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Original Article

Three-dimensional evaluation of skeletal stability after surgery-first bimaxillary surgery for class III asymmetry in 70 consecutive patients

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Angle class III;
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Abstract *Background/purpose:* Skeletal stability after orthognathic surgery is essential for positive treatment outcome. This study evaluated the stability of osteotomy segments after surgery-first bimaxillary surgery for class III asymmetry.
Materials and methods: Seventy adults with class III asymmetry consecutively corrected through surgery-first Le Fort I and bilateral sagittal split osteotomies were investigated. Cone-beam computed tomography before treatment (T0), 1-week after surgery (T1), and after all treatment (T2, ≥1-year after surgery) was used to assess surgical movement (T0 to T1) and skeletal stability (T1 to T2) regarding the translation and rotation of the maxillary, mandibular distal, and proximal segments.
Results: At T1, the maxillary segment had moved forward and upward, turned to the deviated side, and rotated downward (all $P < 0.01$). The distal segment of mandible had moved forward and upward and rotated upward (all $P < 0.001$). The deviated proximal segment had moved upward, tilted to the opposite side, and rotated upward (all $P < 0.001$). The opposite proximal segment had moved upward and tilted to the deviated side (both $P < 0.01$). At T2, significant relapse occurred in the mandible. The distal segment moved forward and upward and rotated upward (all $P < 0.001$). The deviated proximal segment moved upward, tilted to the opposite

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side, and rotated upward (all $P < 0.001$). The opposite proximal segment moved upward and tilted to the deviated side (both $P < 0.01$).

Conclusion: Clinically significant relapse of class III asymmetry was discovered on the mandibular distal and opposite proximal segments.

Introduction

The incidence of class III malocclusion is high in Asian populations, and mandibular prognathism and deviation are two of the major complaints.[1] Bimaxillary surgery, which includes a Le Fort I osteotomy and bilateral sagittal split osteotomy (BSSO), is often required for correction of class III asymmetry. BSSO is a commonly used surgical technique and has been modified in our center to treat various kinds of mandibular deformities while controlling the risk of nerve injury.[2,3] Especially for asymmetry cases, compared to intraoral vertical ramus osteotomy, the distal and proximal segments would be able to be fixed more flexibly at different inter-segmental angulations or with adjunct interventions of inter-segmental gapping or bone grafting in order to maximize the symmetry results.

Favorable skeletal stability after orthognathic surgery is essential to achieving a positive treatment outcome. The stability of BSSO setback is reported to be worse than that of Le Fort I advancement.[4] A meta-analysis of seven studies revealed no difference in skeletal stability between bicortical screw fixation and monocortical plate fixation for BSSO setback.[5] A large degree of mandibular setback has been cited as a potential risk factor for mandibular relapse.[6–8] For patients with mandibular prognathism and deviation, asymmetric setback through BSSO is usually performed with more extensive movement of the distal segment on the opposite side than the deviated side.[9] This asymmetric setback can cause displacement of proximal segments, and post-surgical movement of these segments may affect the stability of the distal segment.[10] Consequently, the stability of proximal and distal segments after BSSO should be considered when assessing mandibular stability.[11]

Several studies evaluated the skeletal stability of correction of class III asymmetry using BSSO[12–18]; however, most of them were based on two-dimensional radiographic methods,[12,14,18] which are limited by image distortion and magnification, often leading to difficulty in superimposing skeletal structures.[19] Furthermore, although other studies evaluated skeletal stability through three-dimensional (3D) computed tomography, they conducted two-dimensional measurements such as linear and angular measurements rather than 6° of movement measurements for each bony segment.[1,15–17] Therefore, this study investigated the stability of the maxillary and mandibular proximal and distal segments in 6° of movement after surgery-first bimaxillary surgery for class III asymmetry. The null hypothesis of this study was that there would be no significant mandibular relapse at the time of the follow-up.

Materials and methods

Patients

The protocol for this prospective study was approved by the hospital's Institutional Ethics Committee (201802052A3). Informed consent was obtained from all participants. The inclusion criteria were: (1) an age of 18 years or older, (2) skeletal class III deformity (A point–Nasion–B point angle $\leq 0°$) and significant facial asymmetry (menton deviation ≥ 4 mm or lip cant ≥ 2 mm or complaint of significant contour asymmetry), (3) receiving Le Fort I osteotomy and BSSO setback through a surgery-first approach from the same team of surgeons, and (4) receiving post-surgical orthodontic treatment by one senior orthodontist. The study was conducted over a 3-year period. The attending surgeons were supervised by one senior surgeon who had more than 40 years of experience at the Chang Gung Craniofacial Center. The exclusion criteria were: (1) craniofacial anomaly, cleft, or genetic syndrome, or (2) a history of temporomandibular joint disorder, facial bone fracture, craniofacial surgery, or orthodontic treatment.

