Transverse Displacement of the Proximal Segment After Bilateral Sagittal Osteotomy

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Purpose: The aim of the present investigation was to evaluate the transverse displacement of the proximal segment and ramus rotation after a bilateral sagittal osteotomy (BSO) with rigid internal fixation (RIF) using bicortical LAG screws.

Patients and Methods: We conducted a retrospective review of 37 patients (14 males and 23 females, age range of 14 to 55 years) who underwent a mandibular advancement with BSO and RIF. Posteroanterior and lateral cephalometric radiographs were obtained 1 to 8 weeks before and 1 to 4 weeks after surgery. The transverse displacement and angulation of the proximal segments after surgery were measured on posteroanterior radiographs, using the best-fit method. The amount of mandibular advancement was compared with the amount of transverse displacement of the proximal segments.

Results: In the 1 to 4-week postoperative period after a BSO, 36 of 37 subjects showed an increased transverse intergonion distance (5.6 mm) ($P < .0001$) and 35 of 37 patients showed an increased transverse interramus width (3.3 mm) ($P < .0001$). No correlation was found between mandibular advancement and transverse displacement of the proximal segment.

Conclusions: The study results indicate that transverse displacements of the proximal segments occur with BSO and RIF. The clinical impact on temporomandibular joint symptomatology or surgical relapse with such displacement was not assessed in the study. Future studies that address these issues may help to determine whether there is an association between proximal segment displacement and surgical relapse, temporomandibular dysfunction, or both.

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Bilateral sagittal osteotomy (BSO) is the most favored surgical procedure for the management of mandibular retrognathia. Despite its popularity, postsurgical instability due to displacement of the condyle from its seated position in the 3 planes of space (sagittal, vertical and transverse) remains of concern. The sagittal and vertical position of the condyle in the glenoid fossa after a BSO was analyzed in several studies,\(^1\)\(^3\)\(^5\) and a superior and posterior movement of the condyle after surgery has been described. Studies have also reported a correlation between an increasing amount of mandibular surgical advancement and increasing postsurgical superior movement of the condyle.\(^1\)\(^3\)\(^4\) Relapse has often been described as associated with condylar resorption and late relapse.\(^16\)\(^17\) Hypomobility has also been reported to be a possible sequelae of condylar rotation and displacement.\(^18\)

The purpose of the present investigation was to evaluate the transverse displacement of the proximal segment and ramus torque after a BSO with RIF using bicortical screws and to compare the amount of transverse displacement of the proximal segment with the amount of surgical advancement.

**Materials and Methods**

**SUBJECTS**

The clinical information was based on records collected at the Division of Oral and Maxillofacial Surgery and the Division of Orthodontics, Dental Specialties, Mayo Clinic, Rochester, MN, and was retrospectively analyzed according to a standardized study design. The choice of treatment was determined by the orthodontist and the surgeon at the clinical and radiographic presurgical examinations.

All patients met the following criteria: 1) the malocclusion was caused by mandibular retrognathia, 2) the patient underwent presurgical and postsurgical phases of orthodontic treatment, 3) BSO with RIF was used as the surgical procedure to advance the mandible with or without genioplasty, and 4) no other adjunctive surgical procedures were performed.

The protocol included 42 patients who were consecutively admitted by 2 surgeons and referred from the Division of Orthodontics between January 1, 1990, and December 31, 1999. Patients referred from private practice orthodontists were not included because orthodontic records were not standardized regarding the number and type of radiographs, radiographic magnification, and so on. Of the 42 patients, 5 were excluded due to inconsistent radiographic follow-up investigation. Therefore, the data presented are for the remaining 37 patients (14 males and 23 females, mean ± SD age of 27.8 ± 11.63 years, age range of 14 to 55 years). All 42 patients received conventional presurgical and postsurgical orthodontic treatment and underwent a mandibular bilateral sagittal ramus osteotomy advancement as described by Obwegeser\(^19\)\(^20\) and modified by Dal Ponte.\(^21\) The planned occlusion was established with a prefabricated splint. The proximal segment was manually repositioned and stabilized with a self-retaining clamp. RIF was accomplished by using 2 lag screws bilaterally in the lateral ramus. The screws were placed through both proximal and distal segments in the region distal to the second molar tooth and above the mandibular canal. The occlusion was checked after the placement of RIF. The patients had intermax-
illary wire fixation with the prefabricated splint for 1 to 2 weeks after surgery. Subjects who underwent maxillary surgery were not included in the study. Seven patients underwent advancement genioplasty in addition to mandibular advancement.

