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Is skeletal stability after bimaxillary surgery for skeletal class III deformity related to surgical occlusal contact?

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Abstract. A stable occlusion at the time of surgery is considered important for post-surgical stability after orthognathic surgery. The aim of this study was to determine whether skeletal stability after bimaxillary surgery using a surgery-first approach for skeletal class III deformity is related to the surgical occlusal contact or surgical change. Forty-two adult patients with a skeletal class III deformity corrected by Le Fort I osteotomy and bilateral sagittal split osteotomy with a surgery-first approach were studied. Dental models were set and used to measure the surgical occlusal contact, including contact distribution, contact number, and contact area. Cone beam computed tomography was used to measure the surgical change (amount and rotation) and post-surgical skeletal stability. The relationship between skeletal stability and surgical occlusal contact or surgical change was evaluated. No relationship was found between maxillary or mandibular stability and surgical occlusal contact. However, a significant relationship was found between maxillary and mandibular stability and the amount and rotation of surgical change. The results suggest that in the surgical-orthodontic correction of skeletal class III deformity with a surgery-first approach, the post-surgical skeletal stability is not related to the surgical occlusal contact but is related to the surgical change.

Key words: surgical occlusion; stability; orthognathic surgery; prognathism; class III malocclusion.

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In recent years, surgical-orthodontic treatment with a surgery-first approach has increased in popularity due to its various advantages, such as a reduced treatment time, efficient tooth decompensation, and early improvement in facial aesthetics, especially in those with a class III malocclusion[1–6]. However, the setup of surgical occlusion is challenging[7]. It is also unclear whether a surgery-first approach can ensure a similar degree of post-surgical skeletal stability as a conventional approach such as orthodontics[2,8–13]. A number of studies have been conducted to investigate factors that influence skeletal stability with surgery-first orthognathic surgery for the correction of class III malocclusion[9,14–17], and some studies have reported that surgical occlusal instability or interference is a risk factor for mandibular relapse[9,15,17]. However, the occlusal instability or interference has not been quantified objectively. A large amount of mandibular setback has also been cited as a potential risk factor. Choi et al. reported that the amount of mandibular relapse increased as the amount of mandibular setback increased[16]. Ko et al. reported that significant horizontal relapse of the mandible was often present when the mandibular setback exceeded 15 mm[14]. Other risk factors, such as the increase in post-surgical vertical dimension[15–17] and a deep bite[14] have also been investigated.

Identifying factors related to skeletal stability after orthognathic surgery may be useful for preventing or managing skeletal instability or relapse. Therefore, the aim of this study was to investigate whether skeletal stability after bimaxillary surgery for skeletal class III deformity is related to the surgical occlusal contact, surgical change (amount and rotation of the facial skeleton), or initial overjet and overbite, by performing a prospective longitudinal analysis.

Materials and methods

Patients

The study protocol was approved by the Ethics Committee for Human Research at Chang Gung Memorial Hospital in Taoyuan, Taiwan. Inclusion criteria were as follows: adult patients (age $\geq$18 years) who were diagnosed with a skeletal class III deformity (A-point–nasion–B-point angle (ANB) $\leq$0°) and no significant facial asymmetry (menton deviation <4 mm), whose surgical occlusion setup, computer-assisted surgical design and post-surgical orthodontic treatment was performed by a single orthodontist, and who underwent Le Fort I one-piece advancement and bilateral sagittal split setback with or without genioplasty using rigid internal fixation (plate and screws) at Chang Gung Craniofacial Centre, Taoyuan, Taiwan during a 2-year period, and who had no intermaxillary fixation after surgery. Patients with one or more of the following criteria were excluded: genetic syndromes or other congenital deformities, history of facial bone surgery, or intellectual disability. A total of 42 patients were eligible for the study and invited to participate.

Surgical occlusal contact

One month before surgery, the patient's maxillary and mandibular dental casts were scanned with a three-dimensional (3D) laser surface scanner (3Shape, Copenhagen, Denmark). Surgical occlusion was then set by hand-articulating the dental casts according to the guidelines described by Liao and Lo[18]. These guidelines were developed to achieve facial and dental aesthetics and simplify the orthodontic treatment after surgery by determining (1) where to place the teeth anteroposteriorly, vertically, and transversely, and (2) how to position these teeth or tooth segments either surgically or orthodontically. After setup, surgical occlusion images were obtained by the same 3D laser surface scanner and measured using Avizo version 7.0 software (FEI, Mérignac, France) by a single investigator.

