Do Patients Treated With Bimaxillary Surgery Have More Stable Condylar Positions Than Those Who Have Undergone Single-Jaw Surgery?

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Purpose: Because condylar positioning after sagittal split ramus osteotomy of the mandible has been known to affect postoperative skeletal stability, accurate positional assessment of the temporomandibular joint after orthognathic surgery is vital to maximize stability of the surgery. The purpose of this study was to evaluate condylar changes after single-jaw and double-jaw surgeries in mandibular prognathism patients by comparing 3-dimensional angular and positional changes of the condylar heads in groups of patients receiving combined maxillary posterior impaction and mandibular setback and those undergoing only mandibular setback surgeries.

Patients and Methods: We assessed condylar changes of patients who have been diagnosed with mandibular prognathism and underwent either bimaxillary surgery or isolated mandibular surgery at Kangdong Sacred Heart Hospital and SmileFuture Orthodontic Clinic, Seoul, South Korea, from August 2008 to February 2011. Condylar angulation, intercondylar distance, and amount of condylar displacement were examined based on the 3-dimensional reconstructed images. Preoperative and postoperative changes within each group were assessed by paired *t* test. Differences between the groups were determined by independent *t* test.

Results: A total of 43 skeletal Class III patients were included in this retrospective, multicenter study. After single-jaw surgery, condylar angulations in all dimensions did not change. In contrast, those who received double-jaw surgery showed forward rotation of 1.93° ($P = .027$) and medial rotation of 1.48° ($P = .032$) in the sagittal and axial planes, respectively. The mean distances of condylar displacements were 0.28 ± 0.44 mm in the single-jaw group and 0.31 ± 0.51 mm in the double-jaw group, but there was no statistically significant difference.

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Conflict of Interest Disclosures: None of the authors reported any disclosures.

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0278-2391/12/7009-0$36.00/0
doi:10.1016/j.joms.2011.08.028

Conclusions: Condylar angulations are more stable after sagittal split ramus osteotomy of the mandible as an isolated procedure than in combination with the posterior maxillary impaction in treatment of skeletal Class III malocclusion patients. Condylar displacements in both the single-jaw and double-jaw groups are clinically insignificant.

J Oral Maxillofac Surg 70:2143-2152, 2012

Postsurgical stability of orthognathic surgery is a major concern for oral and maxillofacial surgeons, as well as orthodontists. Major factors related to surgical relapse include postoperative occlusion and positional change of the condyle.[1] Although good occlusion can be achieved by preoperative and postoperative orthodontics, condylar position is difficult to control during and after surgery. Postoperative condylar position is known to be affected by many factors, such as rotational movement of the distal segment, tensional balance of the surrounding muscles, fixation method, and surgeon's experience.[2] This has led to many studies that suggested methods for avoiding condylar displacement and guiding the postoperative position of the condyle.[1,3-5] Because condylar positioning after sagittal split ramus osteotomy (SSRO) of the mandible has been known to affect postoperative skeletal stability,[6-9] accurate positional assessment of the temporomandibular joint after orthognathic surgery is vital to maximize stability of the surgery and predictable treatment outcome.

Double-jaw surgeries of Class III malocclusion patients have been increasing, and studies on the effects of bimaxillary procedures on the skeletal stability have shown that the maxillary surgical procedure acts as a significant risk factor for mandibular horizontal relapse in addition to other aspects such as severity of the maxillomandibular discrepancies and amount of mandibular setback.[7,9]

The advent of the new 3-dimensional (3D) technology of cone beam computed tomography (CBCT) systems has expanded diagnostic capacities and greatly contributed to understanding of the spatial relationship of the bony segments. Positions and angulations of condyles can be measured in axial, frontal, and sagittal slices with dimensional accuracy.[6] Recently, superimpositions of 3D reconstructed images of the craniofacial complex combined with surface distance analysis and color-mapping techniques have enabled users to visually assess surgical displacements as well as perform quantification of the skeletal changes as a result of the orthognathic surgery.[10-12]

There have been previous 3D studies of skeletal changes after orthognathic surgery, which analyzed positional changes of bony segments to assess surgical outcomes of Class III patients who received bimaxillary orthognathic surgery[13] or compared those who underwent bimaxillary surgery and those who underwent maxillary advancement surgery only.[14] However, there has been no comparative study of double-jaw surgery and isolated mandibular setback surgery in Class III malocclusion patients.

Because the postoperative condylar position is a key factor in mandibular stability, the purpose of this study was to evaluate condylar positions after single-jaw and double-jaw orthognathic surgeries in Class III malocclusion patients. Our null hypothesis was that no difference in postoperative condylar positional changes occurs with single-jaw surgery versus double-jaw surgery. The specific aims of this investigation included *1)* assessment of linear and angular changes of the condyles in 2-dimensional (2D) reformatted slices and *2)* assessment of the direction and amount of condylar displacement in the axial, sagittal, and frontal planes.

