001*
Overjet	7.27	2.14	3.01	0.78	−4.23	2.19	<0.0001*
Vertical (mm)							
Isup (y)	−78.2	5.02	−78.3	5.00	−0.09	1.31	0.5620
Iinf(y)	−74.7	5.12	−76.6	5.20	−1.94	1.88	<0.0001*
Overbite	3.03	1.90	1.57	1.09	−1.46	1.98	<0.0001*
Angular (°)							
Max1-NF	111.7	7.91	112.6	7.09	0.89	3.61	0.0118
Mand1-MP	96.12	7.53	93.70	7.11	−2.42	4.13	<0.0001*
II	126.7	9.18	127.7	7.76	0.94	6.76	0.1514
Soft tissue							
Horizontal (mm)							
Ls(x)	−13.2	5.35	−13.5	5.42	−0.28	1.50	0.0978
Stms(x)	−5.54	5.29	−6.59	5.47	−1.05	1.58	<0.0001*
Stmi(x)	−4.44	5.64	−6.32	5.55	−1.88	2.11	<0.0001*
Li(x)	−6.15	6.15	−9.91	6.09	−3.76	2.24	<0.0001*
B'(x)	2.03	6.74	−2.72	6.87	−4.75	2.09	<0.0001*
Pog'(x)	0.45	8.48	−4.36	8.31	−4.81	2.41	<0.0001*
Me'(x)	18.18	9.14	13.24	9.33	−4.94	3.31	<<0.0001*
Gn'(x)	5.89	9.35	0.97	9.23	−4.92	3.06	<0.0001*
Vertical (mm)							
Ls(y)	−69.2	4.56	−69.0	4.76	0.12	1.57	0.5280
Stms(y)	−75.2	4.36	−75.1	4.59	0.11	1.47	0.4754
Stmi(y)	−77.3	4.98	−76.7	5.17	0.58	1.61	0.0003*
Li(y)	−87.0	5.86	−85.9	6.25	1.17	2.02	<0.0001*
B'(y)	−91.5	6.31	−93.3	6.52	−1.87	2.29	<<0.0001*
Pog'(y)	−105	7.73	−107	8.12	−1.59	2.89	<0.0001*
Me'(y)	−119	7.79	−121	8.02	−2.03	2.08	<0.0001*
Gn'(y)	−114	7.88	−116	8.20	−1.85	2.70	<0.0001*
Thickness (mm)							
Ls-Isup	11.89	2.45	11.94	2.48	0.05	1.02	0.6159
Li-Iinf	14.72	2.18	12.83	1.78	−1.89	1.37	<<0.0001*
B-B'	11.78	2.12	11.67	2.06	−0.11	1.31	0.2332
Pog-Pog'	11.92	2.73	11.70	2.68	−0.22	1.16	0.0177
Me-Me'	7.60	2.05	7.26	1.91	−0.34	1.09	0.0011*
Mlf depth	8.19	1.96	7.19	2.06	−0.99	1.13	<0.0001*
Angular (°)							
Nasolabial angle	109.2	10.21	108.9	10.37	−0.30	5.15	0.9258
G'-Sn-Pog'	−18.7	5.68	−13.4	5.67	5.29	2.76	<0.0001*

T0, before surgery; T1, at least 6 months after surgery; horizontal changes, negative value implies anterior movement, positive value implies posterior movement; vertical changes, negative value implies inferior movement, positive value indicates superior movement; angular changes, negative value implies decrease, positive value implies increase. *P* values are obtained from Signed rank tests.

**P* values smaller than 0.01 are considered significant.

Table 6. Mean changes (T1-T0), SD, and *P* value for low-angle, medium-angle and low-angle group.

