Stability After Bilateral Sagittal Split Osteotomy Setback Surgery With Rigid Internal Fixation: A Systematic Review

Christof Urs Joss, DMD, and Isabella Maria Vassalli, DMD†*

Purpose: The purpose of this systematic review was to evaluate relapse and its causes in bilateral sagittal split setback osteotomy with rigid internal fixation.

Materials and Methods: Literature research was done in databases such as PubMed, Ovid, the Cochrane Library, and Google Scholar Beta. From the original 488 articles identified, 14 articles were finally included. Only 5 studies were prospective and 9 retrospective. The range of postoperative study records was from 6 weeks to 12.7 years.

Results: The horizontal short-term relapse was between 9.9% and 62.1% at point B and between 15.7% and 91.3% at pogonion. Long-term relapse was between 14.9% and 28.0% at point B and between 11.5% and 25.4% at pogonion.

Conclusions: Neither large increase nor decrease of relapse was seen when short-term values were compared with long-term. Bilateral sagittal split osteotomy for mandibular setback in combination with orthodontics is an effective treatment of skeletal Class III and a stable procedure in the short- and long-term. The etiology of relapse is multifactorial: the proper seating of the condyles, the amount of setback, the soft tissue and muscles, remaining growth and remodeling, and gender were identified. Age did not show any correlations. To obtain reliable scientific evidence, further short- and long-term research of bilateral sagittal split osteotomy setback with rigid internal fixation should exclude additional surgery, ie, genioplasty or maxillary surgery, and include correlation statistics.

J Oral Maxillofac Surg 66:1634-1643, 2008

Orthognathic surgery combined with orthodontic treatment is an important treatment option for the correction of Class III patients. These patients continue to represent an important part of the orthognathic surgery population with about 25%.[1] An isolated true mandibular prognathism occurs in only 20% to 25% of all Class III cases.[2] This means that 75% of Class III patients have some degree of maxillary deficiency. This is of great importance with respect to which surgical method would be esthetically best (ie, monomaxillary vs bimaxillary surgery) to treat these patients.

Mandibular prognathism was one of the first dentofacial deformities in history to be treated by orthognathic surgery.[3] The correction of mandibular prognathism was and is mainly corrected by 3 different surgical procedures. The ostectomy of the mandible was done mostly in the beginning of the twentieth century. In the 1950s, the extraoral vertical oblique ramus osteotomy replaced the body ostectomy and the horizontal ramus osteotomy of the ramus of the mandible because the results were more predictable and stable.[4]

After introduction by Trauner and Obwegeser,[5,6] the bilateral sagittal split osteotomy (BSSO) has gained much popularity, especially when combined with rigid internal fixation (RIF).[7] Several modifications of the BSSO have been proposed.[8-11] Since the 1980s, most setback surgeries have been done by intraoral BSSO or by transoral vertical oblique ramus osteotomy (TOVRO). Due to the fact that maxillary surgery was not well developed at the time, Class III problems

*Senior Assistant, Department of Orthodontics, University of Geneva, Geneva, Switzerland.

†Senior Staff, Department of Orthodontics, University of Bern, Bern, Switzerland.

Address correspondence and reprint requests to Dr Joss: Faculté de médecine, Section de médecine dentaire, Rue Barthélémy-Menn 19, CH-1205 Genève, Switzerland; e-mail: christof.joss@medecine.unige.ch

0278-2391/08/6608-0013$34.00/0
doi:10.1016/j.joms.2008.01.046

were typically diagnosed and treated as mandibular excess. Although BSSO advancement surgery is possible, compared with the BSSO, the TOVRO-procedure is limited to mandibular setback. RIF is more difficult to use for TOVRO than in BSSO.[4]

A skeletal Class III is corrected primarily by a combination of Le Fort I osteotomy and mandibular surgery.[12,13] Bailey et al[14] showed that before 1985, 50% of all surgical orthodontic patients were treated by isolated mandibular setback, about one third had bimaxillary surgery, and 15% had maxillary surgery. After 1990, only 9% had mandibular surgery, 50% had bimaxillary surgery, and 40% had maxillary surgery only.

In a report on the hierarchy of stability in orthognathic surgery, Proffit et al[15] ranked isolated mandibular setback as the third least stable orthognathic surgical procedure before maxillary downward positioning and transverse maxillary expansion.

The aim of this study was to systematically review the literature on the stability after BSSO to setback the mandible with different types of RIF. The specific research questions were: *1*) what is the amount of relapse in the short- and long-term BSSO setback surgery with RIF; and *2*) what are the reasons for relapse?