In the setup, occlusal contact was defined as an inter-occlusal distance of $\leq$0.2 mm. The distances were calculated and projected onto the dental surfaces of the maxillary dentition. In order to identify the contact distribution and contact amount, an occlusogram of the maxillary dentition was generated. The occlusogram is a colour map of the distances between the maxillary and mandibular dentition, and a specific colour is assigned to all regions where occlusal contact is presented (Fig. 1).

Contact distribution

The occlusogram of the maxillary dentition was divided into three segments: anterior segment (from right canine to left canine), right buccal segment (right premolars and molars), and left buccal segment (left premolars and molars). Contact distribution was categorized into contact on three segments (anterior, right buccal, and left buccal segments), contact on two segments (anterior and right buccal, anterior and left buccal, or right and left buccal segments), or contact on one segment (anterior, right buccal, or left buccal segment). The location and number of contact segments were recorded.

Contact amount

The location and number of contact teeth and the contact area in each occlusogram were recorded and calculated.

Cone beam computed tomography

Cone beam computed tomography (CBCT) of the head and neck was performed for each patient before treatment (T0), 1 week after surgery (T1), and after treatment (i.e. at orthodontic debonding) (T2) using an i-CAT 3D Dental Imaging System (Imaging Sciences International, Hatfield, PA, USA) with the following parameters: 120 kVp, 0.4 × 0.4 × 0.4-mm voxel size, 40-s scan time, and 16 × 16-cm field of view. The patient's head was positioned in natural head position. The patients were requested not to swallow for

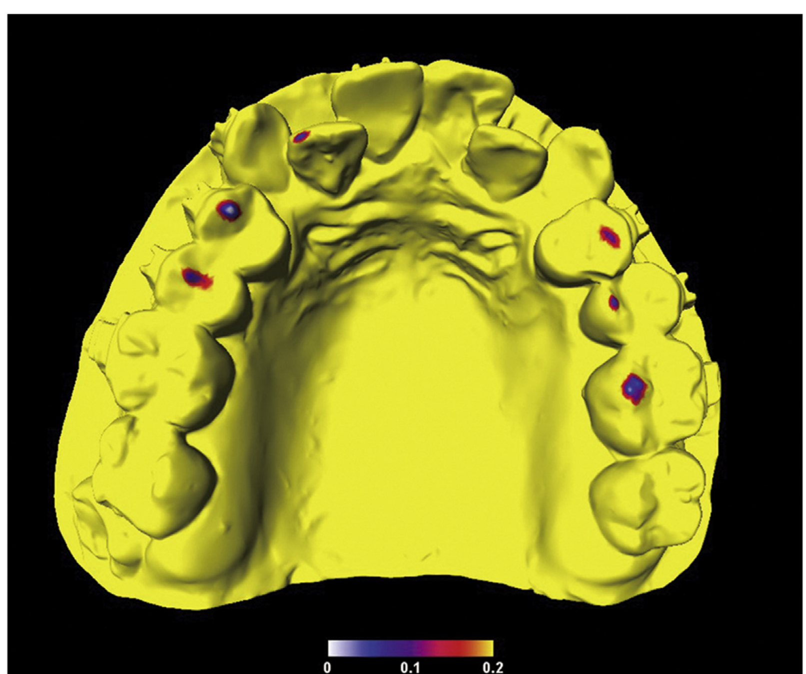

Fig. 1. Maxillary occlusogram of a patient showing surgical occlusal contact on three segments and six teeth.

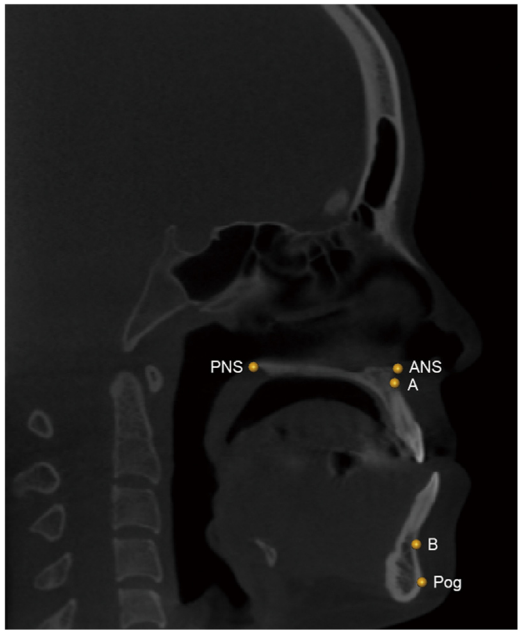

Fig. 2. Skeletal landmarks on a midsagittal cone beam computed tomography scan: anterior nasal spine (ANS), posterior nasal spine (PNS), point A, point B, and pogonion (Pog).

the duration of the scan. They were also instructed to keep their mouth closed and to maintain a centric occlusion bite.