Landmark	Low-angle		Medium-angle		High-angle		*P*
	Mean	SD	Mean	SD	Mean	SD	
Skeletal							
Horizontal (mm)							
Me(x)	−5.6	2.12	−4.8	2.29	−5.4	2.94	0.368
Pog(x)	−5.6	1.89	−4.8	2.17	−5.1	2.69	0.299
Gn(x)	−5.7	2.01	−4.8	2.20	−5.2	2.78	0.219
B(x)	−5.6	1.70	−4.6	1.81	−4.8	2.60	0.083
A(x)	−0.1	0.69	−0.1	0.65	0.2	0.58	0.173
Vertical (mm)							
Me(y)	−2.3	2.61	−2.3	1.95	−2.3	1.52	0.989
Pog(y)	−2.1	2.64	−2.1	2.27	−2.4	2.01	0.820
Gn(y)	−2.3	2.64	−2.1	2.03	−2.3	1.71	0.930
B(y)	−2.0	2.80	−2.3	2.79	−2.2	2.25	0.870
A(y)	0.1	0.78	−0.2	0.58	−0.2	0.78	0.164
Angular (°)							
SNA	−0.0	0.69	−0.0	0.56	−0.4	0.52	0.023
SNB	3.5	1.07	2.8	1.01	2.7	1.52	0.007*
ANB	−3.6	0.99	−2.8	1.09	−3.1	1.55	0.019
SN-GoGn	1.6	1.98	1.3	1.80	0.5	1.94	0.117
Dental							
Horizontal (mm)							
Isup(x)	−0.5	1.01	−0.6	1.32	0.3	0.99	0.010
Iinf(x)	−5.1	2.11	−4.3	1.99	−4.2	2.42	0.170
Overjet	−4.9	2.08	−3.8	1.99	−4.6	2.66	0.137
Vertical (mm)							
Isup (y)	−0.1	1.52	0.0	1.14	−0.4	1.51	0.505
Iinf(y)	−2.1	2.08	−2.0	1.80	−1.6	1.92	0.646
Overbite	−1.6	1.89	−1.6	1.84	−0.9	2.38	0.215
Angular (°)							
Max1-NF	0.3	3.40	1.6	3.74	−0.6	2.97	0.015
Mand1-MP	−3.3	4.49	−2.4	4.34	−1.55	2.92	0.241
II	1.1	5.36	0.2	7.87	2.8	3.92	0.068
Soft tissue							
Horizontal (mm)							
Ls(x)	−0.4	1.35	−0.4	1.68	0.2	1.04	0.261
Stms(x)	−1.2	1.61	−1.3	1.61	−0.2	1.26	0.009*
Stmi(x)	−1.9	1.82	−2.0	2.18	−1.6	2.23	0.512
Li(x)	−4.0	1.73	−3.8	2.33	−3.3	2.50	0.363
B'(x)	−5.3	1.57	−4.7	1.90	−4.5	2.94	0.146
Pog'(x)	−5.6	1.90	−4.5	2.41	−4.8	2.79	0.164
Me'(x)	−6.2	3.19	−4.8	2.90	−4.0	4.19	0.066
Gn'(x)	−5.7	3.12	−4.8	2.82	−4.4	3.58	0.456
Vertical (mm)							
Ls(y)	0.7	1.76	0.1	1.40	−0.3	1.72	0.187
Stms(y)	0.7	1.69	0.0	1.31	−0.3	1.53	0.074
Stmi(y)	0.4	1.87	0.7	1.57	0.5	1.46	0.800
Li(y)	1.2	2.17	1.1	2.00	1.3	2.02	0.962
B'(y)	−2.1	2.77	−1.8	2.12	−1.9	2.27	0.886
Pog'(y)	−1.3	3.64	−1.4	2.66	−2.5	2.56	0.223
Me'(y)	−2.0	2.65	−1.9	2.03	−2.4	1.50	0.496
Gn'(y)	−1.9	3.32	−1.5	2.58	−2.8	2.06	0.107
Thickness (mm)							
Ls-Isup	0.1	1.06	0.0	1.07	0.1	0.87	0.822
Li-Iinf	−2.1	1.14	−1.8	1.44	−2.1	1.40	0.383
B-B'	−0.4	0.80	0.1	1.29	−0.4	1.69	0.135
Pog-Pog'	−0.0	0.66	−0.2	1.32	−0.4	1.11	0.481
Me-Me'	−0.5	0.67	−0.4	1.22	0.1	0.97	0.114
Mlf depth	−1.3	0.92	−0.8	1.05	−1.1	1.48	0.144
Angular (°)							
Nasolabial angle	−0.9	5.56	−0.8	4.99	1.7	4.87	0.227
G'-Sn-Pog'	6.7	2.57	4.7	2.48	5.6	3.21	0.011

Horizontal changes, negative value implies anterior movement, positive value implies posterior movement; vertical changes, negative value implies inferior movement, positive value indicates superior movement; angular changes, negative value implies decrease, positive value implies increase. *P* values are from Kruskal–Wallis tests.