Materials and Methods

LITERATURE SEARCH

A literature search was carried out using PubMed, Ovid (including OLDMEDLINE), Google Scholar Beta and the Cochrane Library to identify articles reporting BSSO setback surgical-orthodontic treatment with RIF to correct Class III patients. Terms used in the search were stability after bilateral sagittal split osteotomy combined with rigid internal fixation and setback of the mandible. A further search, for the sake of verification that all articles had been located, was carried out using abbreviated terms like BSSO, sagittal split osteotomy, RIF (miniplates, bicortical screws), skeletal stability, orthognathic surgery, and relapse. The search was expanded by searching articles consulted.

SELECTION CRITERIA

The following inclusion criteria were chosen initially to select potential articles from the published abstract results: *1*) human clinical trials; *2*) no syndromic or medically compromised patients, and no diseases; *3*) no individual case reports or series of cases; and *4*) combined surgical-orthodontic patients with BSSO and RIF for mandibular setback.

The articles selected ultimately were chosen with the following final inclusion criteria:

1. No other surgical intervention (ie, Le Fort I, etc) other than BSSO for mandibular setback with rigid internal fixation (no wire fixation). Genioplasty was accepted;
2. Lateral cephalograms used for horizontal skeletal stability that was measured on pogonion (Pg) or point B;
3. Adult patients;
4. Articles published from January 1974 (first introduction of RIF into maxillomandibular surgery by Spiessl[7]) to July 2007;
5. Articles in English, German, French, and Italian; and
6. No case reports, case series, descriptive studies, review articles, opinion articles, or abstracts.

In cases of more than 1 publication on the same patient group for the same postoperative follow-up, the most informative and relevant article was included.

Data were extracted on the following items: year of publication, study design, follow-up, number and mean age of patients, ethnical background of patients, number of surgeons operating, type of RIF, maxillomandibular fixation (MMF), genioplasty, mean setback, mean relapse, correlations, and author's conclusion.

Results

The final number of the articles selected according to the initial and final selection criteria are presented in Tables 1 and 2.

The search strategy resulted in 488 articles on BSSO with advancement and setback surgery. After selection according to the inclusion/exclusion criteria, 22 articles qualified for the final review analysis/results

Table 1. ARTICLES INCLUDED IN REVIEW

Articles	Study Design
Borstlap et al[35]	MCT, P
Choi et al[33]	CT, P
Choi et al[34]	CT, P
Chou et al[30]	CT, R
Franco et al[24]	CT, R
Harada and Enomoto[27]	CT, R
Ingervall et al[32]	CT, P
Joss and Thüer[36]	CT, P
Kim et al[29]	CT, R
Kim et al[31]	CT, R
Mobarak et al[28]	CT, R
Proffit et al[4]	CT, R
Schatz and Tsimas[37]	CT, R
Sorokolit and Nanda[38]	CT, R

Abbreviations: CT, clinical trials; MCT, multicenter clinical trial; P, prospective study; R, retrospective study.

Joss and Vassalli. BSSO Setback With RIF. J Oral Maxillofac Surg 2008.