RADIOGRAPHIC EXAMINATION

The radiographic material for this study consisted of 2 posteroanterior (PA) and 2 lateral cephalometric radiographs for each patient. The stereometric PA and lateral cephalometric radiographs were obtained at the following time periods: 0 to 8 weeks before surgery (T1) and 0 to 4 weeks after surgery (T2).

A standardized natural head position was used while obtaining the lateral and PA cephalometric radiographs. The radiographs were taken with the same equipment, and the same film and focus distance were used. All radiographs were taken at optimal exposure, and anatomic landmarks were clearly visualized.

PA Cephalometric Radiographs

The PA radiographs were used to measure the angulation of the proximal segment and the mandibular width. The following reference points and lines were used (Fig 1). Ramus point (RP), was defined as the most superior visible part on the lateral border of the ramus. Gonion (GO), was defined as the most lateral visible part of the mandible determined by a tangent to the outline from RP. Upper orbital margin (UOM) was defined as the most superior visible margin of the orbit.

Reference lines were drawn through GO and RP, and a tangent line to the UOMs was used as a horizontal reference plane. Points GO and RP were then transferred forward from the T1 to the T2 radiograph via a best-fit superimposition of the proximal segment cortical outline.

The variables that were recorded were the medial ramus angles between UOMs and GO-RP lines, the distances between the left GO and the right GO, and the distance between the left RP and the right RP.

Lateral Cephalometric Radiographs

The reference points were marked directly on the lateral cephalometric radiographs. The B-point (defined as the most posterior point on the anterior surface of the symphysis) was transferred forward from the T1 tracing to the T2 tracing via a best-fit superimposition of the distal segments onto each other.22 The lateral cephalometric radiographs were superimposed onto anatomic stable structures in the anterior cranial base, according to the method described by Björk.23

For the detection of errors of superimposition, a control tracing was prepared for each set of lateral radiographs; this is a procedure recommended by Björk and Skieller24 for routine clinical purposes.

To determine the skeletal changes obtained by the BSO, the changed position of B-point was measured. The superimposed lateral radiographs were used to determine the horizontal and vertical movements of B-point from T1 to T2. B-point movements in the superior and anterior direction were recorded as positive values, and movements in the inferior and posterior direction were recorded as negative values.

Change in width between GO and RP points was also recorded as a percentage change (eg, percent change in GO width equals [(T1 − T2 GO)/GO presurgical width]). We used t-tests (P < .05) to determine whether statistically significant differences existed between males and females or between the 2 surgeons. Correlations between variables were tested with bivariate density ellipses (P < .05), and Pearson’s correlation coefficients (r values) were obtained for each comparison.

Five cases were randomly selected, and all tracings and measurements were redone by the same investigator to test for reliability of the method. Measurement errors were determined using the Dahlberg formula:

$$
\sqrt{\frac{\sum D^2}{2N}}
$$

where D is the difference between remeasured values and N is the number of double measurements (N =
Results of *t*-tests showed a significant difference (*P* < .001) between males and females with regard to initial (T1) width between GO points, as well as between RP points. Males had a larger presurgical inter-GO width (108.5 ± 6.7 mm vs 100.0 ± 5.9 mm for females) and a larger RP width (115.8 ± 5.1 mm vs 108.2 ± 4.6 mm for females). As such, data analysis was performed using both linear changes in millimeters and percentage changes to help control for this difference in absolute width. Although all 37 patients were included in the initial data analysis, statistical testing was also performed without these 2 outliers to determine whether they had significantly skewed the outcomes by being included in the data analysis.