**P* values smaller than 0.01 are considered significant.

Table 7. Spearman correlation coefficients between hard and soft tissue changes.

Change in	Relation with	Spearman (95% CI)		P
Horizontal				
Pog	Li	0.647	(0.520;0.743)	<0.0001*
	B'	0.829	(0.758;0.879)	<0.0001*
	Pog'	0.881	(0.830;0.917)	<0.0001*
	Gn'	0.799	(0.717;0.857)	<<0.0001*
	Me'	0.788	(0.702;0.849)	<0.0001*
B	B'	0.874	(0.820;0.912)	<0.0001*
Me	Me'	0.808	(0.730;0.864)	<0.0001*
Iinf	Li	0.687	(0.571;0.774)	<<0.0001*
Vertical				
Pog	Li	0.486	(0.326;0.616)	<0.0001*
	B'	0.694	(0.580;0.779)	<0.0001*
	Pog'	0.769	(0.677;0.835)	<0.0001*
	Gn'	0.784	(0.697;0.846)	<<0.0001*
	Me'	0.836	(0.767;0.884)	<0.0001*
B	B'	0.613	(0.478;0.717)	<0.0001*
Me	Me'	0.898	(0.854;0.929)	<0.0001*
Iinf	Li	0.451	(0.285;0.588)	<0.0001*
B'	Li-IinfatT0	−0.306	(−0.466;−0.124)	0.0011*

**P* values smaller than 0.01 are considered significant.

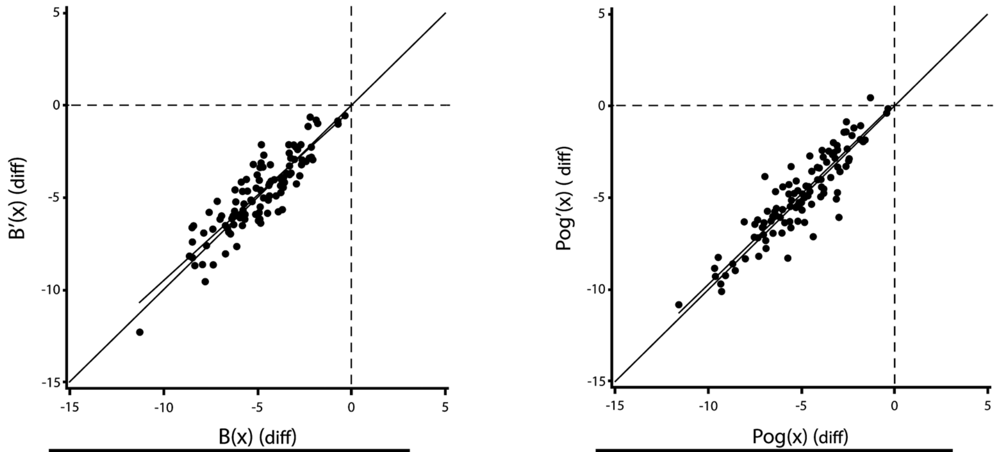
Continuous lowering of labrale superius in the long term may be due to lack of soft tissue strength with age (25). We found no significant changes in the nasolabial angle, which is in contrast with the findings of Mobarak *et al.* (24), who reported an increase of this variable in the low-angle group. Also other authors found an increase of the nasolabial angle (11, 15).

There seems to be some discussion in literature about the behaviour of the lower lip after BSSO advancement. Our results show a significant forward and upward movement, a decrease in thickness and a small decrease of the depth of the mentolabial fold. These findings are also reported in previous studies (5, 7, 9, 12, 24). The decrease in thickness is probably the reason why the anterior movement of labrale inferius is smaller than the landmarks of the soft tissue chin. However, some studies found a correlation between the pre-operative soft tissue thickness and the post-operative response of the lower lip (24). We only reported a correlation between the pre-operative thickness of the lower lip and the vertical movement of the soft tissue B-point. The thicker the lower lip before surgery, the more soft tissue B-point will move downward after mandibular advancement surgery, which implies smoothening of the mentolabial fold. Furthermore, the relationship between the movement of the lower incisor and that of the lower lip shows most variation in literature. In a recent systematic review of Joss *et al.* (25) long-term ratios are reported ranging from 35 to 108 per cent. In our study, we also found that the lower lip followed the lower incisor in lesser extent than Pog':Pog, B':B, and Me':Me, more specific with 76 per cent. Many factors, such as the difficulty to reproduce a relaxed lip position during imaging, bracket removal and individual differences in tonicity, posture and soft tissue morphology account for this variation in results. Also, the lower lip position is mostly supported by the maxillary incisors and thus already maintained in a more forward position.

