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A Modified Method of Proximal Segment Alignment After Sagittal Split Ramus Osteotomy for Patients With Mandibular Asymmetry

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Abstract

Purpose—The purpose of this study was to evaluate a modified method of aligning the proximal segment after bilateral sagittal split ramus osteotomy (BSSO) in the treatment of patients with facial asymmetry.

Patients and Methods—Eleven patients with mandibular excess and facial asymmetries were enrolled in this prospective study. The surgery was planned according to a computer-aided surgical simulation protocol. In addition, the proximal segment on the hypoplastic side was intentionally flared out after the distal segment was rotationally set back. If the gap between the proximal and distal segments was too wide, then bone grafts were used. The surgery was completed according to the computerized plan. The proximal segment on the hypoplastic side was fixed with bicortical lag screws, and the proximal segment on the hyperplastic side was fixed with a 4-hole titanium miniplate. Postoperative evaluation was performed 6 months after surgery. Statistical analyses were performed.

Results—All surgeries were completed uneventfully. Of the 11 patients, 4 also underwent genioplasty and 3 underwent bone grafting to fill in the gap and smooth the anterior step. The physicians and patients were satisfied with the surgical outcomes. Only 1 patient underwent a secondary revision using an onlay hydroxyapatite implant. Results of statistical analyses showed that the computerized surgical plan could be accurately transferred to the patients at the time of surgery and the surgical outcomes achieved with this modified method were better than with the routine method of aligning the proximal and distal segments in maximal contact.

Conclusion—The present modified method of aligning the proximal segment for BSSO can effectively correct mandibular asymmetry and obviate a secondary revision surgery.

It is a challenge to treat patients with mandibular asymmetry, which affects overall facial symmetry. The paradigm shift of computer-aided surgical simulation (CASS) technology has enabled surgeons to better plan an orthognathic surgery for patients with severe facial asymmetry on a computer.^{1,2} At the time of the surgery, this computerized plan can be transferred to the patient using computer-generated surgical splints and templates.¹⁻⁸ Unfortunately, even with CASS technology, only movements of the maxilla, mandibular distal segment, and chin can be quantitatively planned and transferred. The placement of proximal segments is still based on a surgeon's visual judgment. A surgeon traditionally aligns the proximal segment to the mandibular distal segment and places them in maximal contact. This technique might be acceptable in patients with symmetrical deformity. Conversely, the same might not be true in patients with facial asymmetry.

Mandibular symmetry directly contributes to facial harmony.⁴ If there is a residual asymmetry owing to the shape of the mandible after an orthognathic surgery, then a secondary revision (eg, bone graft or prosthetic onlay implant) might be required, likely adding to a patient's discomfort.

It is the authors' belief that placement of the proximal segments plays an important role in the treatment of patients with facial asymmetry. Therefore, the purpose of this study was to evaluate a modified method of aligning the proximal segment for bilateral sagittal split ramus osteotomy (BSSO) in the treatment of patients with facial asymmetry. In this method, the proximal segment was intentionally flared out on the hypoplastic side and fixed with 3 bicortical lag screws in a triangular configuration,⁹ and the hyperplastic side was fixed with a surgical miniplate.

Patients and Methods

This prospective study was carried out from January 2013 to August 2014. Eleven patients (8 male and 3 female) with mandibular excess and facial asymmetry were enrolled at the clinic of the Department of Oral and Craniomaxillofacial Surgery at Shanghai Ninth People's Hospital (Shanghai, China). Their average age was 22.1 years (range, 18 to 31 yr).

The criteria for patient inclusion were 1) patients who were diagnosed with mandibular excess and scheduled to undergo an orthognathic surgery to correct one of the following facial asymmetric deformities: pogonion deviations larger than 5 mm, asymmetric mandibular angles, or laterognathism; 2) patients who were scheduled to undergo computed

tomographic (CT) scanning before and after surgery as a part of their treatment protocol; 3) 3-dimensional (3D) cephalometric analysis showing the necessity for increasing the bone volume of the mandible to correct mandibular asymmetry; and 4) patients who agreed to participate in the study. The exclusion criteria were 1) syndromic patients; 2) patients who had tumors (eg, ameloblastoma or condylar osteochondroma) or trauma; and 3) patients with a systemic disease that contraindicated orthognathic surgery. This study was approved by the Shanghai Ninth People's Hospital institutional review board. Before enrollment, signed informed consent forms were obtained from all patients.

