Cone-beam computerized tomography evaluation of condylar changes and stability following two-jaw surgery: Le Fort I osteotomy and mandibular setback surgery with rigid fixation

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Objectives. The purpose of this study was to compare the changes of the condylar axis, the anteroposterior condylar position relative to the glenoid fossa, and post–2-jaw surgery stability.

Study design. All of the patients (12 male, 14 female) were assessed by cone-beam computerized tomography (CBCT) before surgery, after surgery, and at follow-up. CBCT images were referenced to assess skeletal stability, the condylar axis change, and the anteroposterior condylar position in the glenoid fossa. A repeated-measures analysis of variance (P = .05) also was performed.

Results. The skeletal changes between postsurgery and follow-up (P < .05) were insignificant. Both the axial condylar angles and the anteroposterior condylar position significantly differed among the groups (P < .05).

Conclusions. After surgery, the coronal condylar axis was rotated inward. The anteroposterior condylar position in the glenoid fossa had moved from the anterior to the concentric position, tending to return slightly toward the original position. These changes did not negatively affect the stability.


Cone-beam computerized tomography (CBCT) is an accurate, cost-effective, and relatively low-radiation-exposure 3-dimensional (3D) imaging technique. CBCT is widely used in treatments involving the maxillofacial region. CBCT is the method of choice for condylar bony changes and positional changes in the temporomandibular joint (TMJ) spaces, although magnetic resonance imaging (MRI) remains the gold standard for isolation of soft-tissue changes. For orthognathic surgery patients, CBCT images can provide clinicians with better information on the status of joints and any bony changes.

Sagittal split ramus osteotomy (SSRO) of the mandible is perhaps the most common mandibular osteotomy procedure. Rigid internal fixation (RIF) is used to stabilize the proximal and distal segment after SSRO. RIF offers the advantages of fast bone healing without postoperative intermaxillary fixation (IMF), the earliest restoration of postoperative mandibular function, and minimization of relapse. Regarding stability after orthognathic surgery, Schendel and Epker distinguished between early relapse, or what occurs in the first few months after surgery, and later relapse. They identified the possible sites of relapse as osteotomies, through intersegmental movement, and the TMJ, through condylar distraction, rotation of the proximal segment, or morphologic changes in the condyle. Changes in condylar position after SSRO and RIF are...
frequently-reported findings of 2D radiographic analyses. However, 3D CBCT evaluation could be the better method for assessment of postsurgery stability and changes of the condylar position in the glenoid fossa. The purpose of the present study was to compare the short- and long-term changes in the condylar axis, the anteroposterior condylar position relative to the glenoid fossa, and the stability after Le Fort I osteotomy and SSRO with rigid fixation. The relationship between the pattern of condylar positional changes and stability after orthognathic surgery was also analyzed.

MATERIALS AND METHODS

Subjects

This study examined 26 patients with skeletal class III malocclusion. The individuals included 14 women and 12 men aged 18-28 years (mean age 21.30 ± 4.38 years). All of the patients had undergone pre- and postsurgical orthodontic treatments. Excluded were those with a history of additional orthognathic surgery procedures or who presented with severe facial asymmetry, syndromes, or degenerative joint disease. Informed consent was obtained from each of the patients. This study was approved by the Ethics Committee at Pusan National University Hospital.

Surgical technique

All of the patients in this study underwent Le Fort I osteotomy and bilateral SSRO to correct their maxillo-mandibular deformity. RIF was achieved with plates and screws in the maxilla. After condylar repositioning, RIF was carried out with bicortical screws. Stabilization was achieved with 3 position screws (width 2.0 mm, length 16 mm) at each side of mandible. These were placed at the superior border of the osteotomy site. The screws were placed where bone contact of the proximal and distal segment was sufficient and passive with no tension and the condyle was in proper position to avoid displacement. Stability was checked by the gentle attempt to verify condylar position from the hinge movement. After skeletal fixation, IMF was released, after which the condylar and occlusal positions were checked. IMF was reapplied for 1 week, followed by physiotherapy involving muscle and mouth-opening exercises. One month after surgery, active orthodontic treatment was resumed. Six months after surgery, the bicortical screws and plates were removed.

