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] 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 distraction.[4,5] Schendel and Epker[6] concluded that control of the proximal segment was the most important aspect in the prevention of relapse and stability of the planned postsurgical position.

The transverse displacement of the proximal segment has been studied with computed tomography (CT) scanning and submentovertex radiography. In CT studies, changes in all planes have been described, with a more lateral condylar position and increased condylar angle being the most frequent observations in 1 study.[2] In another study,[7] the condyle was also displaced in all planes but was most frequently medially and medially rotated. Spitzer and Steinhauser[8] also used CT scanning and reported condylar orientation changes (1° to 18°) and changes in intercondylar distance (−5 to +4 mm).

Schultes et al[9] showed significant condylar transverse rotation and lateral displacement in 3-dimensional models obtained from subjects who underwent BSO. This is in agreement with a study that reported an increased condylar angle after BSO.[10] In other studies using submentovertex radiography, no significant difference was found in transverse condylar position.[11,12]

It appears from several studies that the use of rigid internal fixation (RIF) after BSO results in a greater transverse condylar displacement than the use of wire fixation.[10,13,14] Hackney et al[12] suggested that clamp placement and subsequent screw osteosynthesis have more influence on condylar displacement than the direction and amount of surgical advancement.

Although one might expect a direct relationship between condylar position and temporomandibular dysfunction, the literature does not support such a relationship.[15] Transverse condylar displacement clearly has been shown after a BSO with RIF, but no increase in temporomandibular dysfunction has been reported,[8,12] nor has a connection between mandibular advancement or mandibular morphology been described as associated with transverse condylar displacement.[7,10-12] Condylar displacement after a BSO fixated with RIF may, however, be 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 intermaxillary 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.

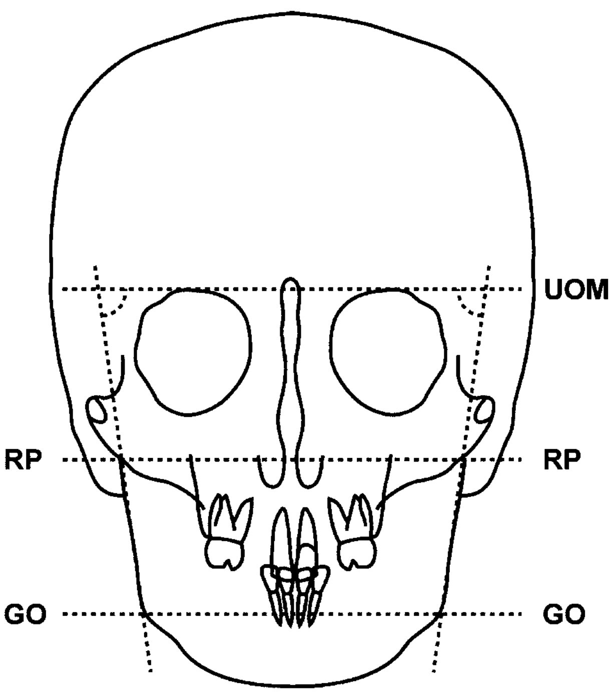

FIGURE 1. The distances from RP to RP and from GO to GO were measured. Reference lines through RP and GO and a tangent line to UOMs were used to measure the angulation of the proximal segment. (UOM, upper orbital margin; RP, ramus point; GO, gonion.)

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 Bjork.[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 Skieller[24] 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:

$$\sqrt{(\sum D^2/2\ N)}$$

where D is the difference between remeasured values and N is the number of double measurements ($N =$

Table 1. RESULTS OF THE T1 AND T2 LATERAL CEPHALOMETRIC RADIOGRAPH MEASUREMENTS

	Range (T1-T2)	Mean	SD	Method Error
Horizontal movement at B-point (mm)	0.9 to 12.0	4.9	2.44	0.29
Vertical movement at B-point (mm)	−7.2 to 6.8	−1.9	2.85	0.41
Mandible angle (°)	16.5 to 51.5	31.6	8.54	0.38

Abbreviations: T1, 0 to 8 weeks before surgery; T2, 0 to 4 weeks after surgery.

5). Method error scores can be found in Tables 1 and 3.

Results

A review of the clinical records of the 37 study patients showed that no significant adverse events occurred before or during surgery and up to the time of the postoperative radiographs, that may have resulted in any unexpected displacements of the segments.