The *t*-tests showed no difference between surgeons on any of the variables measured and no difference between males and females with regard to changes in width from the surgery between GO points and RP points. However, females did have significantly greater ramal angular changes with surgery. The total angular change (left plus right) was 4.2° ± 3.2° for females versus 0.9° ± 3.3° for the males (*P* < .01). On the left side, the mean increase was 2.4° ± 1.3° versus 0.6° ± 2.5° for the males (*P* < .01). On the right side, the mean increase was 1.8° ± 2.6° versus 0.3° ± 1.6° for the males (*P* < .05). However, removal of the 2 outliers from statistical testing made the right-sided angular change difference between the genders no longer significant (*P* = .09).

<table>
<thead>
<tr>
<th>Table 2. DISTRIBUTION OF T1 AND T2 POSTEROANTERIOR CEPHALOMETRIC RADIOGRAPH MEASUREMENTS</th>
<th>Range (T1-T2)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 radiographs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weeks before surgery</td>
<td>1-8</td>
<td>1.5</td>
<td>1.61</td>
</tr>
<tr>
<td>Intergonion (GO) width (mm)</td>
<td>91.0-121.6</td>
<td>103.2</td>
<td>7.42</td>
</tr>
<tr>
<td>Interramus (RP) width (mm)</td>
<td>100.4-124.2</td>
<td>111.1</td>
<td>5.99</td>
</tr>
<tr>
<td>Left UOM/RP/GO angle (°)</td>
<td>76.5-95.0</td>
<td>84.7</td>
<td>4.55</td>
</tr>
<tr>
<td>Right UOM/RP/GO angle (°)</td>
<td>75.5-94.0</td>
<td>84.6</td>
<td>4.19</td>
</tr>
<tr>
<td>T2 radiographs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weeks after surgery</td>
<td>1-4</td>
<td>1.2</td>
<td>0.55</td>
</tr>
<tr>
<td>GO width (mm)</td>
<td>95.2-127.4</td>
<td>108.8</td>
<td>7.40</td>
</tr>
<tr>
<td>RP width (mm)</td>
<td>105.0-130.0</td>
<td>114.3</td>
<td>6.68</td>
</tr>
<tr>
<td>Left UOM/RP/GO angle (°)</td>
<td>78.0-95.0</td>
<td>86.4</td>
<td>4.23</td>
</tr>
<tr>
<td>Right UOM/RP/GO angle (°)</td>
<td>74.0-96.5</td>
<td>85.9</td>
<td>4.70</td>
</tr>
</tbody>
</table>

Abbreviations: T1, 0 to 8 weeks before surgery; T2, 0 to 4 weeks after surgery.
Figure 2. A 20-year-old man before (A) and after (B) bilateral sagittal osteotomy fixated with 4 bicortical screws. C. Increased transverse width and angulation of the proximal segment.