Data acquisition

A CBCT machine (DCT Pro; Vatech, Seoul, Korea) was used to evaluate the change of condylar position as well as the skeletal stability before surgery, 6 months after surgery (average 6.31 ± 0.75 months), and at follow-up (average 18.36 ± 4.01 months). For the purposes of the CBCT, all of the patients sat in an upright position for maximum intercuspation. The patients’ Frankfort horizontal (FH) plane was parallel to the floor. The scanning settings of the CBCT machine were as follows: 20 × 19 cm field of view, 90 kVp tube voltage, 4.0 mA tube current, 24 s scan time. The CBCT data were reconstructed with 3D image software (Ez3D2009; E-WOO Technology Co., Seoul, Korea).

Assessment of CBCT

Measurements of skeletal stability. In this study, 1 examiner (Y.-I.K.) analyzed the reference planes and points by 3D multiplanar reformation (MPR; Table I). An observer recorded the linear and angular measurements under the same image conditions (4,000 window width, 1,000 window level). To assess the horizontal and vertical changes in maxillary and mandibular movement, the distances from the FH plane to the A point and Me and from the Na perpendicular plane to the A point and Me were evaluated before surgery, after surgery, and at follow-up.

Measurement of condylar axis and condylar positional changes in glenoid fossa. To evaluate the changes in the condylar axis, angular (axial, coronal, and sagittal) measurements from 3D MPR images were obtained according to the reference planes (Fig. 1). The spaces between the condyle and glenoid fossa on sagittal MPR images, running parallel to the midsagittal reference (MSR) plane and passing through the center of the condyle, were calculated by Pullinger and Hollender’s method to assess the anteroposterior condylar position in the glenoid fossa (Fig. 1).8

Error of method and statistical analysis

Ten subjects chosen arbitrarily were assessed by the same investigator on 2 separate occasions at least 2
weeks apart. Dahlberg’s formula \((\sqrt{\Sigma d^2/2n})\) was then applied to determine the random errors, which were 0.41° in angular measurement and 0.07 mm in linear measurement. The presurgery, postsurgery, and follow-up data were compared. The differences were considered to be significant at \(P < .05\). Comparisons of the condylar position relative to the glenoid fossa before surgery, after surgery, and at follow-up were made by means of a repeated-measures analysis of variance (\(P = .05\)). Pair-wise comparisons were conducted using the Duncan test (\(P < .05\)).

**RESULTS**

The mean horizontal change of the maxilla was 1.66 ± 2.43 mm on the Na perpendicular plane–A point, and the vertical change was –2.34 ± 1.98 on the FH plane–A point. The extent of horizontal maxillary relapse was –0.03 ± 0.34 mm on the Na perpendicular plane–A point, and the extent of vertical maxillary relapse was –0.12 ± 1.21 on the FH plane–A point. The mean horizontal skeletal change of the mandible was –7.35 ± 5.44 mm on the Na perpendicular plane–Me, and the vertical change was –0.18 ± 8.55 mm on the FH plane–Me. The extent of horizontal mandibular relapse was 0.99 ± 1.38 mm on the Na perpendicular plane–Me, and the extent of vertical mandibular relapse was –0.41 ± 1.22 mm on the FH plane–Me. The skeletal changes were not significantly different between after surgery and follow-up (\(P < .05\)). Both of the axial condylar angles were significantly different among the groups (\(P < .05\)). However, there was no significant difference in the measurements of the other condylar angles (Table I).

The Pullinger values for the right and left condylar positions in the glenoid fossa showed that there were statistically significant differences among the presurgery, postsurgery, and follow-up groups (\(P < .05\)). Furthermore, there were also significant differences among the groups according to the Duncan test (\(P < 0.05\); Table II). Before surgery, the right and left condyles were anterior in the glenoid fossa. After surgery, both of the condyles moved to a concentric position. At follow-up, the condyles tended to have moved more anteriorly than was the case after surgery (Fig. 2).