Virtual surgical planning

3D planning by the Dolphin software (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA) was performed. The maxillo-mandibular complex was moved in three dimensions until a normal jaw relationship (ANB) and symmetry was achieved.

Surgical procedures

Surgery was performed with a maxilla-first sequence. The Le Fort I osteotomy was firstly performed as described by Chu et al.[20] The BSSO was modified from that of Hunsuck by extending the anterior cut of the osteotomy to the first molar and including the mandibular angle within the proximal segment.[2,21] The pterygomasseteric sling was detached. The bilateral medial cortex of the proximal segment was trimmed to reduce the bony interference between the proximal and distal segments. Once the proximal and distal segments had been properly positioned, a pair of 2-hole monocortical plates and screws were used to fix each sagittal split osteotomy of the mandible (Fig. 1). No additional surgery other than genioplasty or mandibular contouring was performed. Genioplasty was performed to improve the patient's profile, proportion or symmetry. Mandibular contouring was performed to improve their

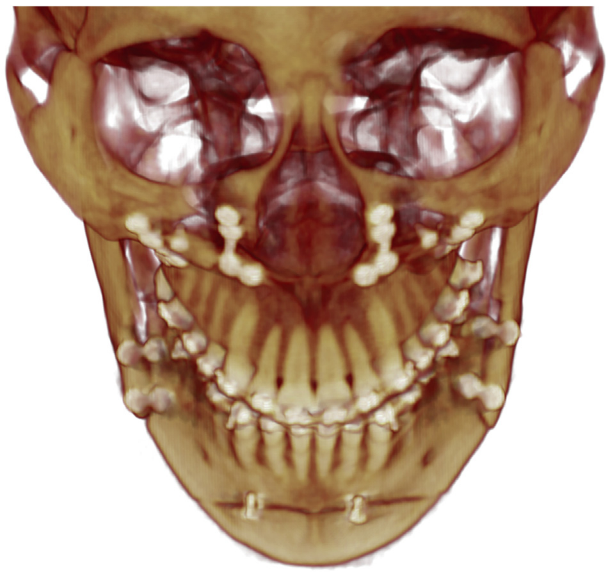

Figure 1 Image of a patient showing the osteosynthesis of the bilateral sagittal split osteotomy.

contour symmetry. No intraoral interarch elastics were used after surgery. After surgery, a liquid diet was generally prescribed in the first 2 weeks and a soft diet the following 2 weeks. Thereafter, a regular diet was permitted.

Cone-beam computed tomography

Cone-beam computed tomography (CBCT) of the head and neck was performed before treatment (T0), 1 week after surgery (T1), and after treatment (at the appointment for orthodontic debonding, at least 1 year after surgery; T2) by using an i-CAT 3D Dental Imaging System (Imaging Sciences International, Hatfield, PA, USA) with the following parameters: 120 kVp, a voxel size of 0.4 mm $\times$ 0.4 mm $\times$ 0.4 mm, a 40-s scan time, and a field of view of 20 cm $\times$ 20 cm. The patient's head was positioned with the Frankfort horizontal plane parallel to the ground. The patient was instructed not to swallow during the scan and to maintain a centric occlusion bite.

Avizo software (v7.0.0, VSG, Bordeaux, France) was used for CBCT measurements by one investigator who was experienced in 3D analysis. Before the analysis, the 3D images were reoriented as shown in Fig. 2. The 3D images were then reflected along the mid-sagittal plane until all the mentons were deviated to the left side (the deviated side). The cranial structures not affected by the surgery were used to superimpose (register) CBCT images taken at T0, T1, and T2 to position them at the same 3D coordinates (x, y, z) with the nasion as the origin. A positive value for the x, y, and z coordinates indicates the left, posterior, and superior side of the face, respectively.

Surgical and post-surgical movement of maxillary and mandibular segments

The position of the segments was determined using three landmarks obtained from CBCT images. Definitions and descriptions of the reference landmarks are presented in Table 1. These landmarks were located on each segment and formed the vertices of a virtual triangle, which contained information on the 3D position and orientation for each segment at all three time points (T0, T1, and T2) (Fig. 3).

Surgical and post-surgical movements of the maxillary, mandibular distal, mandibular proximal deviated and mandibular proximal opposite segments were assessed by calculating the changes in translations and rotations of the virtual triangles through the tip of each triangle (IF for maxillary segment, GT for mandibular distal segment, and SN-d and SN-o for proximal deviated and opposite sides respectively) from T0 to T1 and from T1 to T2.

Reliability

To assess intra-rater error, the investigator performed CBCT measurements twice on 10 randomly selected patients, with the gap between the two measurements for each patient being 2 weeks. Intra-rater reliability, evaluated using the intraclass correlation coefficient (ICC), was excellent (mean ICC $=$ 0.996, 95% confidence interval: 0.966 to 0.999).