Mandibular advancement measured at the B-point ranged from 0.9 to 12.0 mm (Table 1). The distribution of measurements from preoperative (T1) and postoperative (T2) PA radiographs is shown in Table 2.

The changes in width between RP points and between GO points were found to be statistically significant ($P < .0001$) and are shown in Table 3. Changes in width are presented in both millimeters and percentages. Of 37 patients, 36 had an increased intergonial width and 35 had an increased width between RP points. Measurements from 1 male patient and 1 female patient are shown (Figs 2, 3).

The right and left ramus angles, developed by the line through the UOMs and a line through GO and RP, showed an increased angle with a mean of 1.2° (range, −3.5° to 7.0°) on the right side and of 1.7° (range, −3.5° to 5.5°) on the left side (Table 3).

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 2. DISTRIBUTION OF T1 AND T2 POSTEROANTERIOR CEPHALOMETRIC RADIOGRAPH MEASUREMENTS

	Range	Mean	SD
T1 radiographs			
Weeks before surgery	1-8	1.5	1.61
Intergonion (GO) width (mm)	91.0-121.6	103.2	7.42
Interramus (RP) width (mm)	100.4-124.2	111.1	5.99
Left UOM/RP/GO angle (°)	76.5-95.0	84.7	4.55
Right UOM/RP/GO angle (°)	75.5-94.0	84.6	4.19
T2 radiographs			
Weeks after surgery	1-4	1.2	0.55
GO width (mm)	95.2-127.4	108.8	7.40
RP width (mm)	105.0-130.0	114.3	6.68
Left UOM/RP/GO angle (°)	78.0-95.0	86.4	4.23
Right UOM/RP/GO angle (°)	74.0-96.5	85.9	4.70

Abbreviations: T1, 0 to 8 weeks before surgery; T2, 0 to 4 weeks after surgery.

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

	Range	Mean	SD	Method Error
Intergonion (GO) width change (mm)	−2.6 to 12.2	5.6	3.05	0.21
GO width change (%)	−2.4 to 12.9	5.5	3.12	—
Inter-ramus (RP) width change (mm)	−2.8 to 7.2	3.3	2.23	0.29
RP width change (%)	−2.4 to 6.3	3.0	2.0	—
Left UOM/RP/GO angle change (°)	−3.5 to 5.5	1.7	1.98	0.45
Right UOM/RP/GO angle change (°)	−3.5 to 7.0	1.2	2.38	0.47