Table 2. SUMMARIZED DATA OF STUDIES WITH BSSO SETBACK SURGERY REVIEWED

Study	Surgery (Type of RIF, Genioplasty, MMF)	Surgeons (n)	Patients (n)	Mean Age and Range (yr)	Follow-Up	Mean Setback (mm)	Relapse (mm)
Joss and Thüer[36]	3 titanium lag bicortical screws (Ø: 3.5 mm), no genioplasty, MMF for 4-8 days	4	17	27.1 (18.9–40.5)	12.7 yr	6.29 mm (B) 6.79 mm (Pg)	0.94 mm (B), 14.9% 1.46 mm (Pg), 21.5%
Kim et al[31]	Miniplates, no genioplasty, data represent their control group to compare with mandibular angle resection	1	14	21.4 ± 3.4	2 m	9.33 mm (point not specified)	1.04 mm (B), 11.1% 0.96 mm (Pg), 10.3%
Borstlap et al[35]	Stainless steel or titanium miniplates, no genioplasty, MMF for 2-5 days	—	24	23.0 (14–47)	2 yr	4.7 mm (Pg)	1.1 mm (Pg), 23.4%
Chou et al[30]	3 bicortical screws, no genioplasty, acrylic surgical stent	3	64	20.0 ± 1.6	1 yr	7 mm (Pg)	1.46 mm (Pg), 20.9%
Choi et al[34]	15 patients with miniplates (MMF for 6 weeks, splints removed after plate fixation) and 71 with 3 bicortical non-compression screws (Ø: 2 mm), splints removed after surgery, no genioplasty, masticatory functions were allowed in screw group from postoperative day 1	1	15 plates 71 screws	24.0 (16–43)	2 yr	8.2 mm (Pg) plates 7.8 mm (Pg) screws	1.1 mm (Pg), 13.4% 0.9 mm (Pg), 11.5%
Kim et al[29]	4 bicortical screws, (Ø: 2.4 mm), no genioplasty, 2 groups: control group and test group with distal ostectomy	1	Control group: 24 Test group: 37	22.0 ± 3.8 23.2 ± 3.2	12 m	7.98 mm (B-length) 10.01 mm (B-length)	2.32 mm (B-length), 29.1% 0.84 mm (B-length), 8.4%
Choi et al[33]	See Choi et al[34]	1	15 plates 15 screws	22.0 (17–28)	6 w	8.2 mm (Pg) plates 7.5 mm (Pg) screws	0.5 mm (Pg), 6.1% 0.1 mm (Pg), 1.3%
Mobarak et al[28]	3 bicortical screws (Ø: 2.0 mm) with washers, no genioplasty, with or without interocclusal splint	7	80	24.8 ± 7.6 (17.6–51.0)	3 yr	6.3 mm (Pg) 6.9 mm (B)	1.6 mm (Pg), 25.4% 1.3 mm (B), 18.8%
Harada and Enomoto[27]	10 patients with non-compression titanium screws (Ti) and 10 with PLLA-screws (both Ø: 2.7 mm), system for condylar repositioning, IMF for 9.4 (Ti) and 14.6 (PLLA) days	—	10 Ti 10 PLLA	22.4 (20–31) 23.0 (18–30)	12 m	6.7 mm 6.6 mm (points not specified)	0.94 mm (B), 14.0% 1.05 mm (Pg), 15.7% 1.50 mm (B), 22.7% 1.62 mm (Pg), 24.5%
Ingervall et al[32]	3 titanium lag bicortical screws (Ø: 3.5 mm), genioplasty in 2 patients, MMF for 4–8 days	4	29	20.0 (17–54)	14 m	6.0 mm (B) 6.0 mm (Pg)	1.5 mm (B), 25.0% 1.3 mm (Pg), 21.7%
Schatz and Tsimas[37]	Type of RIF not mentioned, no genioplasty	—	13	32.1 (16.7–38.4)	12 m	7.27 mm (B) 7.13 mm (Pg)	2.85 mm (B), 39.2% 3.52 mm (Pg), 49.4%
Proffit et al[4]	Type of RIF not mentioned, genioplasty in 1 patient	—	11	22.6 ± 7.4	12 m	5.8 mm (B) 4.6 mm (Pg)	3.6 mm (B), 62.1% 4.2 mm (Pg), 91.3%
Sorokolit and Nanda[38]	3 2-mm bicortical screws, 7 patients with genioplasty	3	25	23.4 (14–36)	15.3 m	5.14 mm (B)	0.51 mm (B), 9.9%
Franco et al[24]	3 2-mm bicortical screws, with or without genioplasty, MMF for up to 1 w	—	14	—	6 m–3 yr	4.87 mm (Pg)	2.13 mm (Pg), 43.7%

Abbreviations: B, point B; MMF, maxillomandibular fixation; m, month(s); Pg, pogonion; PLLA, poly-L-lactic-acid; RIF, rigid internal fixation; Ti, titanium; w, week(s); yr, year(s).

Joss and Vassalli. BSSO Setback With RIF. J Oral Maxillofac Surg 2008.

report. All articles on BSSO setback surgery were read and studied entirely, and a total of 14 suitable studies were identified after consideration of all inclusion criteria. Eight articles[16-23] that met the first inclusion criteria were rejected due to different reasons that are shown in Table 3.

Most of the studies (9) were retrospective[4,24-31] and few (5) were prospective.[32-36] All of them were clinical trials; no randomized clinical trials were available. The ethnic background of the treated patients in 6 studies was Asian,[27,29-31,33,34] in another 8 the background was mostly Caucasian.[4,24,25,28,32,35-37] Nevertheless, the latest studies published on this subject are mainly on Asian populations.

The range of the follow-up period was from 6 weeks[33] to 12.7 years.[36] If we choose the cut-off value of less than 2 years to separate short- from long-term studies, then 8 studies were short-term[4,24-27,29,30,32] and 4 studies[28,34-36] were long-term follow-ups with one exception[36] that had a postoperative follow-up of 12.7 years. The immediate postsurgical follow-up period was defined from 6 weeks to 2 months postoperatively and contained 2 studies.[31,33]

The statistics used were primarily Student's *t* tests to compare results before and after surgery or groups. Correlation analyses were carried out in only 4 studies[24,28,32,36] to look at contributing factors such as the amount of setback, gender, age, etc.