For the chin, the relationship between hard and soft tissue movements were far more consistent and approached a 1:1 relationship for Pog':Pog, B':B, and Me':Me. Our results were comparable to previous stated ratios, ranging from 88 to 127 per cent. (25) Facial convexity reduced significantly after mandibular advancement surgery, and profile improvement was more evident for the low-angle group. Also, the SNB-angle increased more for the low-angle subjects. This is a remarkable finding, since the mean pre-operative SNB-angle was significantly higher ($P < 0.001$) for the low-angle group (78.4 degrees) than for the high-angle group (71.8 degrees) . This can be explained by the fact that advancement of the mandible in these patients can be performed more straightforward than in high-angle cases, where more clockwise rotation of the mandible occurs during advancement. As far as we observed, only two other studies analysed surgical changes according to growth pattern.(11, 24) No differences were found for the facial convexity between the groups in these studies. However, we need to treat these results with some degree of caution due to weak significance ($P = 0.011$). According to the Class II growth patterns, we only found few differences in our examined variables. This is somewhat surprising, since high-angle and low-angle Class II patients are considered to be two distinct entities with a different treatment approach. Low-angle cases typically have a reduced anterior facial height, a deep bite and a deep mentolabial fold. In these patients, more clockwise rotation of the mandible is desired to improve vertical dimensions. High-angle patients are characterized by an increased anterior facial height, a convex profile with a weak chin, reduced overbite, incompetent lips, and an increased nasolabial angle. Surgical increase in lower anterior facial height is not desirable in this facial pattern. In our retrospective sample however, we only found a significant difference in presurgical patient characteristics between the different facial patterns for SNA and SNB. Variables were evaluated with average values of the subgroups. This may explain why we found no significant differences for horizontal and vertical changes of the lower jaw between high- and low-angle patients.

In our study, we were not able to take skeletal relapse after mandibular advancement surgery into account. It is important to keep in mind that changes between T0 and T1 represent a combination of surgical changes and skeletal relapse. There seems to be some discussion about the timing and amount of skeletal relapse after mandibular advancement surgery. Several authors reported that relapse 6 months after surgery is minimal, ranging from 5.3 per cent – 15 per cent at point B. Keeling et al. (7) found no relapse at the hard tissues of the chin 6 months after surgery, but only a horizontal relapse of the lower lip due to edema in the first 8 weeks. Blomqvist et al. (26) found a somewhat higher amount of short-term relapse of 18.4 per cent. On the other hand, Mobarak et al.(8) reported 33 per cent of relapse at Pog 3 years postoperative, of which most part occurred between 1 week and 2 months and between 1 and 3 years after surgery. High-angle patients showed more skeletal relapse (36 per cent) than low-angle cases (27.6 per cent). For the low-angle group, almost all horizontal relapse (95 per cent) at pogonion took place during the first two months after surgery. Horizontal changes were more progressive in the high-angle group, with 29 per cent of the total relapse occurring within two months, 25.3 per cent between 2 months and 1 year, and 38 per cent between 1 and 3 years after surgery. Low-angle patients seem to have an increased tendency to vertical relapse, while high-angle patients show more horizontal relapse. A recent literature review (27) also reported skeletal relapse in the long-term, with 2–31.4 per cent after 1 year and 60 per cent after 12.7 years. Skeletal relapse is a complex multifactorial process and may be influenced by seating of the condyles, amount of advancement, type of fixation, mandibular plane angle, distal segment rotation, soft tissue and muscle stretch, remaining growth and remodelling and surgeon skills.