Patients and Methods

STUDY DESIGN/SAMPLE

CBCT scans were analyzed to assess linear, angular, and positional changes of the condylar heads in patients who received bimaxillary surgery and those who underwent only mandibular setback surgery. Informed consent was obtained from all patients, and the research protocol was approved by the Institutional Review Board of the Kangdong Sacred Heart Hospital, Seoul, South Korea (No. 10-031).

The study population was composed of patients with mandibular prognathism who had undergone orthognathic surgery at Kangdong Sacred Heart Hospital and SmileFuture Orthodontic Clinic, Seoul, South Korea, from August 2008 to February 2011. Diagnostic inclusion criteria were overjet of 0 mm or less, unilateral or bilateral Angle Class III molar relationship, and ANB (an angle formed by point-A, nasion, point-B) of 0° or less. Patients who had craniofacial syndromes, such as cleft lip and palate, and those with severe facial asymmetry were excluded. Severe facial asymmetry was determined by maxillary canting of more than 3 mm, measured at both upper first molars in reference to the Frankfort Horizontal (FH) plane, which was constructed from the right and left porions and the right orbitale, or mandibular menton deviation of more than 3 mm from the midsagittal plane, constructed by crista galli (the most superior point of crista galli of the ethmoid bone), anterior nasal spine (ANS, the most anterior point of the premaxillary bone in the sagittal plane), and opisthion (the most posterior point on the posterior margin of the foramen magnum).[15] Patients who had symptoms related to temporomandibular disorder and degenerative joint disease on examination were also excluded.

STUDY VARIABLES

The primary predictor variable of this study was the type of orthognathic surgery, and the subjects were grouped into single-jaw and double-jaw surgery groups. The single-jaw surgery group underwent mandibular SSRO, whereas the double-jaw surgery group received combined Le Fort I osteotomy and SSRO of the mandible. The outcome variables were preoperative and postoperative measurements of condylar angulation, intercondylar distance, and condylar displacements observed in the axial, sagittal, and frontal planes. For the condylar analysis, a unilateral condyle for each patient was randomly selected because measurements of right and left condyles of the same patients were considered as correlated variables. Other variables were demographic data, such as age and gender, and lateral cephalometric analysis and surgical variables, including amount of setback and amount of maxillary posterior impaction.

SURGICAL PROCEDURES

Patients who received double-jaw surgery were treated with Le Fort I osteotomy for posterior impaction of the maxilla and SSRO for mandibular setback. The posterior maxilla was impacted by rotation in a clockwise direction with a center of rotation at either ANS or the upper incisal tip. Proximal segments of the mandible were left passive in the articular fossa, whereas the distal segment was repositioned to obtain a functional occlusion with the maxilla as planned. To ensure passive fit of the proximal and distal segments, the short lingual osteotomy technique was used[16]; the horizontal osteotomy line on the lingual surface of the ascending ramus was designed to extend just posterior to the lingula to minimize the bony interferences between the proximal and distal segments. All mandibular setback surgeries were symmetric with no midline changes because patients with facial asymmetry were excluded. Maxillary and mandibular segments were stabilized by semirigid fixation. For those who underwent only mandibular setback, surgical techniques were identical to the mandibular procedures of the double-jaw surgery patients.

An advancement genioplasty was performed as an adjunctive procedure in 9 of the double-jaw surgery patients and 5 of those who underwent single-jaw surgery. Surgical wafers were placed for 3 to 4 weeks after surgery, and interarch elastics were used to stabilize the interarch relationship after removal of the surgical wafers.