Images were stored in Digital Imaging and Communications in Medicine (DICOM) format and rendered into volumetric images using Avizo version 7.0 software (FEI). Sagittal, axial, and coronal slices and 3D reconstructions of images were used for analysis. All images were analyzed by a single investigator. Before analysis, 3D images were reoriented as follows: (1) the midsagittal plane was constructed from nasion, basion, and the anterior nasal spine (ANS); (2) the axial plane was perpendicular to the midsagittal plane, passing through the right or left (clear side) porion and orbitale (Frankfort horizontal plane); (3) the coronal plane was perpendicular to the midsagittal plane and Frankfort horizontal plane, passing through nasion. Cranial structures not affected by surgery were used to superimpose the CBCT images at T0, T1, and T2 to position the images in the same 3D coordinates with nasion as the origin (0, 0, 0).

Surgical and post-surgical changes of the facial skeleton

Surgical and post-surgical changes of the facial skeleton (maxilla and mandible) were assessed by analysis of the changes from T0 to T1 and from T1 to T2, respectively, in five midsagittal slice skeletal landmarks: anterior nasal spine (ANS), posterior nasal spine (PNS), point A, point B, and pogonion (Pog) (Fig. 2). The surgical change in the distal mandibular segment (angle formed by the sella–nasion line and distal mandibular segment) from T0 to T1, including the direction (i.e., clockwise or counterclockwise) and amount, was also recorded.

Reliability

To assess intra-examiner error, all of the CBCT measurements were repeated by the same investigator (SHL) for 10 randomly chosen patients, at an interval of 2 weeks. Intra-examiner reliability, evaluated by intra-class correlation coefficient, was excellent (mean intra-class correlation coefficient = 0.988, 95% confidence interval 0.984–0.991).

Statistical analysis

Data were analyzed using IBM SPSS Statistics version 23.0 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as the mean ± standard deviation (SD) for metric variables and as the frequency and percentage for nominal variables. The paired *t*-test or Mann–Whitney *U*-test was used to compare the difference from T0 to T1 (surgical change) and from T1 to T2 (post-surgical change) when indicated. Pearson's or Spearman's correlation analysis was used to evaluate the relationship between possible factors (surgical occlusal contact, surgical change, initial overjet and overbite) and post-surgical skeletal change (skeletal stability) when indicated. To take account of multiple comparisons, probabilities of 0.01 or less were accepted as significant.

Results

Patient characteristics

Baseline demographic and clinical data for the 42 patients enrolled in the study are shown in Table 1. The mean age of the patients was 24 ± 5 years; 20 patients were male and 22 were female. A genioplasty was performed on 30 patients.

Surgical occlusal contact

Twenty-nine patients (69%) had occlusal contact on three segments. The average number of tooth contacts was 5.1 ± 2.2. The mean occlusal contact area was 15.2 ± 8.9 mm^2 (Table 2).

Surgical change of the facial skeleton

With regard to the maxillary position, ANS and point A moved forward significantly ($P <$ 0.001) and PNS moved forward and upward significantly ($P <$ 0.001) from T0 to T1. With regard to the mandibular position, point B and Pog showed significant backward movement ($P < 0.001$) (Table 3). The angle formed by the sella–nasion line and the distal mandibular segment showed a mean decrease of 1.1 ± 6.4° ($P > 0.05$). Twenty

Table 1. Baseline demographic and clinical characteristics of the study participants ($N = 42$).

Characteristic	Number (%), or mean ± SD
Female	22 (52%)
Age at surgery (years)	24 ± 5
With genioplasty	30 (71%)
SNA (°)	82.0 ± 3.5
SNB (°)	85.8 ± 4.5
ANB (°)	−3.7 ± 3.0
Overjet (mm)	−2.7 ± 3.3
Overbite (mm)	0.8 ± 3.0
Duration of postoperative follow-up (months)	24 ± 8

SD, standard deviation; SNA, sella–nasion–A-point angle; SNB, sella–nasion–B-point angle; ANB, A-point–nasion–B-point angle.

Table 2. Surgical occlusal contact for the study participants ($N=42$).