Statistical analysis

Statistical analyses were performed using the statistical software package SPSS version 23.0 for Windows (SPSS, Chicago, IL, USA). The Kolmogorov–Smirnov test was used to verify the normality of the data distributions. The one-sample t-test was used to test the movement during surgery (T0–T1) and after surgery (T1–T2, relapse). To account for multiple comparisons, probabilities of less than 0.01 were considered significant.

Results

Patients

A total of 70 patients who met the inclusion criteria were recruited. The baseline characteristics of the patients before surgery are listed in Table 2. The mean age was 24.9 $\pm$ 5.7 years. The patients had an average menton deviation of 5.3 $\pm$ 3.1 mm (range: 0.6–14.7 mm) and a lip cant of 2.6 $\pm$ 1.1 mm (range: 0–7.7 mm). Sixteen percent of the patients received maxillary segmentation, and 67% underwent genioplasty. The mean follow-up time after surgery was 1.8 $\pm$ 0.4 years (T2, range: 1–3.1 years).

Movement during surgery in the facial skeleton: pretreatment to 1-week after surgery

The movement during surgery of the maxilla and mandible are illustrated in Fig. 4. Significant translation and rotation were observed at T1 compared with before treatment (T0), as shown in Table 3. The maxillary segment had moved forward (-1.8 ± 1.5 mm) and upward (0.7 ± 1.5 mm; both $P < 0.001$), turned to the deviated side (yaw: $0.8^\circ \pm 2.0^\circ$, $P < 0.01$), and rotated downward (pitch: $4.0^\circ \pm 4.6^\circ$, $P < 0.001$).