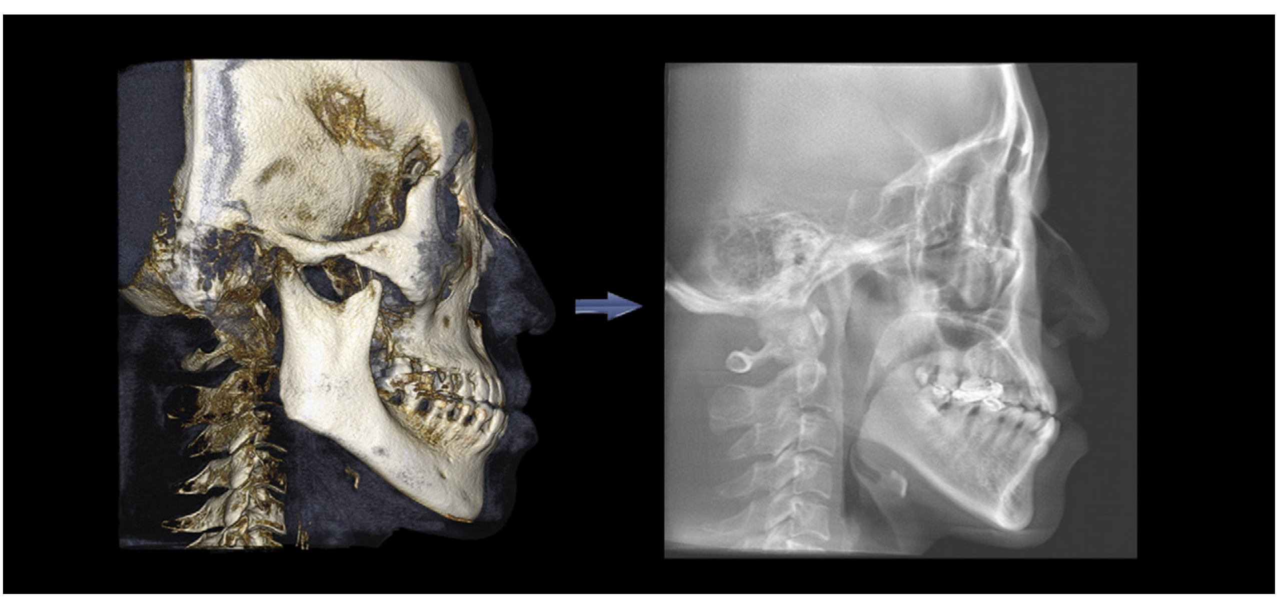

FIGURE 1. The 2D lateral cephalometric images of the subjects were derived from the CBCT scans by creation of an orthogonal projection with parallel rays for conventional 2D analysis.

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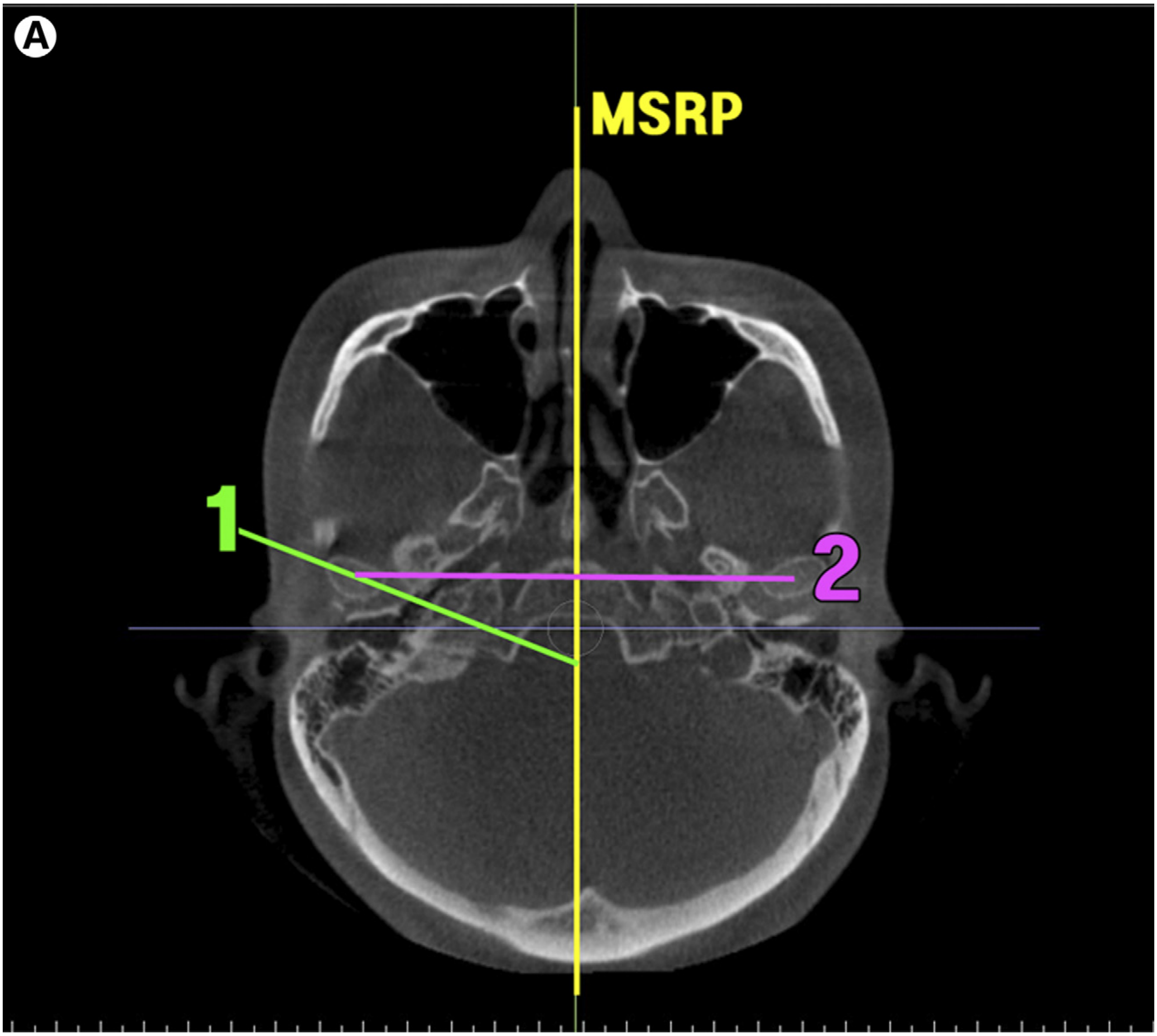