PREOPERATIVE DATA ACQUISITION

A preoperative CT scan was acquired with a slice thickness of 1.25 mm using a hospital-based spiral CT scanner. In addition, routine clinical examination was performed. Clinical photographs were taken with a plumb line hanging in the background when the patient's head was oriented to the neutral head posture. These photographs were used in conjunction with CASS during surgical planning.

Although not used for planning, the following examinations for the temporomandibular joint (TMJ) were performed as a part of the routine clinical protocol. Preoperative magnetic resonance (MR) scans of the TMJ were acquired and used to set a baseline of TMJ morphology. These scans were examined by 2 radiologists. Routine TMJ clinical examination findings, including interincisal distance, jaw opening and closing, lateral and protrusion motion pattern, joint noise, and pain, also were recorded.

SURGICAL PLANNING USING CASS TECHNOLOGY

Surgical planning was carried out according to the CASS protocol⁶ using a surgical planning software package (ProPlan, Materialise Medical, Leuven, Belgium). The first step of the planning process was to generate a composite skull using the CT data. The resulting composite skull model rendered bony structures and dentition with a high degree of accuracy.

The second step was to quantify the deformity. This entailed 3D cephalometric analysis, the mirror-imaging method, and physical examination to determine the degree of asymmetry.¹⁰⁻¹³ The reference frame of the head and the midsagittal plane was determined by clinical examination and photographs.⁶

The third step in the planning process was to simulate the entire surgery on the computer. A maxillary Le-Fort I osteotomy was simulated first, followed by a BSSO and then a genioplasty, if desired. Only the proximal segment on the hyperplastic side was aligned to the distal segment.

The fourth step in the planning process was to align the proximal segment on the hypoplastic side using the mirror-imaging technique (Fig 1). The mirror image was created along the midsagittal plane. According to the mirror image, the proximal segment on the hypoplastic side was aligned to the distal segment until it was matched to the hyperplastic side. This was achievable because the distal segment was rotationally set back and its proximal aspect was rotated toward the hypoplastic side. It is important to note that the proximal segment was

rotated only in pitch (swinging anteroposteriorly) and roll (swinging mediolaterally) within a limited range (ie, within 4° and 3°, respectively). There was no yaw rotation (rotating along the inferosuperior axis) during alignment of the proximal segment. If the distal segment moved the proximal segment beyond the limited range, then the excess proximal end of the distal segment was trimmed off or the magnitude of the rotational setback was decreased. Afterward, the excess distal aspect of the proximal segment on the hyperplastic side was resected. It was used for the hypoplastic side if the step between the proximal and distal segments was excessive (ie, >4 mm). In this case, the resected bone segment was split into 2 pieces. One was used to fill the gap between the proximal and distal segments on the hypoplastic side. The other was reshaped and used as an onlay between the anterior aspect of the proximal segment and the posterior aspect of the mental foramen to smooth the step.

The fifth step in the planning process was to design and fabricate the surgical splints. After the surgical simulation was finalized, intermediate and final surgical splints were designed on the computer and fabricated using a 3D printer (3D System ProJet3510s, 3D Systems, Rock Hill, SC). The printed splints were used at the time of surgery.

In the sixth step, a backup surgical plan and a dental acrylic splint were created using the traditional planning method, that is, 2-dimensional cephalometric analysis and surgery according to a plaster dental model. This was performed as a part of the human subject protection protocol.