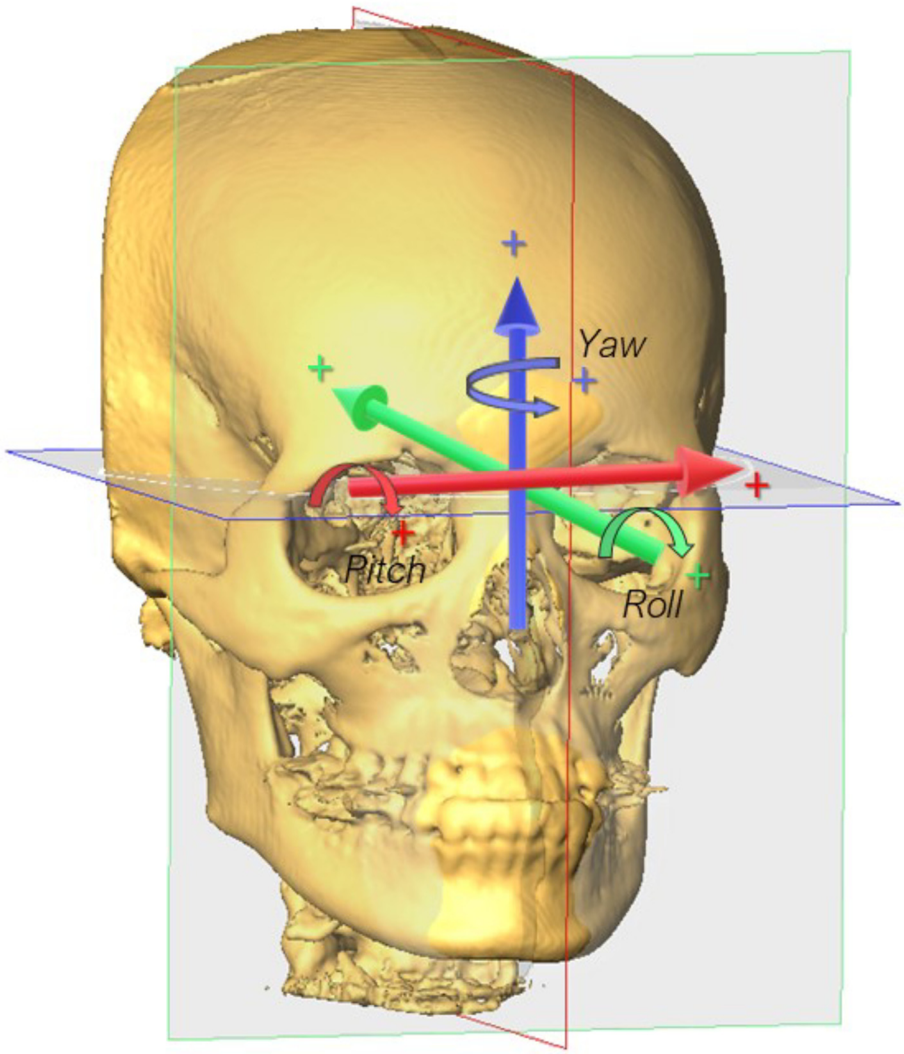

Figure 2 Representative 3D image after head reorientation with 6° of movement in translation and rotation. Head reorientation was based on (1) the midsagittal plane (MSP) passed through the nasion, posterior nasal spine, and basion; (2) the axial plane was perpendicular to the MSP, parallel to the clear side of the porion and orbitale and passing through the nasion; and (3) the coronal plane was perpendicular to the MSP and axial plane and passed through the nasion. Translation: left—right (along the *x*-axis; more to the left: +, more to the right: −), posterior—anterior (along the *y*-axis; more posteriorly: +, more anteriorly: −), and up—down (along the *z*-axis; more cranially: +, more caudally: −). Rotation: pitch (around the *x*-axis; clockwise rotation: +, counterclockwise rotation: −), roll (around the *y*-axis; clockwise rotation: +, counterclockwise rotation: −), and yaw (around the *z*-axis; clockwise rotation: −, counterclockwise rotation: +).

The mandibular distal segment had moved backward (7.9 ± 4.5 mm), shifted to the opposite side (−3.5 ± 3.2 mm), turned and tilted to the opposite side (yaw: −1.5° ± 2.1°; roll: 1.9° ± 2.3°, respectively), and rotated downward (pitch: 4.5° ± 5.6°; all $P < 0.001$). The deviated proximal segment of the mandible had also moved backward (1.0 ± 1.2 mm) and downward (−1.2 ± 1.5 mm), shifted (−0.7 ± 1.0 mm) and turned (yaw: −2.5° ± 3.8°) to the opposite side, and rotated downward (pitch: 3.0° ± 4.0°; all $P < 0.001$). The opposite proximal segment had moved backward (1.4 ± 1.4 mm) and downward (−1.5 ± 1.4 mm), tilted to the opposite side (roll: 2.7° ± 3.4°; all $P < 0.001$), turned to the deviated side (yaw: 1.2° ± 3.6°, $P < 0.01$), and rotated downward (pitch: 2.9° ± 4.1°; $P < 0.001$).

Post-surgical stability of the facial skeleton: From 1-week after surgery to completion of treatment

Fig. 5 illustrates the stability of the maxilla and mandible after surgery. Changes in measurements of translation and rotation between T1 and T2 are shown in Table 4. No significant relapse was found in the maxilla between 1 week after the surgery and after the full treatment.

Table 1 Definition of reference landmarks for virtual triangles.

Landmark	Symbol	Definition
Incisive foramen	IF	The most posterior midpoint of the incisive foramen
Greater palatine foramen, deviated or opposite	GPF-d GPF-o	The most lateroposterior point of the greater palatine foramen on the deviated or opposite side
Genial tubercle, posterior	GT	The most posterior midpoint of the genial tubercle
Mental foramen, deviated or opposite	MF-d MF-o	The most anteroinferior point of the mental foramen on the deviated (d) or opposite (o) side
Sigmoid notch, deviated or opposite	SN-d SN-o	The inferior midpoint of the upper border concavity of the ramus on the deviated or opposite side
Anterior ramus, deviated or opposite	AR-d AR-o	The most anterior midpoint of the anterior border concavity of the ramus on the deviated or opposite side
Posterior ramus, deviated or opposite	PR-d PR-o	The most posterior midpoint of the posterior border of the ramus on the deviated or opposite side