Surgical occlusion	Number (%), or mean ± SD
Contact distribution	
Three segments	29 (69%)
Two segments	8[a] (19%)
One segment	5[b] (12%)
Number of contacts	
Anterior teeth	1.6 ± 1.2
Premolars	1.8 ± 1.4
Molars	1.7 ± 1.2
Total	5.1 ± 2.2
Contact area, mm^2	15.2 ± 8.9

SD, standard deviation.
[a] Six right and left buccal segments, two anterior and right buccal segments.
[b] Four anterior segments, one left buccal segment.

Table 3. Surgical and post-surgical changes of the facial skeleton; mean ± SD values (millimetres).

Position	Surgical change (T1 − T0)	Post-surgical change (T2 − T1)
Horizontal (−anterior, + posterior)		
ANS	−2.1 ± 1.6**	1.5 ± 1.2**
PNS	−3.4 ± 1.6**	0.2 ± 0.8
Point A	−2.1 ± 1.4**	1.0 ± 0.9**
Point B	8.3 ± 4.0**	−0.9 ± 1.7*
Pog	7.0 ± 5.8**	−1.0. ± 2.1*
Vertical (−inferior, + superior)		
ANS	−0.5 ± 1.8	0.0 ± 1.6
PNS	3.8 ± 2.2**	−0.3 ± 1.2
Point A	−0.3 ± 2.2	0.1 ± 1.6
Point B	0.1 ± 3.7	1.9 ± 1.7**
Pog	0.4 ± 3.9	1.0 ± 1.8*

ANS, anterior nasal spine; PNS, posterior nasal spine; Pog, pogonion.
* $P < 0.01$.
** $P < 0.001$.

patients (48%) had clockwise rotation of the distal mandibular segment from T0 to T1.

Post-surgical change of the facial skeleton

With regard to maxillary position, only ANS and point A moved backward significantly ($P < 0.001$) from T1 to T2. With regard to mandibular position, point B and Pog showed significant upward and forward movements ($P < 0.01$) (Table 3).

Relationships with post-surgical skeletal stability

Post-surgical maxillary and mandibular stability were not related to the surgical occlusal contact (Table 4), but were related to their surgical changes, horizontally and vertically (Table 5). Furthermore, the vertical stability of the posterior maxilla was related to the amount of rotation of the distal mandibular segment (Table 6). Post-surgical maxillary and mandibular stability were not related to the initial overjet or overbite (Table 7).

Discussion

Despite the evident advantages of surgery-first orthognathic surgery, it lacks worldwide popularity. One of the challenges for the surgery-first approach is the surgical occlusion setup. For example, in the conventional approach, pre-surgical orthodontic treatment brings the maxillary and mandibular teeth into ideal relationships with their individual underlying skeletal base[19,20], such that the surgical occlusion is very close to the final, ideal occlusion after complete pre-surgical orthodontic treatment. Thus, in an orthodontics-first approach, surgical occlusion is ideally set as normal overjet and overbite[19,21,22], class I canine and molar relationship[18–23], bilateral tooth-to-tooth contacts[20,24,25], and no occlusal interference[20,22,25]. In contrast, in the surgery-first approach, dental alignment, levelling, decompensation, and coordination are deferred until after surgery; therefore, the surgical occlusion is different from the final occlusion. Thus, the occlusion is set as a treatable malocclusion[5,26]. However, the relatively unstable malocclusion might lead to post-surgical skeletal instability and the potential for immediate skeletal relapse[9,15–17]. The present study is novel in quantifying surgical occlusal contact and demonstrating that surgical occlusal contact has no impact on maxillary or mandibular stability. The results of this study indicate that a stable occlusion can also be achieved by occlusal contact

Table 4. Correlation coefficients for the association between post-surgical skeletal stability and surgical occlusal contact.

Stability	Surgical occlusal contact					
	Contact distribution (%)		Contact number (n)		Contact area (mm^2)	
	r	P-value	r	P-value	r	P-value
Horizontal stability (mm)						
ANS	−0.12	0.45	−0.05	0.76	0.00	1.00
PNS	0.20	0.21	0.07	0.65	0.12	0.46
Point A	0.11	0.48	0.09	0.57	0.12	0.44
Point B	−0.04	0.79	−0.11	0.48	−0.09	0.59
Pog	−0.07	0.66	−0.11	0.48	−0.03	0.84
Vertical stability (mm)						
ANS	0.12	0.43	0.11	0.49	0.16	0.32
PNS	−0.15	0.34	−0.16	0.31	−0.16	0.31
Point A	0.20	0.20	−0.06	0.72	0.01	0.95
Point B	−0.05	0.76	−0.07	0.65	−0.09	0.57
Pog	0.02	0.92	−0.17	0.29	−0.05	0.75

ANS, anterior nasal spine; PNS, posterior nasal spine; Pog, pogonion.