Table 3. RESULTS OF T1 AND T2 POSTEROANTERIOR CEPHALOMETRIC RADIOGRAPH MEASUREMENTS

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Mean</th>
<th>SD</th>
<th>Method Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intergonion (GO) width change (mm)</td>
<td>-2.6 to 12.2</td>
<td>5.6</td>
<td>3.05</td>
<td>0.21</td>
</tr>
<tr>
<td>GO width change (%)</td>
<td>-2.4 to 12.9</td>
<td>5.5</td>
<td>3.12</td>
<td>-</td>
</tr>
<tr>
<td>Inter-ramus (RP) width change (mm)</td>
<td>-2.8 to 7.2</td>
<td>3.3</td>
<td>2.25</td>
<td>0.29</td>
</tr>
<tr>
<td>RP width change (%)</td>
<td>-2.4 to 6.3</td>
<td>3.0</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>Left UOM/RP/GO angle change (°)</td>
<td>-3.5 to 5.5</td>
<td>1.7</td>
<td>1.98</td>
<td>0.45</td>
</tr>
<tr>
<td>Right UOM/RP/GO angle change (°)</td>
<td>-3.5 to 7.0</td>
<td>1.2</td>
<td>2.38</td>
<td>0.47</td>
</tr>
</tbody>
</table>
Correlation analysis showed no trends with either age at surgery or surgical date for any of the variables measured. Significant correlations were found, however, between change in intergonial width and several variables. Not surprisingly, changes in GO width were correlated to changes in RP width ($r = 0.62$, $P < .001$). This held true even when percent changes in width were substituted for the millimetric variables ($r = 0.64$). Removal of the 2 outliers (patients 14 and 34) did not change the Pearson’s correlation coefficients.

GO width change also was correlated with ramal angular changes: for GO versus left angular change, ($r = 0.47$ and $P < .005$); for GO versus right angular change, ($r = 0.49$ and $P < .001$); and for GO versus left and right angular changes, ($r = 0.59$ and $P < .005$). Again, substitution of percentage change in inter-GO width changed the $r$ values minimally ($r = 0.45, 0.51$, and $0.60$, respectively). The removal of the outliers from these correlation analyses changed the coefficients only slightly. For the GO millimetric variable versus left, right, and left plus right angular

change, r values were 0.39, 0.60, and 0.64, respectively. For the GO percentage variable, the r values were 0.39, 0.63, and 0.66, respectively, with the outliers removed.

Change in RP width was not significantly correlated to any variable other than change in GO width, as mentioned previously. The only other correlation found was between left and right angular change variables, although the correlation was weak (r = 0.35; P < .05). In addition, this correlation lost statistical significance with the removal of the 2 outliers.

Discussion

The results of the present study show that the transverse width between proximal segments increased significantly after routine mandibular sagittal ramus osteotomy advancement surgery. Both the intergonial and interramus widths increased. Furthermore, an increased outward angulation of the ramus was observed. Due to the radiographs used, no statements can be made on the actual condylar position changes.

Recent studies with tantalum markers have demonstrated positional stability between proximal and distal segments after a BSO of the mandible with RIF.25,26 Therefore, the postsurgical mandible can be assumed to be a single rigid body. The displacements observed in this study are likely to occur during the surgical procedure and not in the postsurgical period.

Transverse condylar displacement has been studied previously, but different methods have been used and different results have been presented (Table 4). To our knowledge, the transverse changes that occur after a BSO have not been analyzed with PA cephalometric radiographs. PA radiographs were used to report the angulation change of the condylar fragment after oblique ramus ostetomy surgery,27 and a lateral angulation change in the condyle fragment of about 8° of outward inclination was observed. Because the PA radiograph is a routine radiograph that can be used in the planning and follow-up of patients treated with BSO, the advantage of the use of this radiograph is obvious.

In a recent study,28 it was reported that GO could not be used as a valid landmark on PA radiographs due to a large range in identification. In the present study, GO and RP were transferred via the best-fit superimposition from T1 to T2, and identification errors were thereby avoided.

An important source of error may be the variability in the radiographic enlargement of transverse skeletal