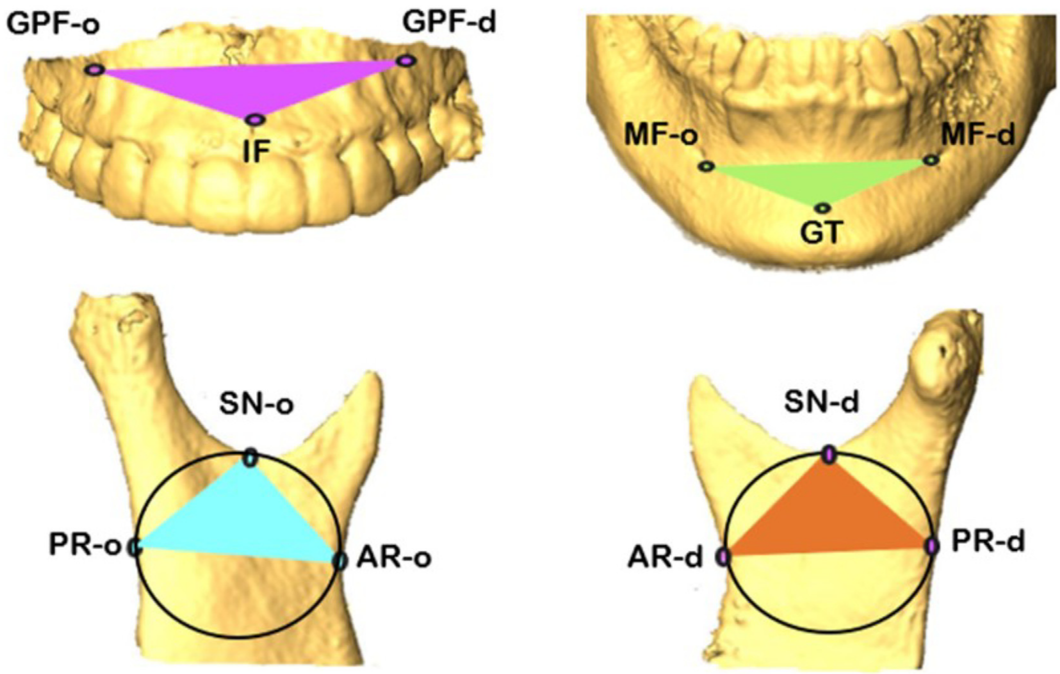

Figure 3 Four triangles in the maxillary and mandibular segments. The maxillary triangle (upper left) was constructed using the incisive foramen (IF), and greater palatine foramens (GPF-o and GPF-d) on both sides. The mandibular distal triangle (upper right) was constructed using the genial tubercle (GT) and mental foramens (MF-o and MF-d) on both sides. The mandibular proximal triangle (opposite [lower left] and deviated [lower right]) was constructed using the sigmoid notch both opposite and deviated (SN-o and SN-d, respectively) and anterior and posterior ramus points both opposite and deviated (AR-o, AR-d; and PR-o, PR-d, respectively).

Significant relapse occurred between T1 and T2 in the mandible. The distal segment moved forward (-1.9 ± 1.6 mm) and upward (1.1 ± 1.5 mm; both $P < 0.001$) and rotated upward (pitch: $-2.9^\circ \pm 2.4^\circ$, $P < 0.001$). The deviated proximal segment moved upward (1.0 ± 1.2 mm, $P < 0.001$), tilted to the opposite side (roll: $1.3^\circ \pm 2.5^\circ$, $P < 0.001$), and rotated upward (pitch: $-1.6^\circ \pm 2.2^\circ$, $P < 0.001$). The opposite proximal segment moved upward (1.0 ± 1.4 mm, $P < 0.001$) and tilted to the deviated side (roll: $-1.1^\circ \pm 3.2^\circ$, $P < 0.01$).

Discussion

Our novel study performed a 3D analysis and used 6° of movement to evaluate surgical movement and skeletal stability after bimaxillary surgery for class III asymmetry. Our study determined the translational and rotational movements of the maxillary segments and proximal and distal segments of the mandible during and after surgery by using a triangular method, which was unaffected by the

Table 2 Demographic and clinical characteristics of patients ($N = 70$).

Characteristic	n (%)	Mean ± SD
Female	35 (50)	
Age at surgery, years		24.9 ± 5.7
Maxillary segmentation, *n* (%)	11 (16)	
Genioplasty, *n* (%)	47 (67)	
Overjet, mm		−3.2 ± 2.1
Overbite, mm		0.6 ± 2.8
Menton deviation to the left, *n* (%)	37 (53)	
Menton deviation, mm		5.3 ± 3.1
Upper anterior occlusal cant, mm		1.2 ± 0.9
Upper posterior occlusal cant, mm		1.8 ± 1.7
Lip cant, mm		2.6 ± 1.1
Upper incisor deviation, mm		1.1 ± 0.8
Lower incisor deviation, mm		3.1 ± 2.0
Duration of postoperative orthodontic treatment, years		1.8 ± 0.4

Abbreviations: SD, standard deviation.

type of osteotomy cut or bone remodeling. The results revealed that at the end of treatment, significant relapses had occurred in the distal and proximal segments of the mandible. Therefore, the null hypothesis was rejected.

Maxillary stability was favorable in all directions (<0.5 mm and <0.5°). This finding corresponded with that of a previous study, which observed that maxillary impaction or advancement was highly stable.[4] The reasons for this high stability may be the fixation to the upper maxilla and bone grafting for maxillary extrusion.[4]

A significant class III relapse was observed in the mandibular distal segment. After surgery, the distal segment had moved forward (mean: 1.9 mm) and upward (mean: 1.1 mm) with a counterclockwise pitch rotation (mean: 2.9°), which led to a class III relapse. The post-surgical relapse of SN-d may have been due to the ability of condyles to return to their original position.[22] In other words, although the deviated condyle was pushed backward and downward during surgery, it tended to return to its original position after surgery. Studies have reported that the clockwise pitch rotation of the proximal segment during setback of the distal segment is a primary risk factor affecting stability of symmetric BSSO setback.[11,23–25]

Counterclockwise pitch rotation of the distal segment of the mandible after BSSO setback is relatively common in a surgery-first approach.[6,26,27] The pitch relapse can be partly due to (1) bite settling after the removal of occlusal interference during post-surgical orthodontic treatment[6,27,28] and (2) rehabilitation of the pterygomasseteric sling, which is routinely detached during BSSO setback at our center.[6] Although relatively unstable surgical occlusion in the surgery-first approach may affect the post-surgical stability of the facial skeleton, studies have demonstrated that the distribution or amount of surgical occlusal contact is unrelated to post-surgical maxillary or mandibular