SURGICAL TECHNIQUE

The computerized surgical plan was transferred to the patient at the time of surgery according to the routine surgical procedure.⁵ Maxillary surgery was performed first, followed by mandibular surgery and genioplasty, if planned. The computerized intermediate splint was used to position the maxillary segment, and the computerized final splint was used to position the mandibular distal segment.

The distal and proximal segments were aligned using the modified method described earlier. On the hyperplastic side, an osteotomy was performed to remove the excess distal aspect of the proximal segment as indicated in the CASS plan. The resected bony segment was saved for the hypoplastic side. The proximal and distal segments were fixed using a 4-hole titanium miniplate.

On the hypoplastic side, the proximal segment was slightly flared out and aligned to the distal segment based on the CASS plan (Fig 2). While maintained in this position, the 2 segments were gently fixed using 3 bicortical lag screws. It is important to note that excessive force during fixation should be avoided, especially at the anterior aspect of the proximal segment. This is to maintain the fullness of the mandibular body as planned and to prevent a postoperative temporomandibular disorder owing to the unwanted yaw rotation of the proximal segment. If indicated in the surgical plan, then the resected bony segments from the hyperplastic side were reshaped, used to fill the gap, and used as an onlay to smooth the step. The onlay bone graft was fixed using an additional titanium screw.

POSTOPERATIVE DATA ACQUISITION

All postoperative data were collected 6 months after surgery. Postoperative CT scans were acquired using the same scanning protocol while the upper and lower teeth were in maximal intercuspation. These were used to evaluate surgical outcomes. In addition, post-operative MR scans of the TMJ were acquired to evaluate any possible morphologic and positional changes of the condyle and disc based on the clinical protocol. The same clinical examination of the TMJ also was performed. These scans also were used to detect any changes in symptoms of temporomandibular disorder. The same 2 radiologists who were blinded to the patient's surgical history evaluated the MR images.

DATA ANALYSIS

Postoperative 3D midface and mandibular CT models were generated for each patient. The postoperative models were superimposed on the planned model by aligning surgically unaltered volumes (ie, the cranium and midface above the Le Fort I osteotomy line).⁵

After the postoperative CT models were registered, 7 anatomic landmarks were digitized on the original, planned, and postoperative mandibles by a single examiner (Z.L.) who was not involved in the original surgical planning. These landmarks were the menton and right and left most prominent points on the mandibular body corresponding to the canine tip anteroposteriorly on the bottom view (MPP3) on the distal segment and the right and left most prominent points on the mandibular body corresponding to the second molar's mesiobuccal cusp anteroposteriorly on the bottom view (MPP7) and gonion on the proximal segments (Table 1, Fig 3). The method of landmark digitization was based on a published report.⁵ Subsequently, the MPP7 and gonion landmarks were digitally "glued" onto the planned proximal segments, which were reset to their original unaligned positions. The distal segment remained static at the planned position. A second examiner (S.S.) who was experienced in orthognathic surgery, but not involved in the original planning, realigned the proximal segments to the distal segment according to the routine procedure of ensuring maximal contact between the segments.

The coordinates of each landmark were recorded, paired, and tabulated in an Excel (Microsoft, Redmond, WA) spreadsheet. For easy presentation, the landmarks on the hypoplastic side were normalized to the right, and the landmarks on the hyperplastic side were normalized to the left. The differences () of paired coordinates between the hypoplastic and hyperplastic sides were computed in mediolateral (x), anteroposterior (y), and inferosuperior (z) directions. In addition, the asymmetry index for each pair of landmarks (MPP3, MPP7, and gonion) in the mediolateral direction was calculated using the following equation:

$$\text{asymmetry index} = \frac{\text{absolute}(\chi_{\text{hypoplastic}}) - \text{absolute}(\chi_{\text{hyperplastic}})}{\text{absolute}(\chi_{\text{hypoplastic}}) + \text{absolute}(\chi_{\text{hyperplastic}})} \times 100\%$$

where $\chi_{\text{hypoplastic}}$ represents the χ coordinate on the hypoplastic side and $\chi_{\text{hyperplastic}}$ represents the χ coordinate on the hyperplastic side.