**DISCUSSION**

The orthognathic surgical corrections showed various severities of relapse. Potential postsurgical relapse is indeed a major concern. Possible factors influencing stability and relapse after surgery, as identified by many studies, include the extent of movement, the type and materials of fixation, the mandibular plane angle, control of the proximal segment, soft tissue and muscular tension, remaining growth and remodeling, preoperative age, and the skill of the surgeon. These factors can contribute to improper condylar positioning, which can impede postsurgical stability. In fact, improper condylar positioning is directly related to unstable occlusion after IMF release. As a means of improving postsurgical stability, the use of RIF has greatly increased in orthognathic surgery. RIF has many advantages, including faster bony healing, earlier return of functionality, increased postoperative stability, easier oral hygiene maintenance, and the ability to verify the condylar position during surgery. All of these can prevent condylar malposition.
In the present study, CBCT was conducted 6 months after surgery and at 1.5 years’ follow-up. The maxillary skeletal relapse rates were 14.6% at the Na perpendicular plane to ANS and 21.4% at the FH plane to ANS; the mandibular skeletal relapse rates were 16.2% at the Na perpendicular plane to Me, and 37.7% at the FH plane to Me. These changes represented long-term skeletal relapse. Schendel and Epker explained that most early relapse affecting postsurgical stability occurs within 6 months. Until six months after surgery, active orthodontic treatment has still continued. Orthodontic effect on the stability was included in the postsurgery data. Widely various relapse rates for bicortical screws have been reported, including 1.5%-32.7% short term and 2.0%-50.3% long term. However, there are as yet few data on vertical relapse. In the present study, the vertical relapse rates were high, possibly influenced by the extent of maxillary movement. The vertical movements of the maxilla and mandible were smaller than their anteroposterior movements. The maxillary vertical change after surgery was about 2.3 mm, and that of the mandible was \[1 \text{ mm}.\] This small extent of vertical movement affected the vertical relapse rates in this study. In early postsurgery instability, changes in condylar position and soft-tissue stretching are frequent findings. Even with control of the condylar position, later relapse has been attributed largely to increased soft tissue and muscular tension. Comparing the findings of short-term and long-term studies, there is a general trend toward higher relapse rates with the use of bicortical screws.

Our study investigated the possibility that condylar positional changes from after surgery to follow-up might be related to later relapse. To assess condylar positional changes, CBCT MPR imaging was used following the defined reference plane and line (Table I).

### Table II. Cone-beam computerized tomography analysis results for presurgery, postsurgery, and follow-up groups

<table>
<thead>
<tr>
<th></th>
<th>Presurgery (T0)</th>
<th>Postsurgery (T1)</th>
<th>Follow-up (T2)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na perpendicular plane–A point</td>
<td>2.76 ± 2.07</td>
<td>4.42 ± 2.12</td>
<td>4.39 ± 2.16</td>
<td>.086</td>
</tr>
<tr>
<td>FH plane–A point</td>
<td>24.25 ± 3.95</td>
<td>21.92 ± 3.94</td>
<td>21.80 ± 4.54</td>
<td>.249</td>
</tr>
<tr>
<td>Na perpendicular plane–Me</td>
<td>8.19 ± 9.32</td>
<td>0.85 ± 7.02b</td>
<td>1.84 ± 6.63b</td>
<td>.043*</td>
</tr>
<tr>
<td>FH plane–Me</td>
<td>94.94 ± 9.53</td>
<td>94.75 ± 8.69</td>
<td>94.35 ± 9.18</td>
<td>.986</td>
</tr>
<tr>
<td>Axial condylar angle (right)</td>
<td>74.90 ± 6.88a</td>
<td>68.58 ± 7.46a</td>
<td>68.68 ± 7.16a</td>
<td>.048*</td>
</tr>
<tr>
<td>Axial condylar angle (left)</td>
<td>73.24 ± 5.27a</td>
<td>67.44 ± 6.40a</td>
<td>67.13 ± 6.09a</td>
<td>.020*</td>
</tr>
<tr>
<td>Coronal condylar angle (right)</td>
<td>78.28 ± 5.13</td>
<td>79.27 ± 3.86</td>
<td>78.77 ± 4.05</td>
<td>.849</td>
</tr>
<tr>
<td>Coronal condylar angle (left)</td>
<td>82.18 ± 4.23</td>
<td>81.70 ± 4.74</td>
<td>80.97 ± 4.46</td>
<td>.786</td>
</tr>
<tr>
<td>Sagittal condylar angle (right)</td>
<td>63.99 ± 6.14</td>
<td>61.69 ± 4.36</td>
<td>60.90 ± 3.97</td>
<td>.262</td>
</tr>
<tr>
<td>Sagittal condylar angle (left)</td>
<td>64.51 ± 5.77</td>
<td>63.31 ± 4.05</td>
<td>61.85 ± 4.27</td>
<td>.373</td>
</tr>
<tr>
<td>Anterior space (right)</td>
<td>1.81 ± 0.73a</td>
<td>2.40 ± 0.68b</td>
<td>1.88 ± 0.42a</td>
<td>.043*</td>
</tr>
<tr>
<td>Superior space (right)</td>
<td>2.67 ± 0.79</td>
<td>2.70 ± 0.57</td>
<td>2.42 ± 0.51</td>
<td>.464</td>
</tr>
<tr>
<td>Posterior space (right)</td>
<td>2.43 ± 0.65</td>
<td>2.28 ± 0.64</td>
<td>2.25 ± 0.46</td>
<td>.703</td>
</tr>
<tr>
<td>Anterior space (left)</td>
<td>1.68 ± 0.44a</td>
<td>2.25 ± 0.40b</td>
<td>1.92 ± 0.44b</td>
<td>.010*</td>
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<tr>
<td>Superior space (left)</td>
<td>2.67 ± 0.81</td>
<td>2.68 ± 1.18</td>
<td>2.69 ± 0.93</td>
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<tr>
<td>Posterior space (left)</td>
<td>2.69 ± 0.80</td>
<td>2.18 ± 0.79</td>
<td>2.44 ± 0.64</td>
<td>.230</td>
</tr>
</tbody>
</table>