FIGURE 2. *A*, Axial condylar angulation (*1*) was determined by an angle between a line connecting the medial and lateral pole of the condylar head and the midsagittal reference plane (MSRP). Intercondylar distance (*2*) was measured from midpoints of the right and left condylar heads. **(Figure 2 continued on next page.)**

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IMAGE ACQUISITION

CBCT scans were acquired a mean of 2 weeks (range, 0-3 weeks) before surgery and 3 months (range, 2-6 months) after surgery. CBCT volume scans of all subjects at Kangdong Sacred Heart Hospital were obtained with the Master 3D dental-imaging system (Vatech, Seoul, South Korea), and the imaging protocol used a 19 × 20–in field of view to include the entire craniofacial anatomy. The axial slice thickness was 0.3 mm, and the voxels were isotropic. CBCT scans of patients at SmileFuture Orthodontic Clinic were acquired with the iCat CBCT unit (Imaging Science International, Hatfield, PA) with a full field of view (19 × 20 in), and the voxels were isotropic. All patients were sitting upright in natural head position, and jaws were at maximum intercuspation with the lips and tongue in a resting position.

LATERAL CEPHALOMETRIC ANALYSIS

The axial images were imported to InVivoDental software (version 6.0; Anatomage, San Jose, CA), and 2D lateral cephalometric images were derived by creating an orthogonal projection with parallel rays (Fig 1). The images were imported into a cephalometric analysis software program (V-ceph, version 5.5; Osstem, Seoul, South Korea) for conventional 2D analysis. Landmark identifications and physical measure-