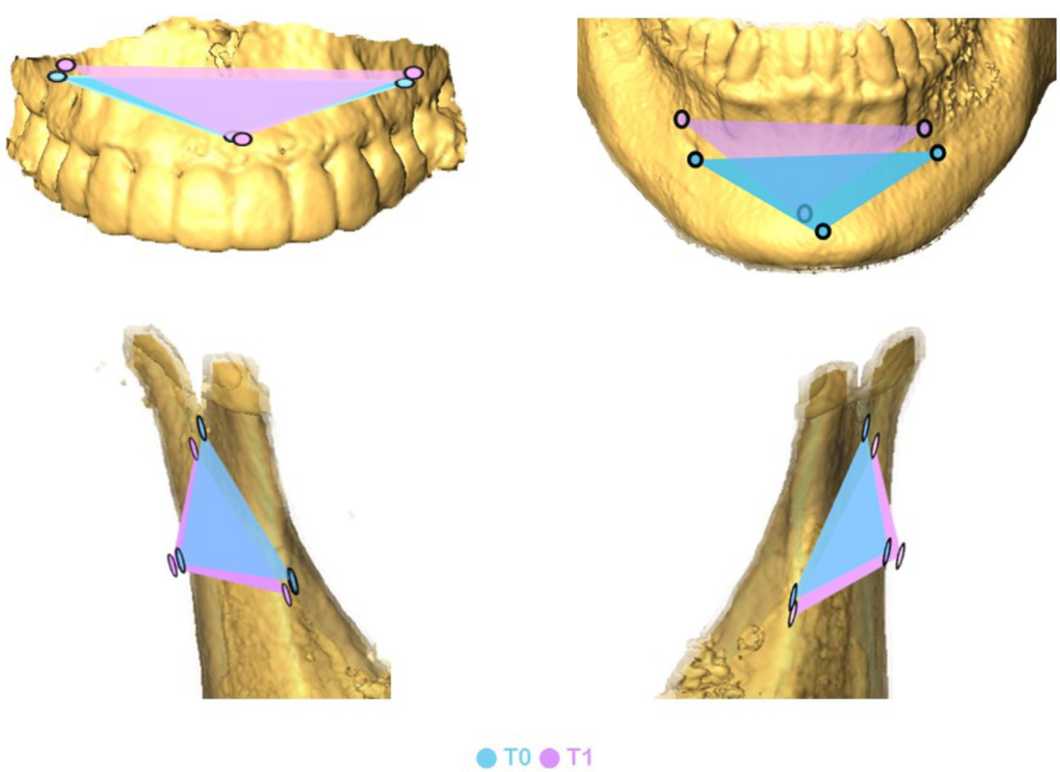

Figure 4 Representative 3D images of movement during surgery (T0—T1) in the maxillary and mandibular segments. Maxillary (upper left), mandibular distal (upper right), and mandibular proximal segments both opposite (lower left) and deviated (lower right). Blue triangle = T0, pink triangle = T1.

Table 3 Movement of segments in the facial skeleton from pretreatment (T0) to 1 week after surgery (T1).

	Maxillary segment		Mandibular distal segment		Mandibular proximal segment, deviated		Mandibular proximal segment, opposite	
Movement	Mean ± SD	*P*	Mean ± SD	*P*	Mean ± SD	*P*	Mean ± SD	*P*
Translation, mm								
Left–right[a]	−0.2 ± 1.2	0.140	−3.5 ± 3.2	<0.001	−0.7 ± 1.0	<0.001	0.1 ± 1.0	0.550
Posterior–anterior[b]	−1.8 ± 1.5	<0.001	7.9 ± 4.5	<0.001	1.0 ± 1.2	<0.001	1.4 ± 1.4	<0.001
Up–down[c]	0.7 ± 1.5	<0.001	−0.1 ± 2.5	0.756	−1.2 ± 1.5	<0.001	−1.5 ± 1.4	<0.001
Rotation, °								
Pitch[d]	4.0 ± 4.6	<0.001	4.5 ± 5.6	<0.001	3.0 ± 4.0	<0.001	1.2 ± 3.6	0.008
Roll[e]	0.7 ± 3.5	0.113	1.9 ± 2.3	<0.001	0.5 ± 3.7	0.269	2.7 ± 3.4	<0.001
Yaw[f]	0.8 ± 2.0	0.002	−1.5 ± 2.1	<0.001	−2.5 ± 3.8	<0.001	2.9 ± 4.1	<0.001