Distances are given in mm, angles in degrees.

*FH, Frankfort horizontal.

*Significant difference in the 3 groups by analysis of variance (P < .05).

The same superscripts indicate no statistically significant differences among the indicated groups (P > .05).

In the present study, CBCT was conducted 6 months after surgery and at 1.5 years’ follow-up. The maxillary skeletal relapse rates were 14.6% at the Na perpendicular plane to ANS and 21.4% at the FH plane to ANS; the mandibular skeletal relapse rates were 16.2% at the Na perpendicular plane to Me, and 37.7% at the FH plane to Me. These changes represented long-term skeletal relapse. Schendel and Epker explained that most early relapse affecting postsurgical stability occurs within 6 months. Until six months after surgery, active orthodontic treatment has still continued. Orthodontic...
In the present study’s clinical examination, changes caused temporomandibular joint disorder improper condylar positioning and condylar axial follow-up period. In the findings of several investigations, affect changes of axial condylar angles during the follow-up, and the resultant values were classified into 3 groups: anterior, concentric, and posterior positions. In the results, the condylar anteroposterior position before surgery was anterior in the glenoid fossa. After surgery, it had moved to a concentric position (Tables II and III). This change can vary according to the type of fixation and the material used, control of the proximal segment, and skill of the surgeon. However, in the course of active postsurgical orthodontic treatment, interdigitation and elastic guides can negatively affect condylar anteroposterior changes occurring later after surgery. All of the subjects of the present study had finished their orthodontic treatment an average 7.80 months after surgery. At follow-up, the condyle had moved slightly back to its original position (Tables II and III). This condylar movement might follow physiologic adaptation. Indeed, the soft tissue, muscles, joints, and their discs can adapt to the new skeletal morphology affected by orthognathic surgery.29,38 These changes appear over the long term. The extent of later relapse depends on the ability to adapt to the changed neuromuscular environment and other time-dependent factors.

Orthognathic surgery can correct dentofacial deformities and change neuromuscular environments. Condylar positional changes occurring after surgery can aggravate TMD. Two studies used MRI to assess articular disc positions before and after surgery, and both indicated that displaced discs were corrected or improved after surgery in some patient groups.39,40 In other papers, a >50% postsurgery versus presurgery decrease in the prevalence of the typical signs and symptoms of TMD has been reported.41-43 Although orthognathic surgery should not be advocated solely for TMD, patients undergoing orthognathic treatment for correction of other dentofacial deformities, and who also suffer from TMD, appear to be more likely to see improvement in their signs and symptoms than deterioration.44 In the present study, one of the patients manifested clinical signs and symptoms of TMD, even though their condylar position had moved in the posterior direction and had slightly returned to its original point over time. This means that physiologic adaptation can accommodate small changes in the condylar position. And this would be followed either by later skeletal relapse or condylar remodeling. Regarding specific manifestations of TMD signs and symptoms, this depends on the individual patient’s physiologic adaptation capacity. Physiologic adaptation, moreover, re-
quires a sufficiently long time period.\textsuperscript{38} In our study, most of the patients adapted to the new stomatognathic functionality of the condylar positional changes without showing any TMD signs or symptoms. Furthermore, this did not impede long-term stability.

REFERENCES


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