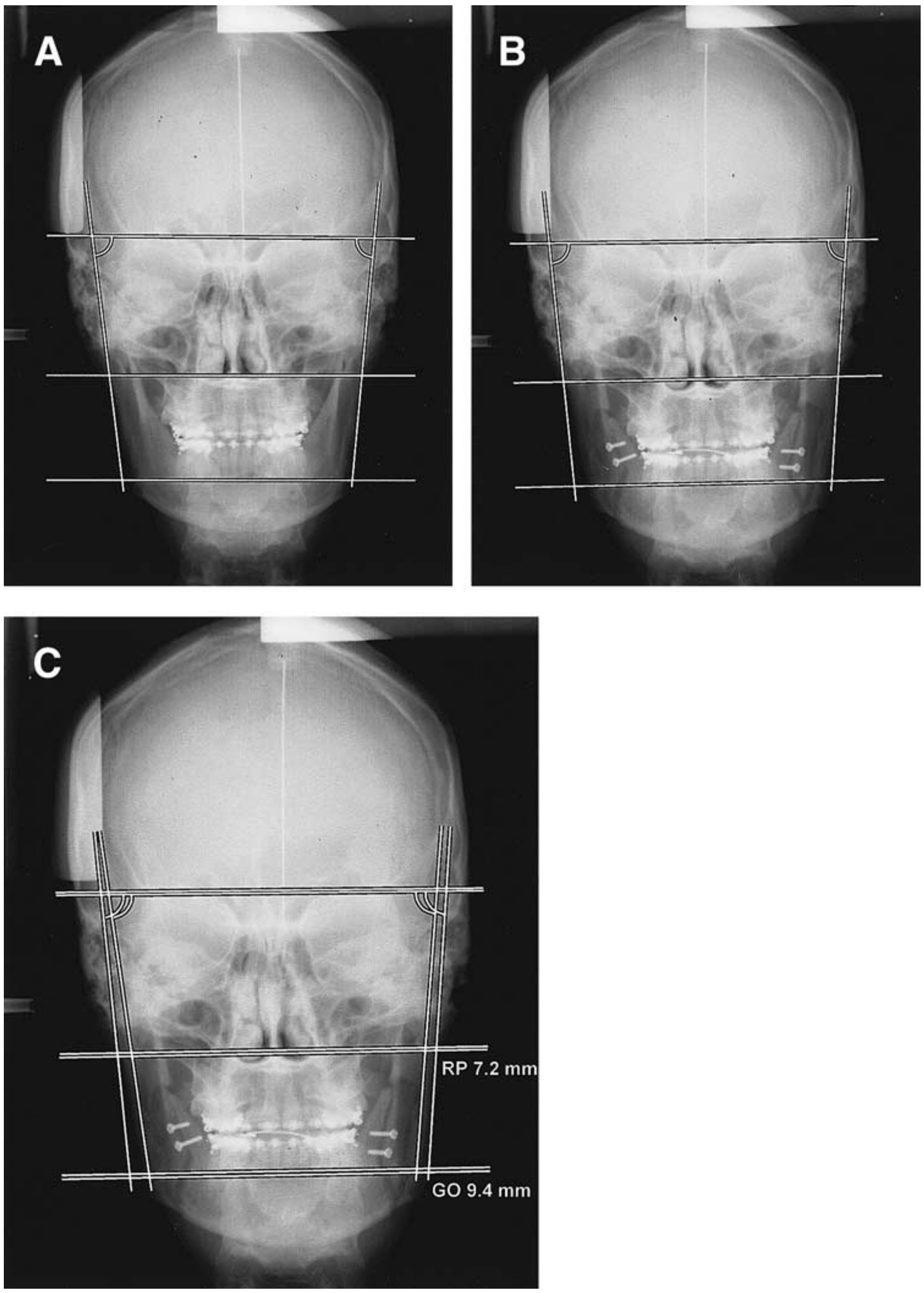

FIGURE 2. A 20-year-old man before (*A*) and after (*B*) bilateral sagittal osteotomy fixated with 4 bicortical screws. *C*, Increased transverse width and angulation of the proximal segment.