Table 5. Correlation coefficients for the association between post-surgical skeletal stability and surgical change.

Stability	Surgical change (T1 − T0)			
	Horizontal (mm)		Vertical (mm)	
	r	*P*-value	*r*	*P*-value
Horizontal stability (mm)				
ANS	0.55[a]	<0.001	0.15[b]	0.33
PNS	0.40[a]	<0.01	0.36[b]	0.02
Point A	0.28[a]	0.07	0.14[b]	0.39
Point B	0.47[a]	<0.01	0.13[b]	0.40
Pog	0.52[a]	<0.001	0.06[b]	0.71
Vertical stability (mm)				
ANS	0.01	0.95	0.60[c]	<0.001
PNS	0.18	0.25	0.54[c]	<0.001
Point A	0.26	0.09	0.60[c]	<0.001
Point B	0.23	0.15	0.38[c]	0.01
Pog	0.23	0.14	0.10[c]	0.51

ANS, anterior nasal spine; PNS, posterior nasal spine; Pog, pogonion.

[a] A positive value indicates that anterior/posterior movement of the facial skeleton after surgery was correlated with posterior/anterior movement of the facial skeleton.

[b] A positive value indicates that anterior/posterior movement of the facial skeleton after surgery was correlated with inferior/superior movement of the facial skeleton.

[c] A positive value indicates that superior/inferior movement of the facial skeleton after surgery was correlated with inferior/superior movement of the facial skeleton.

Table 6. Correlation coefficients for the association between post-surgical skeletal stability and surgical change of the distal mandibular segment.

Stability	Surgical change (T1 − T0)			
	Clockwise rotation (%)		Amount of rotation (°)	
	r	*P*-value	*r*	*P*-value
Horizontal stability (mm)				
ANS	0.05	0.77	0.20	0.21
PNS	−0.20	0.20	−0.16	0.31
Point A	−0.35	0.03	−0.09	0.59
Point B	0.14	0.37	0.11	0.50
Pog	0.21	0.18	0.13	0.41
Vertical stability (mm)				
ANS	−0.10	0.52	−0.15	0.35
PNS	0.31	0.05	0.38[a]	0.01
Point A	−0.17	0.30	−0.05	0.74
Point B	0.17	0.28	0.19[a]	0.22
Pog	0.03	0.86	−0.09	0.55

ANS, anterior nasal spine; PNS, posterior nasal spine; Pog, pogonion.

[a] A positive value indicates that superior movement of the facial skeleton after surgery was correlated with clockwise rotation of the distal mandibular segment.

Table 7. Correlation coefficients for the association between post-surgical skeletal stability and initial overjet and overbite.

Stability	Initial overjet (mm)		Initial overbite (mm)	
	r	*P*-value	*r*	*P*-value
Horizontal stability (mm)				
ANS	0.02	0.90	−0.01	0.95
PNS	0.16	0.32	−0.30	0.05
Point A	0.31	0.05	−0.24	0.12
Point B	−0.21	0.18	0.25	0.11
Pog	−0.21	0.19	0.10	0.53
Vertical stability (mm)				
ANS	0.13	0.42	0.08	0.62
PNS	−0.19	0.23	0.09	0.56
Point A	0.11	0.48	0.06	0.72
Point B	0.34	0.03	0.23	0.14
Pog	0.30	0.06	−0.03	0.88

ANS, anterior nasal spine; PNS, posterior nasal spine; Pog, pogonion.

on five to six teeth, or by occlusal contact on not only three segments but also on two segments or one (anterior) segment.

This study showed that maxillary stability was good in the vertical direction. In the horizontal direction, significant relapse was found in the anterior maxilla but not in the posterior maxilla (Fig. 3, Table 3). An explanation for this phenomenon is the bony remodelling of the anterior maxilla secondary to the advancement of the maxilla. In the horizontal direction, a mild but significant ($P < 0.001$) rate of mandibular relapse was found for both point B (11%) and Pog (14%). The vertical mandibular stability was relatively worse (Fig. 4, Table 3). This demonstrates that the mandible continued to move upward approximately 1 mm to 1.9 mm after surgery, thus increasing the overbite. An explanation for this phenomenon is the closing rotation of the mandible secondary to the removal of occlusal interference by the post-surgical orthodontics[2,16], or rehabilitation of the pterygomasseteric sling after surgery[16]. Although levelling of the lower occlusal plane from the post-surgical orthodontics is also possible[14], this was not considered a factor because of the insignificant correlation between the vertical mandibular stability and the initial overbite ($P > 0.05$).