Abbreviations: SD, standard deviation.
[a] A positive value indicates that the segment was located more to the left (deviated side) compared with pretreatment; a negative value indicates that the segment was located more to the right (opposite side) compared with pretreatment.
[b] A positive value indicates that the segment was located more posteriorly compared with pretreatment; a negative value indicates that the segment was located more anteriorly compared with pretreatment.
[c] A positive value indicates that the segment was located more cranially compared with pretreatment; a negative value indicates that the segment was located more caudally compared with pretreatment.
[d] A positive value indicates a clockwise rotation around the *x*-axis compared with pretreatment; a negative value indicates a counterclockwise rotation around the *x*-axis compared with pretreatment.
[e] A positive value indicates a clockwise rotation around the *y*-axis compared with pretreatment; a negative value indicates a counterclockwise rotation around the *y*-axis compared with pretreatment.
[f] A positive value indicates a clockwise rotation around the *z*-axis compared with pretreatment; a negative value indicates a counterclockwise rotation around the *z*-axis compared with pretreatment.

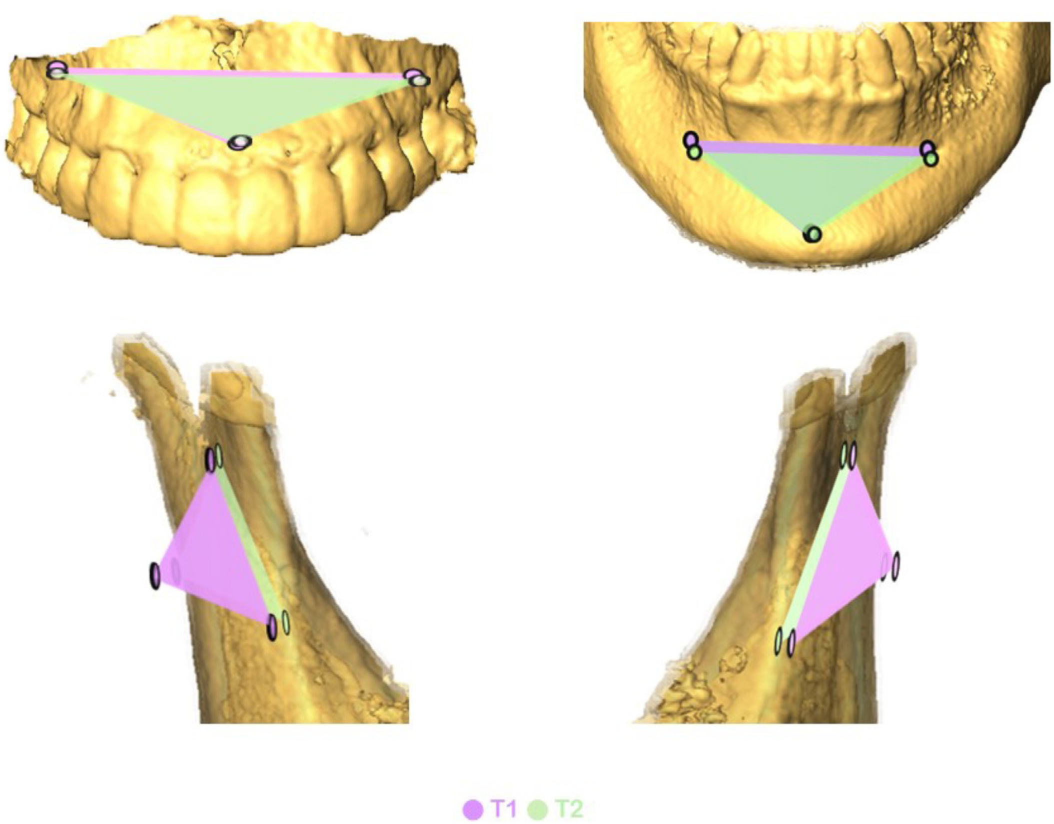

Figure 5 Representative 3D images of post-surgical movement (T1–T2) in the maxillary and mandibular segments. Maxillary segment (upper left), mandibular distal segment (upper right), and mandibular proximal segments both opposite (lower left) and deviated (lower right). Pink color = T1, green color = T2.

Table 4 Movement in segments of the facial skeleton from 1 week after surgery (T1) to completion of treatment (T2).

Movement	Maxillary segment		Mandibular distal segment		Mandibular proximal segment, deviated		Mandibular proximal segment, opposite	
	Mean ± SD	*P*	Mean ± SD	*P*	Mean ± SD	*P*	Mean ± SD	*P*
Translation, mm								
Left–right[a]	0.1 ± 0.6	0.177	0.3 ± 1.1	0.029	−0.2 ± 0.6	0.022	−0.1 ± 0.9	0.537
Posterior–anterior[b]	0.1 ± 0.6	0.400	−1.9 ± 1.6	<0.001	−0.3 ± 0.9	0.010	−0.1 ± 1.0	0.514
Up–down[c]	−0.1 ± 0.6	0.132	1.1 ± 1.5	<0.001	1.1 ± 1.2	<0.001	1.0 ± 1.4	<0.001
Rotation, °								
Pitch[d]	−0.2 ± 1.5	0.259	−2.9 ± 2.4	<0.001	−1.6 ± 2.2	<0.001	−0.8 ± 3.1	0.034
Roll[e]	−0.1 ± 2.2	0.581	−0.3 ± 0.9	0.019	1.3 ± 2.5	<0.001	−1.1 ± 3.2	0.007
Yaw[f]	0.0 ± 1.0	0.916	−0.0 ± 0.8	0.984	0.7 ± 2.5	0.017	−1.0 ± 3.2	0.011

Abbreviations: SD, standard deviation.