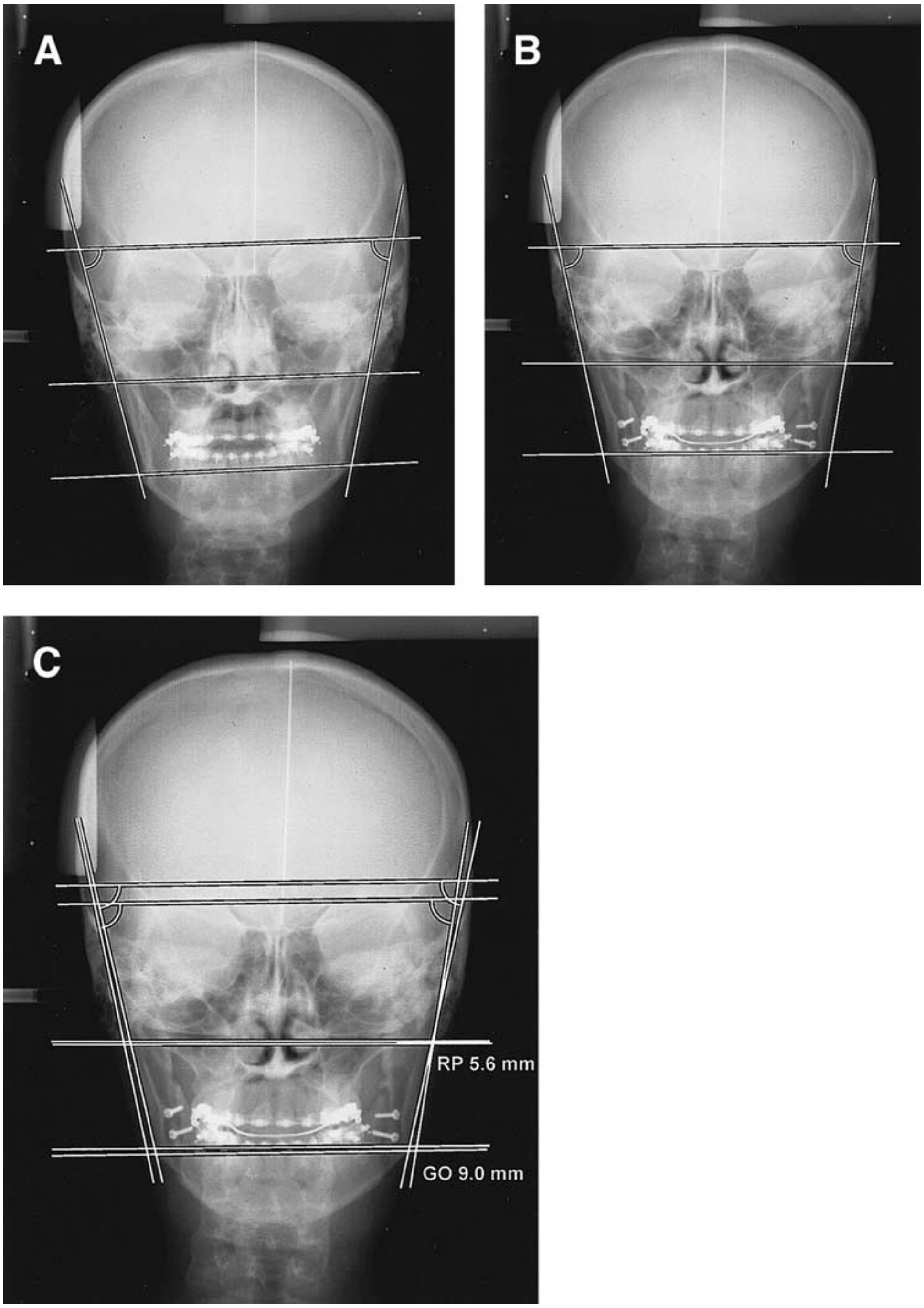

FIGURE 3. A 27-year-old woman before (*A*) and after (*B*) bilateral sagittal osteotomy fixated with 4 bicortical screws. *C*, Increased transverse width and angulation of the proximal segment.

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

	Year	Method/Time	Osteosynthesis	Condyle Angulation	Transverse Displacement	Mean (mm)	Other
Alder et al[2]	1992	CT scans/8 wk after surgery	Bicortical screws	60% Lateral, 40% medial	55% Lateral, 45% medial	1.2 1.5	—
Harris et al[7]	1999	CT scans/8 wk after surgery	Bicortical screws	71% Medial, 29% lateral	65% Medial, 35% lateral	1.4 0.7	No correlation to advancement or to shape of mandible
Schultes et al[9]	1998	CT scans/6 to 8 wk after surgery 3-dimensional models	Screws	Decreased intercondylar angle (medial)	Lateral	2.0	Distance between coronid processes increased with 6.6 mm
Stroster et al[10]	1994	Submentovertex	Bicortical screws	Lateral	Not measured		More displacement in screw group compared with wire group; no correlation to advancement
Hackney et al[12]	1989	Submentovertex/ 6 to 12 mo after surgery	Screws	Increase and decrease in intercondylar angle but no significant change	Lateral and medial displacement observed but not significant		No correlation to advancement or TMD
Will et al[11]	1984	Submentovertex/ 1 wk after surgery	Wires	No significant change	No significant change		No correlation to advancement

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 studies[10,13,14] 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 al[12] 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