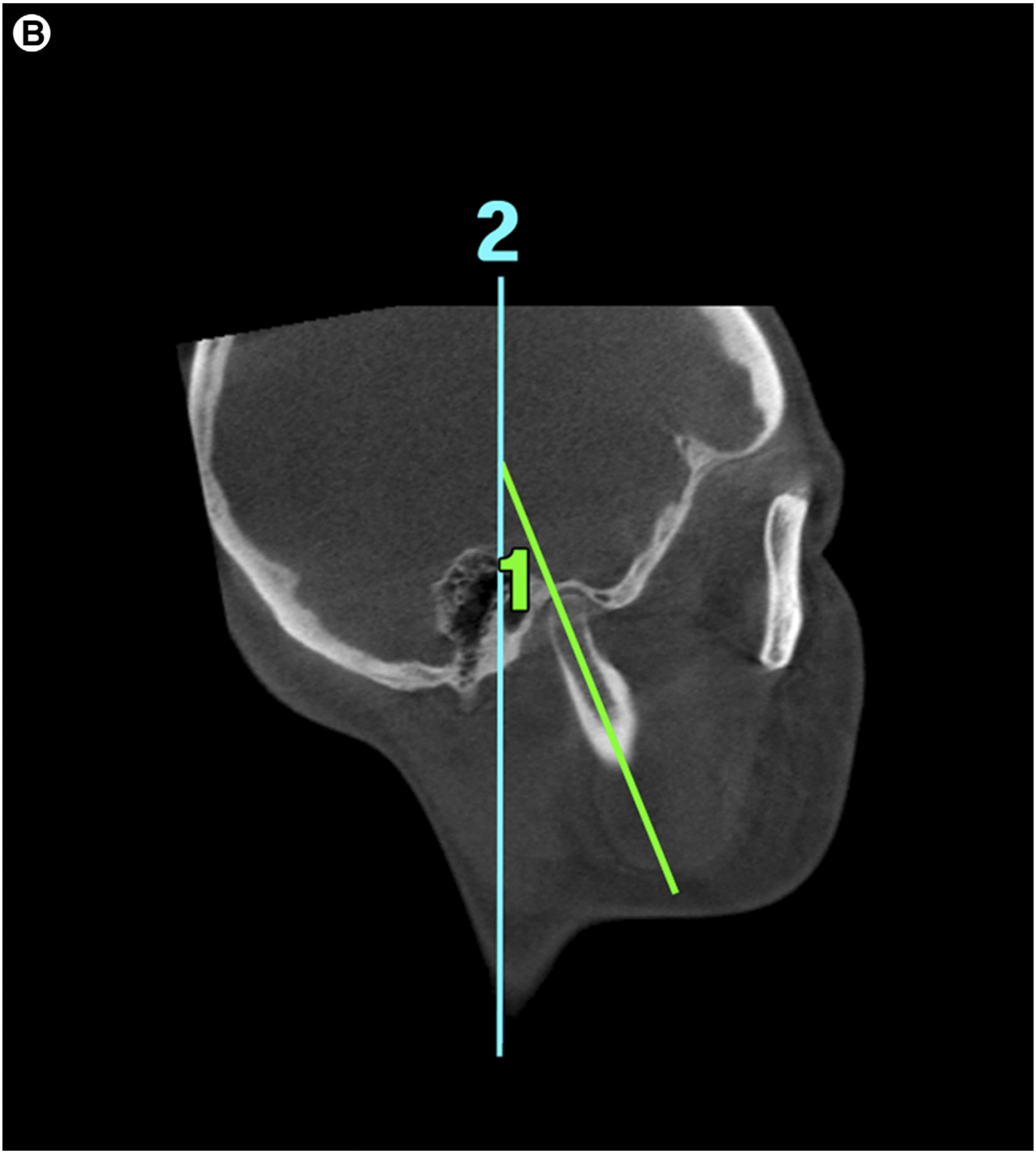

FIGURE 2 (cont'd). *B*, Sagittal condylar angulation (*1*) was measured from a line bisecting the anterior and posterior border of the condylar head to the frontal plane (*2*), which is perpendicular to the Frankfort Horizontal (FH) plane.**(Figure 2 continued on next page.)**

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ments were performed by the same investigator (Y.-J.K.).

LINEAR AND ANGULAR CHANGES OF CONDYLES

Each 3D rendered image was reoriented by use of the FH plane as its horizontal reference plane, which was constructed from the right and left porions that are located in the most laterosuperior point of the external auditory meatus, as well as the right orbitale (ie, the most inferior point of the lower margin of the bony orbit). A unilateral condyle on either side was randomly selected in each subject for the condylar

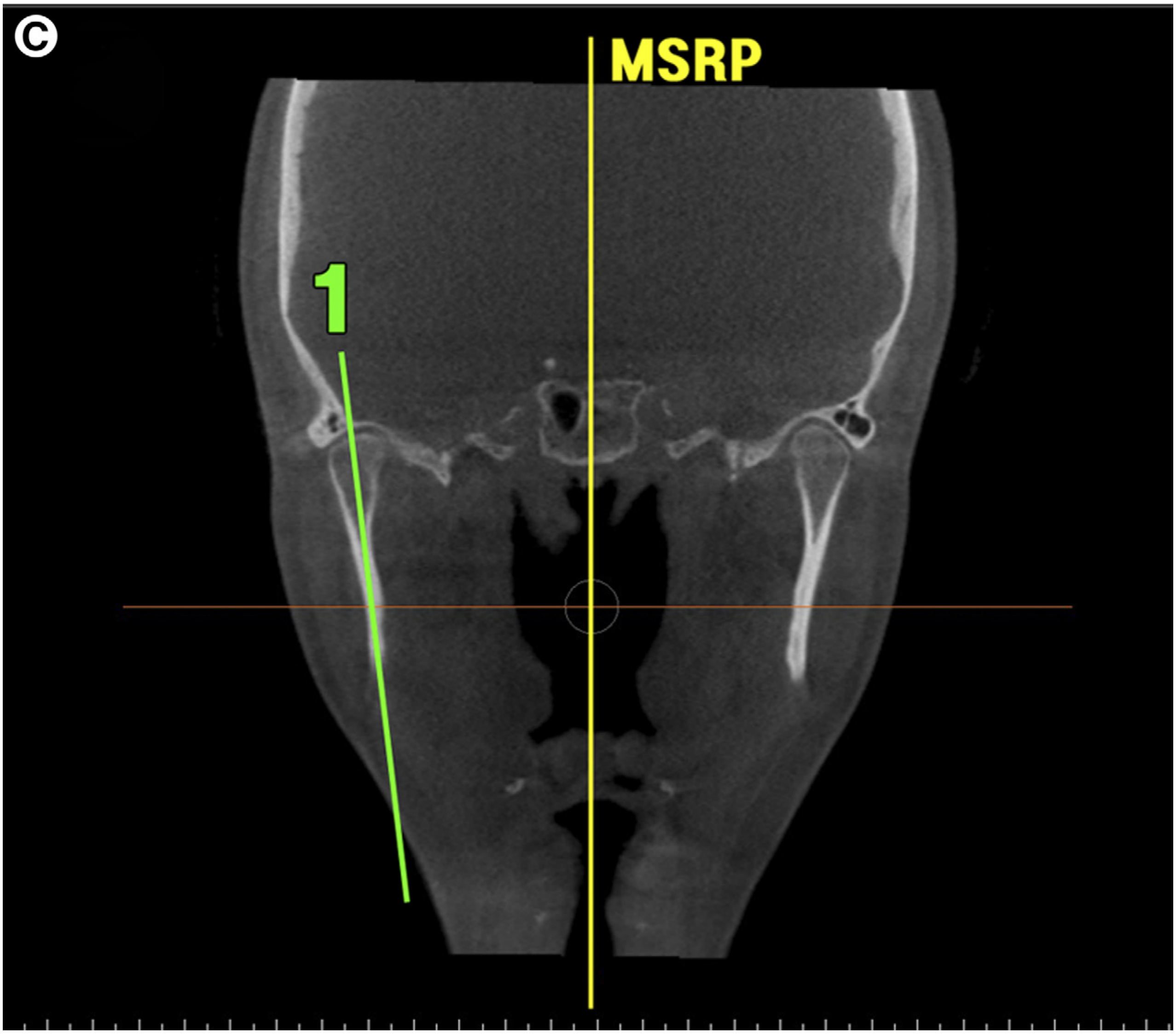

FIGURE 2 (cont'd). *C*, Frontal condylar angulation (*1*) was measured from an angle formed by lines bisecting the medial and lateral pole of the condylar heads to the MSRP.