All data were checked and found normally distributed. The mean and 95% confidence interval (CI) were calculated. A stepwise statistical approach was used. The first step was to detect whether the CASS plan could be accurately transferred at the time of the surgery. The planned outcome was compared with the postoperative outcome. Intraclass correlation coefficients (ICCs) with absolute agreement definition were used. The variables were the paired x , y , and z co-ordinates of each landmark between the planned and postoperative outcomes. The second step was to detect whether there was a statistical decrease in asymmetry after surgery. A repeated measures analysis of variance (ANOVA) was used. The response variable was the α value. The within factors ($2 \times 3 \times 4$) were status (preoperative condition and postoperative outcome), direction (x , y , and z), and landmark (menton, MPP3, MPP7, and gonion). If statistically important, then within contrast would be further computed. The third step was to detect whether this method of aligning the proximal segment could achieve better mandibular symmetry mediolaterally. A repeated measures ANOVA was used. The response variable was the α value in the x axis. The within factors (2×2) were status (postoperative outcome and outcome achieved with the hypothetical routine alignment) and landmark (MPP7 and gonion). If statistically important, then within contrast would be further computed.

Results

All surgeries were completed uneventfully by a single surgeon (X.W.). The backup splints were never used. Six-month postoperative CT scan showed that the proximal and distal segments healed normally on the right and left sides of the mandible. Postoperative patient physical examination showed no change in interincisal distance, jaw motion pattern, and joint noise 6 months after the surgery. Six-month postoperative MR image also showed no evidence of morphologic and positional changes in the disc and condyle (Fig 4).

Of the 11 patients, 4 also underwent genioplasty and 3 underwent bone grafting to fill in the gap and smooth the step during the orthognathic surgery. Only 1 patient had a severe residual vertical deficiency in the mandibular gonial angle and underwent a secondary revision surgery using an onlay hydroxyapatite implant.

The means and 95% CIs of the difference and asymmetry index between the hypoplastic and hyperplastic sides are presented in Tables 2 and 3, respectively. The results of the first step of the statistical analysis showed a high degree of absolute agreement between the planned and postoperative outcomes (ICC, 0.926-0.999). It indicated that the distal and proximal segments could be accurately positioned at the time of surgery according to the CASS plan. The result of repeated measures ANOVA for the second step showed a statistically significant difference between the original condition and the postoperative outcomes ($F_{1,10} = 25.04$; $P < .001$). It indicated a statistical decrease in asymmetry after surgery. In addition, the result of within contrast showed that all significant decreases occurred in the x axis for all landmarks ($F_{6,60} = 2.47$; $P < .05$), whereas changes in the y and z axes remained statistically minor. This indicated that the decrease in asymmetry occurred mainly in mediolateral direction. The result of repeated measures ANOVA in the last step showed a statistically significant difference ($F_{1,10} = 101.46$; $P < .001$) between the postoperative outcome and the outcome achieved with the hypothetical routine alignment. It indicated that

the present method of proximal alignment would achieve better mandibular mediolateral symmetry. In addition, the result of within contrast showed that the significant difference occurred at MPP7 and the gonion ($F_{1,10} = 6.61$; $P < .05$). It indicated that the mandibular asymmetry achieved with the present method of proximal segment alignment was statistically better than the one achieved with routine alignment.

Discussion

The authors have developed a modified method of aligning the proximal segment after BSSO in the treatment of patients with facial asymmetry. The proximal segment on the hypoplastic side was intentionally flared (kicked) out after the distal segment was rotationally set back and fixed using 3 bicortical lag screws. If the step between the proximal and distal segments on the hypoplastic side was excessive (>4 mm), then a bone graft was used to fill in the gap between the 2 segments and another was used as an onlay between the distal aspect of the proximal segment and the posterior aspect of the mental foreman to smooth the step. To the authors' knowledge, this modified procedure has not been reported previously.