Table 4. PREVIOUS REPORTS ON TRANSVERSE CONDYLAR DISPLACEMENT AFTER BILATERAL SAGITTAL OSTEOTOMY

<table>
<thead>
<tr>
<th>Year</th>
<th>Method/Time</th>
<th>Osteosynthesis</th>
<th>Condyle Angulation</th>
<th>Transverse Displacement</th>
<th>Mean (mm)</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alder et al2</td>
<td>1992</td>
<td>CT scans/8 wk after surgery Bicortical screws</td>
<td>60% Lateral, 40% medial</td>
<td>55% Lateral, 45% medial</td>
<td>1.2</td>
<td>—</td>
</tr>
<tr>
<td>Harris et al7</td>
<td>1999</td>
<td>CT scans/8 wk after surgery Bicortical screws</td>
<td>71% Medial, 29% lateral</td>
<td>65% Medial, 35% lateral</td>
<td>1.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Schultes et al9</td>
<td>1998</td>
<td>CT scans/6 to 8 wk after surgery 3-dimensional models Screws</td>
<td>Decreased intercondylar angle (medial)</td>
<td>Lateral</td>
<td>2.0</td>
<td>Distance between coronid processes increased with 6.6 mm</td>
</tr>
<tr>
<td>Stroster et al10</td>
<td>1994</td>
<td>Submentovertex Screws</td>
<td>Lateral</td>
<td>Not measured</td>
<td></td>
<td>More displacement in screw group compared with wire group; no correlation to advancement</td>
</tr>
<tr>
<td>Hackney et al12</td>
<td>1989</td>
<td>Submentovertex/6 to 12 mo after surgery Screws</td>
<td>Increase and decrease in intercondylar angle but no significant change</td>
<td>Lateral and medial displacement observed but not significant</td>
<td></td>
<td>No correlation to advancement or TMD</td>
</tr>
<tr>
<td>Will et al11</td>
<td>1984</td>
<td>Submentovertex/1 wk after surgery Wires</td>
<td>No significant change</td>
<td>No significant change</td>
<td></td>
<td>No correlation to advancement</td>
</tr>
</tbody>
</table>

Abbreviations: CT, computed tomography; TMD, temporomandibular disease.
dimensions projected onto PA films. The subjects were positioned facing the film, and the head was placed in the cephalometer with the Frankfort plane horizontal. Although the radiographs for this study were taken by experienced technicians, some degree of up and down tilting of the head was probably inevitable, so some difference in enlargement between 2 PA radiographs could be expected. A change of up to 10° of up and down movement or right or left rotation of the head, however, has been shown to be less than the method error and is therefore a negligible factor in breadth measurements.27,29 A change of 10° in rotation of the head would have easily been detected by the technicians.

In addition, the fact that 36 of 37 patients showed increased intergonial width supports the results, because by chance alone, 50% of T2 PA radiographs would be expected to be decreased compared with T1 with head-positioning errors. One could hypothesize that the increase and decrease would cancel each other.

It is conceivable that the adaptation capacity of the temporomandibular joint (TMJ) could be exceeded with a significant transverse change in the proximal segment positioning due to surgery, especially in a susceptible individual. Surgeons and orthodontists should carefully observe patients who complain of pain in the TMJ after a BSO. The patient who complains of a physical barrier to opening should be assessed for excessive condylar torque.18

Several studies10,13,14 have shown that the use of RIF after BSO results in a greater transverse condylar displacement than wire fixation. This suggests that the role of fixation technique in condylar and proximal segment displacement could be of importance and should be further investigated. Lag screws may also result in a different proximal segment position compared with positional screws.

The consideration by Hackney et al12 that V-shaped mandibles with more divergent rami would produce a larger increase in intercondylar width when advanced, compared with U-shaped mandibles, was unfounded in their study. In the present study, no submentovertex radiographs were taken, and the issue could not be investigated. A correlation between mandibular advancement and transverse displacement of the proximal segment was not found, which is in agreement with other reports.7,10,12

Conclusion

Our results indicate that transverse displacements of the proximal segments occur with BSO surgery and RIF. The clinical impact on TMJ symptomatology or surgical relapse with such displacement was not assessed in this study. Future studies that address these issues may help to determine whether there is an association between proximal segment displacement and surgical relapse and/or the development of temporomandibular disorders. In addition, the role of fixation technique in proximal segment displacement should be investigated.

The results of this study support the routine use of presurgical and postsurgical PA cephalometric radiographs to evaluate transverse proximal segment displacement after BSO with RIF.

References

13. Freihoffer HP Jr: [Model test on the change of position of the mandibular condyle after sagittal splitting of the mandible]. SOS Schweiz Monatsschr Zahnheilkd 87:12, 1977