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analysis, because right and left condyles in the same subject are correlated variables. CBCT scans of randomly selected condyles were processed to obtain 3D sectional views, and condylar angulations in the axial, sagittal, and frontal planes, as well as intercondylar distances measured in the axial plane, were assessed by the same investigator (Y.-J.K.) (Fig 2). All measurements were calculated to the nearest 0.01° and 0.01 mm.

CONDYLAR DISPLACEMENTS

To calculate the direction and amount of condylar displacement in each dimension, CMF Application software (Maurice Müller Institute, Bern, Switzerland) was used. This utility enables quantitative evaluation of the greatest surface distance, as well as color mapping of the calculated distances on any point between 2 models, thus visualizing a total pattern of displacement of the condyles (Fig 3). Registration of the preoperative and postoperative CBCT scans for each patient was performed with IMAGINE software (developed by the National Institutes of Health, Bethesda, MD, and modified at the University of North Carolina at Chapel Hill) by use of the cranial base as a reference. Preoperative and postoperative models of condyles on a randomly selected side for each patient were then created with ITK-SNAP software.[17,18] Conversion of file formats from the originally saved ".gipl" to an SGL open inventor format ".iv" was needed to carry out the surface distance analysis of the preoperative and postoperative condyles, and this was performed with the publicly available Vol2Surf software program. Condylar models were imported into CMF

Application, and direction and amount of condylar displacement were recorded.

STATISTICAL ANALYSIS

SPSS software (version 12.0 for Windows; SPSS, Chicago, IL) was used for all statistical analyses. The same investigator remeasured 3D images from 15 randomly selected computed tomography scans 2 weeks after the first measurement. The paired *t* test was used to estimate the presence of systemic error,[19] and the Dahlberg formula was used to calculate random error.[20]

The independent *t* test was performed to assess the differences in cephalometric and surgical variables between the 2 study groups. The paired *t* test was used for the within-group analysis of preoperative and postoperative changes in condylar angulations and intercondylar distances. Between-group analysis of condylar displacements was carried out by independent *t* test. $P \leq .05$ was considered significant for all analyses.

Results

PATIENT DEMOGRAPHICS

A total of 43 consecutive skeletal Class III patients were included in this retrospective, multicenter study. All of the measurements were free of systemic error, and random error varied from 0.28 to 1.41 mm in linear measurements and from 0.85° to 1.97° in angular measurements.

Bivariate analysis of the clinical and demographic characteristics of subjects is shown in Table 1. No statistically significant differences were noted regarding the lateral cephalometric variables. The mean amounts of mandibular setback were 7.08 ± 2.97 mm in the single-jaw group and 8.75 ± 4.02 mm in the double-jaw group, with no statistically significant difference ($P = .65$).

LINEAR AND ANGULAR CHANGES IN CONDYLES AFTER SURGERY

Intercondylar distances were maintained in both groups after surgery. In the single-jaw surgery pa-