Since all surgeries were performed by the same surgeon, no variability in hard or soft tissue changes after mandibular advancement

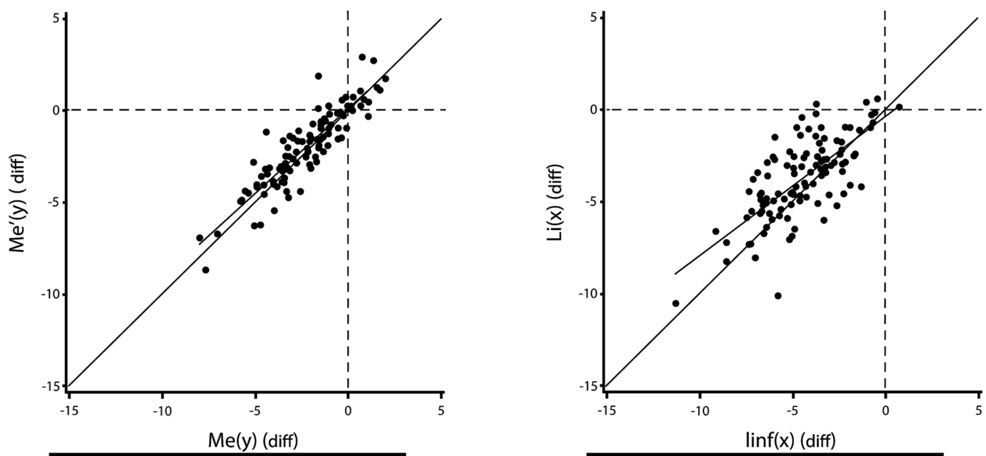


Slope (95%CI) = 0.928 (0.835;1.022)

Pattern	Slope (95%CI)	P-value for interaction
Low-angle	0.828 (0.591;1.065)	
Medium-angle	0.920 (0.784;1.056)	0.4123
High-angle	1.014 (0.852;1.176)	

Slope (95%CI) = 0.981 (0.895;1.067)

Pattern	Slope (95%CI)	P-value for interaction
Low-angle	0.943 (0.719;1.166)	
Medium-angle	0.980 (0.861;1.098)	0.9532
High-angle	0.983 (0.819;1.147)	



Slope (95%CI) = 0.923 (0.835;1.011)

Pattern	Slope (95%CI)	P-value for interaction
Low-angle	0.969 (0.823;1.114)	
Medium-angle	0.924 (0.804;1.043)	0.4340
High-angle	0.773 (0.510;1.035)	

Slope (95%CI) = 0.756 (0.615;0.898)

Pattern	Slope (95%CI)	P-value for interaction
Low-angle	0.632 (0.323;0.941)	
Medium-angle	0.771 (0.572;0.970)	0.5385
High-angle	0.867 (0.585;1.148)	

Figure 2. Scatterplots presenting changes of soft tissue landmarks and their underlying hard tissue structures.

surgery can be attributed to the number of surgeons involved. Different surgeons can use different surgical protocols, can differ in experience or manual dexterity, influencing surgical variables as type of sagittal split, occurrence of bad splits or nerve damage, but once the correction of the overjet is reached, the tooth bearing mandibular fragment is in place, independently of the technique used (28).

Limitations

The study was marked by some limitations derived from its retrospective nature. We were only able to evaluate short-term changes 6 months after mandibular advancement surgery. The distinction between surgical changes and changes due to skeletal relapse is difficult to assess. Also, the difficulty to reproduce a relaxed lip position during imaging may influence our results.

Conclusion

In Class II patients who received mandibular advancement surgery, the following changes could be observed:

- The bony chin changed to a more forward and downward position.
- There was no influence on the upper lip position, while the lower lip moved upward and forward and decreased in thickness. Also a small smoothening of the mentolabial fold was noticed.
- The change of the soft tissue of the lower lip was smaller than the movement of underlying hard tissue, while the soft tissue landmarks of the chin follow the change of the corresponding skeletal points almost completely.
- We also reported some differences between Class II facial patterns:
  - o SNB increased more in low-angle cases, despite a significantly higher mean preoperative value for this group.
  - o The facial convexity had the tendency to improve more in low-angle patients. This can be due to the possibility of a more straightforward surgical advancement in low-angle patients, while in high-angle cases also a clockwise rotation of the mandible occurs during advancement.

- o Stomium superius moved more forward in the low- and medium- angle subjects.
- o For the ratio of hard and soft tissue changes, we found no differences between Class II facial patterns.

Conflict of interest

None to declare.

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