The foundation of this technique is a good surgical plan that can be transferred to the patient at the time of surgery. The ICC result indicates that the CASS plan can be accurately transferred to the patient at the time of surgery to correctly position the distal segment using the digital splints. Moreover, alignment of the proximal segments on the computer also can be accurately achieved at time of the surgery without a surgical template. In addition, with the use of the mirror-imaging technique during surgical planning, one can quantify the volume needed to expand the hypoplastic side and correctly align the proximal segment by intentionally flaring out the proximal segment, rather than making maximal contact. The results of the 2 repeated measures ANOVAs show that this technique can effectively correct mandibular asymmetry in the mediolateral direction and achieve better surgical outcomes than those achieved with routine alignment. Furthermore, because the facial soft tissue expands with the increased bone volume, the vertical bony deficiency at the mandibular body and angle also can be camouflaged. This can considerably obviate secondary revision surgery. In the present patient group, only 1 patient underwent a secondary hydroxyapatite onlay surgery to correct a deficiency in the gonial angle.

It is important to note that during planning, the proximal segment, especially on the hypoplastic side, should be rotated only in pitch and roll. Yaw rotation should be avoided. The authors believe the pitch rotation and the flare out (roll rotation) will not disturb the original TMJ structure if it is within a limited range (ie, within 4° and 3° , respectively). It also is important to avoid excessive force during fixation, especially at the anterior aspect of the proximal segment, which also can result in unwanted yaw rotation and cause TMJ problems. In this study, no patient showed any sign of a temporomandibular disorder 6 months after surgery and postoperative MR images showed no changes in TMJ structure.

Three bicortical lag screws were used on the hypoplastic side. The triangle configuration allows solid fixation of the proximal and distal segments. The authors recommend avoiding

the use of a miniplate on the hypoplastic side, where the proximal segment is intentionally flared out, because it will increase the step between the proximal and distal segments.

In conclusion, the present results suggest that this modified method of aligning the proximal segment for BSSO could be a simple solution for correcting mandibular asymmetry. This procedure could obviate a secondary revision and thus be beneficial to the patient.

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FIGURE 1.

The mirror-imaging technique was used to assist planning. The mandible showed good symmetry after the proximal segment was aligned on the hypoplastic side. The distal segment (*pink*), mirror-imaged distal segment (*blue*), right proximal segment (*brown*), and left proximal segment (*green*) are depicted. *A*, Front view. *B*, Bottom view.

FIGURE 2.

The right proximal segment on the hypoplastic side was intentionally flared out according to the computer-aided surgical simulation plan. Three bicortical lag screws were used in a triangular configuration to fix the distal and proximal segments together. The resected bony segments from the hyperplastic side were reshaped, used to fill the gap (*white arrow*), and used as on onlay to smooth the step (*black arrow*) on the hypoplastic side.

FIGURE 3.

All landmarks used for evaluation (*red dots*). *A*, Seven landmarks were digitized on the planned mandible, in which the proximal segment was intentionally flared out. This surgical plan was the one used in surgery. *B*, Landmarks for the right and left proximal and distal segments of the planned mandible were transferred to the postoperative mandible using a published approach.⁵ *C*, On the hypoplastic side, landmarks of the proximal segment shown in *A* were digitally “glued” to the proximal segment, which was reset to the original position. A second examiner realigned the proximal segment according to the routine protocol (not intentionally flaring it out). The landmarks were automatically moved to the new positions accordingly. Go-L, most inferior and posterior point on the left mandibular gonion angle;

Go-R, most inferior and posterior point on the right mandibular gonion angle; Me, most inferior point on the mandibular symphysis; MPP3-L, most prominent point on the left mandibular body corresponding to the canine tip anteroposteriorly on the bottom view; MPP3-R, most prominent point on the right mandibular body corresponding to the canine tip anteroposteriorly on the bottom view; MPP7-L, most prominent point on the left mandibular body corresponding to the second molar's mesiobuccal cusp anteroposteriorly on the bottom view; MPP7-R, most prominent point on the right mandibular body corresponding to the second molar's mesiobuccal cusp anteroposteriorly on the bottom view.