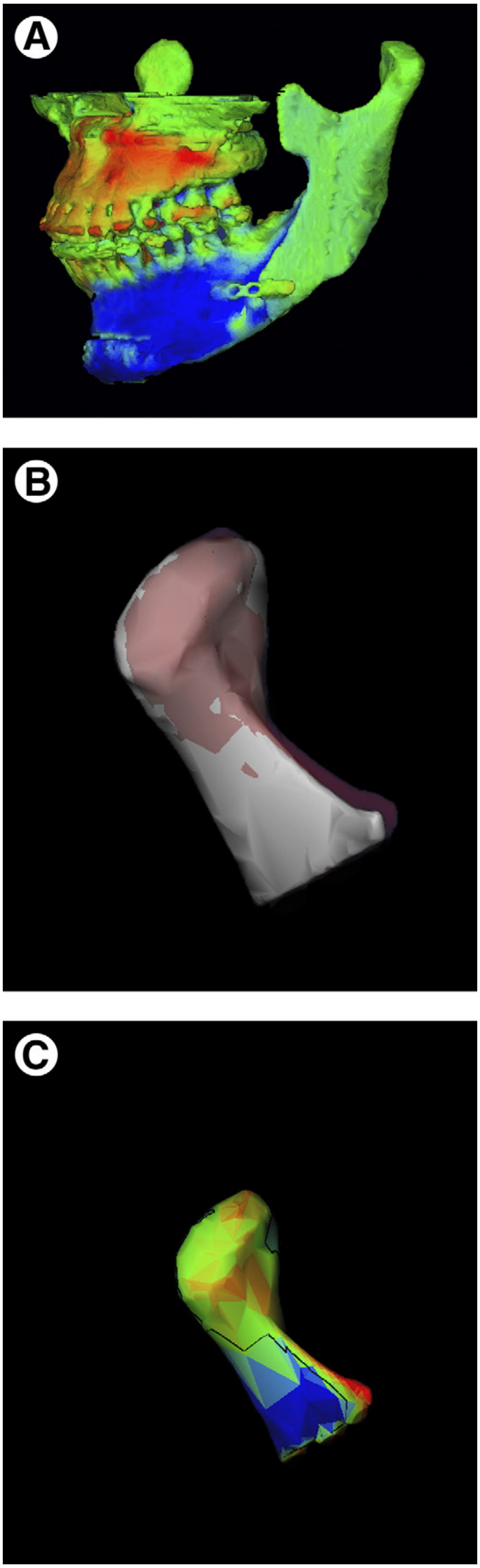

FIGURE 3. *A*, Surface distance analysis was performed, and the resultant color map of the postoperative model of a double-jaw surgery patient was created. Skeletal changes of the targeted structures are displayed in different colors to represent the direction and amount of change. *B*, Preoperative (*gray*) and postoperative (*red*) condylar models are superimposed to visualize the positional changes. *C*, To assess the direction and amount of condylar displacement, surface distance analysis was carried out. A color map was created on the postoperative condylar model.

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Table 1. SAMPLE CHARACTERISTICS

	Single Jaw	Double Jaw	*P* Value
Demographic variables			
Sample size (n)	13	30	
Age (mean ± SD) (yr)	29 ± 2.1	30 ± 1.6	
Female gender (n)	5	25	
Cephalometric variables (mean ± SD)			
ANB (°)	−2.90 ± 2.59	−3.10 ± 3.16	.86
Wits appraisal (mm)	−10.66 ± 4.34	−11.68 ± 5.52	.60
Facial convexity (°)	−7.44 ± 5.92	−8.27 ± 7.84	.75
Overjet (mm)	−1.72 ± 2.86	−2.37 ± 3.08	.57
FMA (°)	27.29 ± 5.28	26.91 ± 5.47	.86
Lower facial height (°)	50.20 ± 4.38	50.05 ± 5.82	.94
Upper occlusal plane–FH (°)	8.76 ± 3.47	7.31 ± 5.38	.41
Surgical variables			
Advanced genioplasty (n)	5	9	
Posterior maxillary impaction (mean ± SD) (mm)	0.0	3.6 ± 0.72	<.001
Mean amount of setback (mean ± SD) (mm)	7.08 ± 2.97	8.75 ± 4.02	.65

Abbreviations: ANB, an angle formed by point-A, nasion and point-B; FMA, Frankfort mandibular plane angle; FH, Frankfort horizontal plane.

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tients, condylar angulations in all dimensions did not change after surgery (Table 2). In contrast, the double-jaw surgery group showed significant changes in axial and sagittal condylar angulations. Forward rotation of 1.93° ($P = .027$) and medial rotation of 1.48° ($P = .032$) were observed in the sagittal and axial condylar angulations, respectively. Frontal angulations of the condyles were maintained after surgery.

CONDYLAR DISPLACEMENTS

The mean distances of condylar displacements were 0.28 ± 0.44 mm in the single-jaw group and 0.31 ± 0.51 mm in the double-jaw group, and they were neither significantly nor clinically significant. In comparison of the single-jaw and double-jaw surgery groups, the amount of condylar displacement in the 3 planes of space also showed no statistically significant differences (Table 3).

Discussion

This study was undertaken to evaluate the condylar positional changes after orthognathic surgery of Class III malocclusion patients. Linear, angular, and displacement changes in the condylar heads were assessed by use of CBCT images to test the null hypothesis, which stated that single-jaw and double-jaw surgeries yield no difference in postoperative condylar positional changes. Significant changes in condylar angulations were observed in the double-jaw surgery patients, whereas single-jaw surgery patients showed no changes. The mean distances of condylar displacements were 0.28 ± 0.44 mm in the single-jaw surgery group and 0.31 ± 0.51 mm in the double-jaw surgery group, and they were clinically insignificant (<2.0 mm).

In patients who have undergone double-jaw surgery, posterior maxillary impaction was 3.6 ± 0.72

Table 2. CHANGES IN CONDYLAR ANGULATIONS IN AXIAL, SAGITTAL, AND FRONTAL PLANES AND INTERCONDYLAR DISTANCES BEFORE SURGERY AND AFTER SURGERY

	Single-Jaw Group					Double-Jaw Group				
	Preoperative		Postoperative			Preoperative		Postoperative		
	Mean	SD	Mean	SD	*P* Value	Mean	SD	Mean	SD	*P* Value
Axial (°)	73.72	7.13	70.68	7.88	.170	70.82	6.61	69.34	6.34	.032*
Sagittal (°)	20.75	6.05	21.31	4.87	.450	19.81	5.48	21.74	5.80	.027*
Frontal (°)	9.85	4.56	9.95	2.63	.951	8.38	3.50	9.38	3.20	.114
Intercondylar distance (mm)	124.26	5.88	124.03	5.43	.485	123.87	6.36	123.51	6.25	.346

*Statistically significant ($P < .05$).