1. Van Sickels JE, Larsen AJ, Thrash WJ: Relapse after rigid fixation of mandibular advancement. J Oral Maxillofac Surg 44:698, 1986
2. Alder ME, Deahl ST, Matteson SR, et al: Short-term changes of condylar position after sagittal split osteotomy for mandibular advancement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 87:159, 1999
3. Rebellato J, Lindauer SJ, Sheats RD, et al: Condylar positional changes after mandibular advancement surgery with rigid internal fixation. Am J Orthod Dentofac Orthop 116:93, 1999
4. Gassmann CJ, Van Sickels JE, Thrash WJ: Causes, location, and timing of relapse following rigid fixation after mandibular advancement. J Oral Maxillofac Surg 48:450, 1990
5. Van Sickels JE, Larsen AJ, Thrash WJ: A retrospective study of relapse in rigidly fixated sagittal split osteotomies: Contributing factors. Am J Orthod Dentofacial Orthop 93:413, 1988
6. Schendel SA, Epker BN: Results after mandibular advancement surgery: An analysis of 87 cases. J Oral Surg 38:265, 1980
7. Harris MD, Van Sickels JE, Alder M: Factors influencing condylar position after the bilateral sagittal split osteotomy fixed with bicortical screws. J Oral Maxillofac Surg 57:650, 1999
8. Spitzer WJ, Steinhauser EW: Condylar position following ramus osteotomy and functional osteosynthesis: A clinical function-analytic and computer tomographic study. Int J Oral Maxillofac Surg 16:257, 1987
9. Schultes G, Gaggl A, Karcher H: Changes in the dimensions of milled mandibular models after mandibular sagittal split osteotomies. Br J Oral Maxillofac Surg 36:196, 1998
10. Stroster TG, Pangrazio-Kulbersh V: Assessment of condylar position following bilateral sagittal split ramus osteotomy with wire fixation or rigid fixation. Int J Adult Orthod Orthognath Surg 9:55, 1994
11. Will LA, Joondeph DR, Hohl TH, et al: Condylar position following mandibular advancement: Its relationship to relapse. J Oral Maxillofac Surg 42:578, 1984
12. Hackney FL, Van Sickels JE, Nummikoski PV: Condylar displacement and temporomandibular joint dysfunction following bilateral sagittal split osteotomy and rigid fixation. J Oral Maxillofac Surg 47:223, 1989
13. Freihofer HP Jr: [Model test on the change of position of the mandibular condyle after sagittal splitting of the mandible]. SSO Schweiz Monatsschr Zahnheilkd 87:12, 1977
14. Kundert M, Hadjianghelou O: Condylar displacement after sagittal splitting of the mandibular rami: A short-term radiographic study. J Maxillofac Surg 8:278, 1980
15. Ellis E 3rd: Condylar positioning devices for orthognathic surgery: Are they necessary? J Oral Maxillofac Surg 52:536, 1994
16. Arnett GW: A redefinition of bilateral sagittal osteotomy (BSO) advancement relapse. Am J Orthod Dentofacial Orthop 104:506, 1993
17. Cutbirth M, Van Sickels JE, Thrash WJ: Condylar resorption after bicortical screw fixation of mandibular advancement. J Oral Maxillofac Surg 56:178, 1998
18. Van Sickels JE, Tiner BD, Alder ME: Condylar torque as a possible cause of hypomobility after sagittal split osteotomy: Report of three cases. J Oral Maxillofac Surg 55:398, 1997

19. Obwegeser H: Zur Operationstechnik bei der Progenie und anderen Unterkieferanomalien. Dtsch Zahn Mund-u Kieferheilk 23:11, 1955
20. Obwegeser H: The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. Oral Surg 10:677, 1957
21. Dal Ponte G: Retromolar osteotomy for the correction of prognathism. J Oral Surg 19:42, 1961
22. Nielsen IL: Maxillary superimposition: A comparison of three methods for cephalometric evaluation of growth and treatment change. Am J Orthod Dentofacial Orthop 95:422, 1989
23. Bjork A: The use of metallic implants in the study of facial growth in children: Method and application. Am J Phys Anthropol 29:243, 1968
24. Björk A, Skieller V: Normal and abnormal growth of the mandible: A synthesis of longitudinal cephalometric implant studies over a period of 25 years. Eur J Orthod 5:1, 1983
25. Rubenstein LK, Strauss RA, Lindauer SJ, et al: Tantalum implants as markers for evaluating postoperative orthognathic surgical changes. Int J Adult Orthod Orthognath Surg 8:203, 1993
26. Strauss RA, Rubenstein LK: A technique for accurate long-term follow-up of segment positional changes following sagittal split osteotomies. J Oral Maxillofac Surg 51:815, 1993
27. Astrand P, Ericson S: Relation between fragments after oblique sliding osteotomy of the mandibular rami and its influence on postoperative conditions. Int J Oral Surg 3:49, 1974
28. Legrell PE, Nyquist H, Isberg A: Validity of identification of gonion and antegonion in frontal cephalograms. Angle Orthod 70:157, 2000
29. Ishiguro K, Krogman WM, Mazaheri M, et al: A longitudinal study of morphological craniofacial patterns via P-A x-ray headfilms in cleft patients from birth to six years of age. Cleft Palate J 13:104, 1976