FIGURE 4.

Magnetic resonance imaging evaluation of the temporomandibular joint on the hypoplastic side (*arrows*). Six-month postoperative magnetic resonance image shows no evidence of morphologic and positional changes in the disc and condyle compared with the preoperative magnetic resonance image. *A*, Preoperative and *B*, postoperative magnetic resonance images in closed-mouth position. *C*, Preoperative and *D*, postoperative magnetic resonance images in open-mouth position.

Table 1
DEFINITION OF LANDMARKS

Landmark	Definition
Menton	Most inferior point on the mandibular symphysis
MPP3	Most prominent point on the mandibular body corresponding to the canine tip anteroposteriorly on the bottom view
MPP7	Most prominent point on the mandibular body corresponding to the second molar's mesiobuccal cusp anteroposteriorly on the bottom view
Gonion	Most inferior and posterior point on the mandibular gonion angle

Table 2
MEANS AND 95% CONFIDENCE INTERVALS OF THE DISTANCE DIFFERENCE
BETWEEN THE HYPOPLASTIC AND HYPERPLASTIC SIDES

Landmarks	Original Condition		Planned Outcome		Postoperative Outcome		Hypothetical Routine Alignment	
	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
Menton								
Mediolateral	-6.53	-8.68 to -4.39	0.65	0.09-1.20	0.41	-0.20 to 1.03	N/A	
MPP3								
Mediolateral	-10.97	-15.79 to -6.15	-0.68	-1.87 to 0.50	-0.83	-2.15 to 0.48	N/A	
Anteroposterior	0.50	-0.91 to 1.90	1.25	0.05-2.44	0.78	-0.34 to 1.89		
Inferosuperior	-0.48	-1.81 to 0.84	0.05	-0.80 to 0.89	-0.16	-1.06 to 0.74		
MPP7								
Mediolateral	-8.87	-14.50 to -3.24	0.77	-0.94 to 2.48	1.75	0.18-3.31	-4.16	-6.11 to -2.21
Anteroposterior	0.85	-1.63 to 3.33	2.26	0.36-4.16	1.52	-0.46 to 3.49	2.09	-1.30 to 5.48
Inferosuperior	1.04	-2.69 to 4.76	2.29	-0.30 to 4.88	2.38	0.30-4.45	-0.52	-5.28 to 4.24
Gonion								
Mediolateral	-5.77	-10.02 to -1.52	-0.63	-2.25 to 0.98	0.29	-1.39 to 1.97	-2.48	-4.27 to -0.68
Anteroposterior	-1.78	-5.69 to 2.13	0.02	-1.45 to 1.50	-0.99	-2.87 to 0.88	-4.11	-6.90 to -1.33
Inferosuperior	-1.56	-5.07 to 1.96	-0.81	-3.00 to 1.38	0.83	-2.06 to 3.71	2.59	-0.03 to 5.21

Abbreviations: CI, confidence interval; MPP3, most prominent point on the mandibular body corresponding to the canine tip anteroposteriorly on the bottom view; MPP7, most prominent point on the mandibular body corresponding to the second molar's mesiobuccal cusp anteroposteriorly on the bottom view; N/A, not applicable.

Table 3
ASYMMETRY INDEX OF THE MPP7 AND GONION LANDMARKS

Landmarks	Original Condition		Postoperative Outcome		Hypothetical Routine Alignment	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
MPP3	-38.74	-56.36 to -21.1	-2.61	-7.53 to 2.32	—	
MPP7	-11.67	-18.89 to -4.44	2.34	0.28-4.40	-6.17	-9.07 to -3.28
Gonion	-6.00	-10.41 to -1.59	0.29	-1.48 to 2.05	-2.69	-4.60 to -0.78

Abbreviations: CI, confidence interval; MPP3, most prominent point on the mandibular body corresponding to the canine tip anteroposteriorly on the bottom view; MPP7, most prominent point on the mandibular body corresponding to the second molar's mesiobuccal cusp anteroposteriorly on the bottom view.