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Table 3. POSTOPERATIVE CONDYLAR DISPLACEMENTS IN SINGLE-JAW AND DOUBLE-JAW SURGERY GROUPS

	Single-Jaw Group		Double-Jaw Group		
Condylar Displacement	Mean	SD	Mean	SD	*P* Value
Medial-lateral (mm)	−0.02	0.525	−0.21	0.569	.352
Anterior-posterior (mm)	0.01	0.255	0.15	0.599	.457
Superior-inferior (mm)	0.07	0.347	−0.08	0.441	.340

NOTE. Positive values indicate a posterior, superior, and medial displacement; negative values represent an anterior, inferior, and lateral displacement.

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mm; thus the maxilla was rotated in a clockwise direction, correcting the labioversion of the upper incisors and midfacial deficiencies concomitantly as it moved forward. The mandible was also rotated clockwise and set back to achieve a proper occlusion with the upper arch and obtain a functional overbite and overjet. As a result, the gonions moved upward and the pogonion could be relocated more posteriorly. These changes could be accounted for by greater amounts of mandibular setback in the double-jaw surgery group, though not statistically significant.

Postoperative condylar angulations significantly changed in the axial and sagittal views in the double-jaw surgery patients, whereas the single-jaw surgery group showed no changes at all. These findings differ from previous reports that concluded that isolated mandibular setback is an unstable procedure.[14,21,22] However, Proffit et al[23] pointed out that the problems of stability of the mandibular setback are associated with surgical technique. They also stated that when the position of the proximal segment is poorly controlled, it can be pushed back with the distal segment, which later rebounds to its original position and brings the chin forward. Data from this study show no changes in the proximal segment in the single-jaw group, and surgical stability is anticipated. In the double-jaw surgery group, although angulations showed significant changes in the sagittal plane, the direction of the condylar rotation is forward instead of backward, and this will have minimal effects on the forward horizontal relapse of the chin position.

Intercondylar distance remained constant throughout the surgery in both groups of patients. This coincides with the minimal change in the frontal condylar angulations observed in both groups. Our results are contrary to those of Kerstens et al,[24] who reported that intercondylar width increases when the mandible is advanced and decreases when it is set back. However, Draenert et al[13] observed in their 3D analysis that there are no significant changes in intercondylar distance and the intercondylar angles in patients who received mandibular setback surgery either with or without maxillary surgery. Lee and Park[2] suggested that there are other factors, such as fixation method and surgical technique, that influence the intercondylar distance.

Condylar rotation in the axial view showed differences between the 2 groups. The double-jaw surgery group showed inward rotation of the mandible, whereas the SSRO group had the same rotations without statistical significance. The V-shaped mandibular morphology and the location of the osteotomy line contribute to the inward rotation of the condylar head as the proximal segments are fixated to the narrower distal segment. Our results coincide with those of Baek et al[25] and Lee and Park.[2]

Condylar displacements in the frontal, sagittal, and axial planes showed no difference between the single-jaw and double-jaw surgery groups, suggesting that both procedures are stable. Although displacement varied greatly, it was less than 2 mm, lacking clinical significance. These results are comparable to previous reports of condylar displacement ranging from 0.03 to 0.53 mm.[2,14,25] These data also had a large standard deviation, indicating a variable response in condylar positions. Proffit et al[23] have suggested that postsurgical changes do not have a normal distribution, and only a few patients show considerable changes. In another study regarding surgical stability, Kawakami et al[26] reported in their study of magnetic resonance images that condylar and temporomandibular joint disc positions remain constant in mandibular setback. On the other hand, Kim et al[27] reported in their long-term study that condyles move backward 6 months after surgery and then return to their original position during the retention period of 12 months after surgery.

This study has focused on the condyles and used CBCT scans to accurately assess the changes that occur after orthognathic surgery. Because significant condylar changes were observed in the double-jaw surgery patients, further investigations of skeletal changes of the maxilla and the mandible and their relationship with condylar changes will allow better understanding of the skeletal stability. In addition, longitudinal assessment of post-treatment condylar remodeling would be helpful in identifying its effects on the long-term skeletal stability.

Our results suggest that condylar angulations are more stable after SSRO of the mandible as an isolated procedure than in combination with the posterior maxillary impaction in the treatment of skeletal Class III malocclusion patients. However, the sagittal angulation changes observed in the double-jaw surgery group were directed forward instead of backward, which will have minimal effects on the forward horizontal relapse of the chin position. Condylar displacements in both the single-jaw and double-jaw groups were clinically insignificant.

Acknowledgments

The authors thank Bo-Ram Kim and Min-Ah Kim for their contributions to the collection of data for this study.

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