The relationship between the amount of mandibular setback and surgical relapse remains controversial. de Villa et al. found no correlation between the horizontal mandibular relapse and the amount of mandibular setback[27]. Choi et al. reported that the greater the setback and vertical movement of the mandible, the higher the horizontal and vertical mandibular relapse[16], and the present study showed similar findings. Ko et al. studied the causes of mandibular instability in a surgery-first approach and found a relationship with the amount of setback; mandibular instability was more likely to be found in patients when the mandibular setback exceeded 15 mm[14]. Based on the line of best fit in the scatter plots, clinically significant relapse (>2 mm) can be expected when mandibular setback exceeds 12 mm to 14 mm (Figs 5 and 6), suggesting the need for the design of an overcorrection.

Various mandibular rotations are indicated according to the different vertical skeletal patterns, which may influence post-surgical stability of the mandible[2,15,28]. Although mandibular rotation might affect the post-surgical position of the mandible, this has not been considered fully. Of note, the present study successfully demonstrated that mandibular rotation, as defined by the angle between the sella–nasion line and distal mandibular segment, was not related to the horizontal or vertical mandibular stability, but was related to the vertical stability of the posterior maxilla. That is, the greater the clockwise rotation of the mandible, the greater the upward movement of the posterior maxilla after surgery.

In this study, the setup of the surgical occlusion (i.e., virtual surgical occlusion) was used to define the surgical occlusion, because intermaxillary fixation was used during surgery. However, surgical occlusion is not always the real surgical occlusion since some relapse occurs quite early after intermaxillary fixation is removed. A further study is needed to investigate whether skeletal stability is related to the real surgical occlusion.

In conclusion, in the surgical-orthodontic correction of skeletal class III deformity with a surgery-first approach, the post-surgical skeletal stability is not related to the surgical occlusal contact or the initial overjet or overbite, but is related to the surgical change.

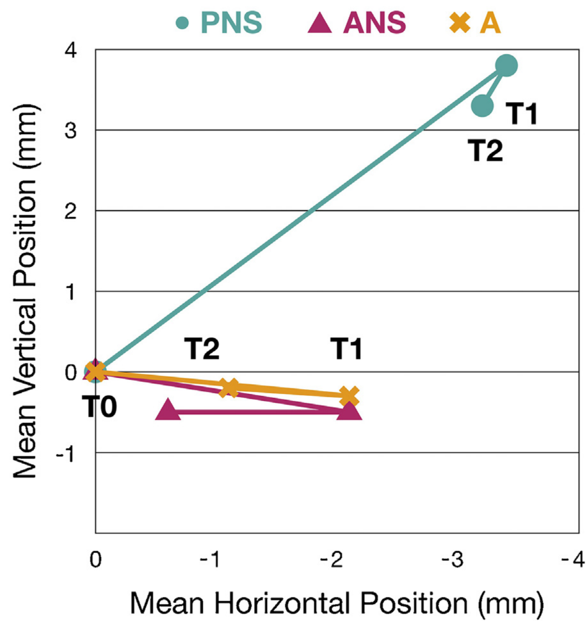

Fig. 3. Horizontal and vertical changes in maxillary position (ANS, PNS, point A) from T0 (before treatment), to T1 (1 week after surgery), to T2 (after treatment). Points were normalized to zero at T0. Values are the means in both horizontal and vertical directions. In the horizontal direction, negative values indicate anterior movement and positive values indicate posterior movement. In the vertical direction, negative values indicate inferior movement and positive values indicate superior movement.

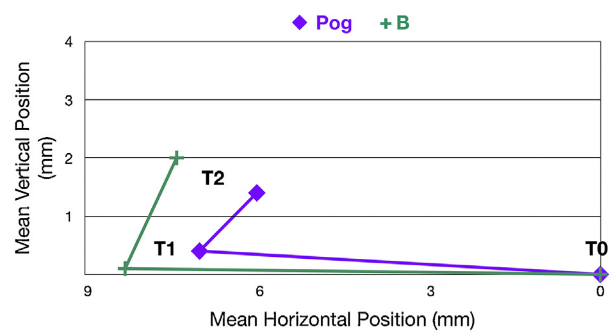

Fig. 4. Horizontal and vertical changes in mandibular position (point B, Pog) from T0 (before treatment), to T1 (1 week after surgery), to T2 (after treatment). Points were normalized to zero at T0. Values are means in both the horizontal and vertical directions. In the horizontal direction, positive values indicate posterior movement. In the vertical direction, positive values indicate superior movement.