[a] A positive value indicates that the segment was located more to the left (deviated side) compared with 1-week after surgery; a negative value indicates that the segment was located more to the right (opposite side) compared with 1-week after surgery.

[b] A positive value indicates that the segment was located more posteriorly compared with 1-week after surgery; a negative value indicates that the segment was located more anteriorly compared with 1-week after surgery.

[c] A positive value indicates that the segment was located more cranially compared with 1-week after surgery; a negative value indicates that the segment was located more caudally compared with 1-week after surgery.

[d] A positive value indicates a clockwise rotation around the *x*-axis compared with 1-week after surgery; a negative value indicates a counterclockwise rotation around the *x*-axis compared with 1-week after surgery.

[e] A positive value indicates a clockwise rotation around the *y*-axis compared with 1-week after surgery; a negative value indicates a counterclockwise rotation around the *y*-axis compared with 1-week after surgery.

[f] A positive value indicates a clockwise rotation around the *z*-axis compared with 1-week after surgery; a negative value indicates a counterclockwise rotation around the *z*-axis compared with 1-week after surgery.

stability in bimaxillary surgery for correcting class III symmetry or asymmetry.[8,29] Based on the results of previous studies[6,8,26–29] as well as the findings in the current study, an approximately 2-mm overcorrection in the sagittal direction is recommended and has been adopted in our center for surgical design.

Significant asymmetric relapse was observed in the proximal segments of the mandible. The direction and amount of relapse differed in the deviated and opposite proximal segments. The roll relapse of the proximal segments (inward movement) was favorable for the deviated side but unfavorable for the opposite side, with the mean roll being 1.3° and 1.1°, respectively. After surgery, the opposite proximal segment was tilted to the deviated side. If patients have concerns on the contour asymmetry, secondary surgery of bone/fat grafting could be an option.

In BSSO, fixation is believed to affect the stability of bony segments. Rigid fixation by using a 4-hole monocortical plate has been reported frequently in the literature.[3] However, the plate must be molded to the shape of the mandible surface. Despite 4-hole plate fixation being traditional, 2-hole plate fixation has been used at our center for more than 15 years because (1) 2-hole plate fixation does not require extensive bending when the short 2-hole plate is being fixed on the mandible surface; (2) more plates can be added if the stability worsens; (3) 2-hole plate fixation sustains more shearing force, which is the most significant load that affects the stability of mandibular fixation[30]; and (4) 2-hole plate fixation shares the shear stress at 2 sites to resist the compressive action of the masseter muscle, which causes clockwise pitch rotation of the distal segment and counterclockwise pitch rotation of the proximal segment of the mandible.[2,27,30–33]

This study has some limitations. Due to the adopted study design, we did not calculate interrater reliability for the CBCT analysis. Additionally, the use of a landmark-dependent method to construct the virtual triangles at three time points has been criticized for yielding questionable validity and reliability.[34,35] Although the intra-rater reliability in terms of the 3D landmarks used in this study was excellent (ICC >0.96), future studies should perform voxel- or surface-based registration to eliminate the need to identify cephalometric landmarks multiple times. However, these regional registrations of the maxillary and mandibular segments are still far from accurate due to significant orthodontic tooth movement in the surgery-first approach, bony remodeling 1 year after surgery, and maxillary or mandibular segmentation in some patients.

The study did not address other key factors that can affect the stability of the bony segments, such as osteotomy technique, muscle pull and type of fixation. However, our 3D quantitative data are based on a specific group of adult patients with class III asymmetry who were managed by the same orthodontist and same team of attending surgeons. Moreover, the surgeons were trained and served at our center by using the same osteotomy technique, pterygomasseteric sling management and fixation type through a surgery-first approach and 3D-assisted maxilla-first bimaxillary surgery. In addition, patients with varying degrees of asymmetry were included in this study. These factors represent the unique approach of orthognathic and orthodontic treatment at our center.

In conclusion, significant relapse was discovered in the mandible, including distal and proximal segments, after bimaxillary surgery for correcting class III asymmetry. The distal segment moved forward, upward and rotated in a counterclockwise pitch direction, which led to class III relapse. The opposite proximal segment tilted to the deviated side, which led to asymmetric relapse.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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