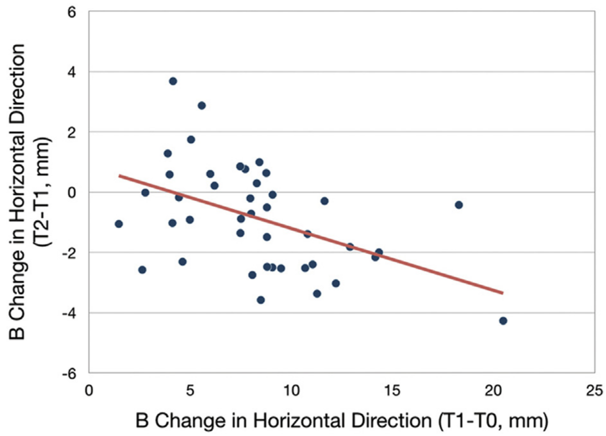

Fig. 5. Scattergram showing the post-surgical change (T2 – T1) of point B plotted against the surgical change (T1 – T0) of point B in the horizontal direction. A significant correlation was found between horizontal mandibular relapse and mandibular setback ($P < 0.01$). T0, before treatment; T1, 1 week after surgery; T2, after treatment.

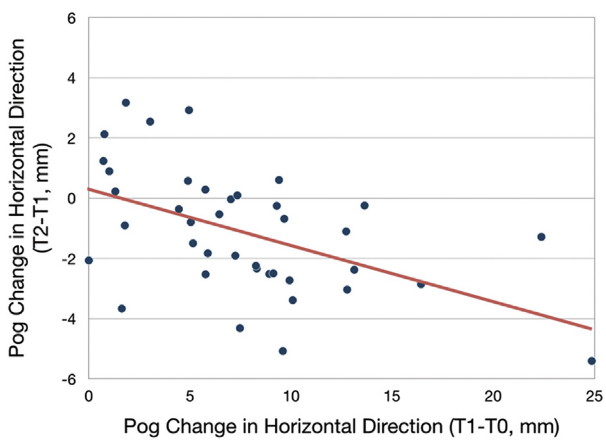

Fig. 6. Scattergram showing the post-surgical change (T2 – T1) of Pog plotted against the surgical change (T1 – T0) of Pog in the horizontal direction. A significant correlation was found between horizontal mandibular relapse and mandibular setback ($P < 0.001$). T0, before treatment; T1, 1 week after surgery; T2, after treatment.

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Ethical approval

This study was conducted in accordance with the guidelines of the Declaration of Helsinki and was approved by the Institutional Review Board and Medical Ethics Committee of Chang Gung Memorial Hospital (No. 201509870A3, No. 201702234A3C501).

Competing interests

No competing interests.

Patient consent

Not required.

References

1. Nagasaka H, Sugawara J, Kawamura H, Nanda R. ‘‘Surgery first’’ skeletal class III correction using the Skeletal Anchorage System. *J Clin Orthod* 2009;**43**:97–105.
2. Liao YF, Chiu YT, Huang CS, Ko EW, Chen YR. Presurgical orthodontics versus no presurgical orthodontics: treatment outcome of surgical-orthodontic correction for skeletal class III open bite. *Plast Reconstr Surg* 2010;**126**:2074–83.
3. Villegas C, Uribe F, Sugawara J, Nanda R. Expedited correction of significant dentofacial asymmetry using a ‘‘surgery first’’ approach. *J Clin Orthod* 2010;**44**:97–103.
4. Yu CC, Chen PH, Liou EJ, Huang CS, Chen YR. A surgery-first approach in surgical-orthodontic treatment of mandibular prognathism—a case report. *Chang Gung Med J* 2010;**33**:699–705.
5. Liou EJ, Chen PH, Wang YC, Yu CC, Huang CS, Chen YR. Surgery-first accelerated orthognathic surgery: orthodontic guidelines and setup for model surgery. *J Oral Maxillofac Surg* 2011;**69**:771–80.
6. Hernandez-Alfaro F, Guijarro-Martinez R, Molina-Coral A, Badia-Escriche C. ‘‘Surgery first’’ in bimaxillary orthognathic surgery. *J Oral Maxillofac Surg* 2011;**69**:e201–7.
7. Lo SH, Liao YF. Surgical occlusion setup in orthognathic surgery using surgery-first approach for skeletal class III deformity: a systematic review. *Taiwan J Orthodont* 2018;**30**:82–91.
8. Ko EW, Hsu SS, Hsieh HY, Wang YC, Huang CS, Chen YR. Comparison of progressive cephalometric changes and postsurgical stability of skeletal class III correction with and without presurgical orthodontic treatment. *J Oral Maxillofac Surg* 2011;**69**:1469–77.
9. Kim CS, Lee SC, Kyung HM, Park HS, Kwon TG. Stability of mandibular setback surgery with and without presurgical orthodontics. *J Oral Maxillofac Surg* 2014;**72**:779–87.
10. Park HM, Yang IH, Choi JY, Lee JH, Kim MJ, Baek SH. Postsurgical relapse in class III patients treated with two-jaw surgery: conventional three-stage method versus surgery-first approach. *J Craniofac Surg* 2015;**26**:2357–63.
11. Akamatsu T, Hanai U, Miyasaka M, Muramatsu H, Yamamoto S. Comparison of mandibular stability after SSRO with surgery-first approach versus conventional ortho-first approach. *J Plastic Surg Hand Surg* 2016;**50**:50–5.
12. Park KH, Sandor GK, Kim YD. Skeletal stability of surgery-first bimaxillary orthognathic surgery for skeletal class III malocclusion, using standardized criteria. *Int J Oral Maxillofac Surg* 2016;**45**:35–40.
13. Mah DH, Kim SG, Oh JS, You JS, Jung SY, Kim WG, Yu KH. Comparative study of postoperative stability between conventional orthognathic surgery and a surgery-first orthognathic approach after bilateral sagittal split ramus osteotomy for skeletal class III correction. *J Korean Assoc Oral Maxillofac Surg* 2017;**43**:23–8.
14. Ko EW, Lin SC, Chen YR, Huang CS. Skeletal and dental variables related to the stability of orthognathic surgery in skeletal class III malocclusion with a surgery-first approach. *J Oral Maxillofac Surg* 2013;**71**:e215–23.

15. Rhee CH, Choi YK, Kim YI, Kim SS, Park SB, Son WS. Correlation between skeletal and dental changes after mandibular setback surgery-first orthodontic treatment: cone-beam computed tomography-generated half-cephalograms. *Korean J Orthod* 2015;**45**:59–65.
16. Choi SH, Hwang CJ, Baik HS, Jung YS, Lee KJ. Stability of pre-orthodontic orthognathic surgery using intraoral vertical ramus osteotomy versus conventional treatment. *J Oral Maxillofac Surg* 2016;**74**:610–9.
17. Han JJ, Chong JH, Ryu SY, Oh HK, Park HJ, Jung S, Kook MS. Postoperative changes in mandibular position after mandibular setback surgery via the surgery-first approach in relation to the increase of vertical dimension and the amount of mandibular setback. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2016;**122**:666–71.
18. Liao YF, Lo SH. Surgical occlusion setup in correction of skeletal class III deformity using surgery-first approach: guidelines, characteristics and accuracy. *Sci Rep* 2018;**8**:11673.
19. Sinclair PM. Orthodontic considerations in adult surgical orthodontic cases. *Dent Clin North Am* 1988;**32**:509–28.
20. Tompach PC, Wheeler JJ, Fridrich KL. Orthodontic considerations in orthognathic surgery. *Int J Adult Orthodon Orthognath Surg* 1995;**10**:97–107.
21. Jacobs JD, Sinclair PM. Principles of orthodontic mechanics in orthognathic surgery cases. *Am J Orthod* 1983;**84**:399–407.
22. Woods M, Wiesenfeld D. A practical approach to presurgical orthodontic preparation. *J Clin Orthod* 1988;**32**:350–8.
23. Worms FW, Isaacson RJ, Speidel TM. Surgical orthodontic treatment planning: profile analysis and mandibular surgery. *Angle Orthod* 1976;**46**:1–25.
24. Grubb J, Evans C. Orthodontic management of dentofacial skeletal deformities. *Clin Plast Surg* 2007;**34**:403–15.
25. Sabri R. Orthodontic objectives in orthognathic surgery: state of the art today. *World J Orthod* 2006;**7**:177–91.
26. Huang CS, Chen YR. Orthodontic principles and guidelines for the surgery-first approach to orthognathic surgery. *Int J Oral Maxillofac Surg* 2015;**44**:1457–62.
27. de Villa GH, Huang CS, Chen PK, Chen YR. Bilateral sagittal split osteotomy for correction of mandibular prognathism: long-term results. *J Oral Maxillofac Surg* 2005;**63**:1584–92.
28. Mucedero M, Coviello A, Baccetti T, Franchi L, Cozza P. Stability factors after double-jaw surgery in class III malocclusion. A systematic review. *Angle Orthod* 2008;**78**:1141–52.

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