The great majority (10) of the reviewed articles used bicortical screws of different types for RIF.[24,27-30,32-34,36,38] Miniplates were used in 4 articles[31,33-35] and in another 2 articles there was no indication about the RIF system used.[4,26] Additional genioplasty was carried out on only a few patients in 3 studies[4,24,32] of 14 included in this systematic review.

Immediate postsurgical relapse (from 6 weeks to 2 months) was between 6.1% and 10.3% at pogonion and 11.1% at point B.[31,33] Short-term relapse was between 9.9% and 62.1% at point B[4,38] and between 15.7% and 91.3% at pogonion.[4,27] Long-term relapse was between 14.9% and 18.8% at point B[28,36] and between 11.5% and 25.4% at pogonion.[28,34] Several studies[26-28,32,35,36,38] showed that even further postsurgical backward movement is possible.

Discussion

A lack of randomized clinical trials and prospective studies makes a realization of a meta-analysis for the moment impossible in this field. Uniformity in study design, such as exclusion of genioplasty and other concomitant surgical procedures and inclusion of correlation statistics as well as the analysis of the error of the method, is necessary for further research.

Considering the fact that the BSSO procedure is the procedure used most widely to setback the mandible,[14] it is rather surprising that, to date, only a few articles have dealt with its postoperative stability. This could be due to the fact that what was once the most frequently used orthognathic surgical procedure now is used for a minority of dentofacial deformity patients.

WHEN AND TO WHICH AMOUNT DOES RELAPSE OCCUR?

Analyzing the different relapse rates showed that main relapse mostly takes place immediately after surgery and in the short-term. The values of long-term relapse mostly stay the same as short-term values. With the exception of 1 study that showed extremely high relapse rates in point B and Pg,[4] the rest of the studies had the same trends in relapse rate. It is interesting to note the evident trend in the reviewed articles that the older the study, the higher the relapse rate. Refinements in surgical techniques and increased experience of surgeons in the field of BSSO for mandibular setback with time could contribute to this fact.

Proffit et al[4] reported that in their RIF group, about 50% of the total forward relapse of the mandible occurred during the first 6 weeks, soon after function resumed. In contrast, in the WF group with MMF, the mandible maintained its position or moved posteriorly during MMF fixation. The postsurgical forward movement occurred after MMF fixation was released and function resumed.

The majority of the studies do not include patients with genioplasty. Additional genioplasty was carried out on only a small number of patients in 3 studies[4,24,32] of the 14 included in this systematic review. In the opinion of the authors, it would be best to exclude these patients in further research studies for the sake of standardization and uniformity of the results, and to eliminate influence of the genioplasty itself on point B and Pg. Whether or not the genioplasty procedure does not affect point B, as claimed by de Villa et al[39] is still matter of discussion. That pogonion is affected is evident. However, genioplasty is a procedure that was found to be very stable.[40,41]

Presurgical orthodontic treatment aims to decompensate incisor inclination toward normal values. The introduction[4,18] of a cut-off value of 2 mm to 4 mm and how many patients are included makes sense given that postsurgical orthodontic treatment can compensate for 2 mm to 4 mm of unfavorable changes. Nevertheless, we should keep in mind that skeletal relapse is masked frequently by compensatory changes in the axial inclination of the teeth.[42,43] Unfortunately, few studies used for this review had

Table 3. STUDIES WITH BSSO SETBACK SURGERY AND RIF THAT WERE NOT INCLUDED IN THE REVIEW

Author	Surgery (Type of RIF, Genioplasty, MMF)	Patients (n)	Follow-Up	Mean Setback (mm)	Relapse (mm)	Reason of Rejection
Ueki et al[22]	PLLA group (20) and titanium plate group (20), MMF for 2 w	20 (Ti) 20 (PLLA)	1 yr	6.55 mm (Ti) 6.75 mm (PLLA)	—	No relapse for Pg and point B published, only data for ANB available Point for measurement of the initial setback and amount of relapse not specified
Busby et al[23]	Genioplasty in 28%, RIF in 50%	18	7.1 yr	Mandible was setback at least 2 mm (point B)	3.59 mm (B) 3.74 mm (Pg)	No presurgical data published No initial setback published No relapse of the initial setback published
Ayoub et al[21]	Bicortical position screws, some patients with genioplasty and 3 with Le Fort I	31	1 yr	5.8 mm (B)	2.2 mm, 37.9% (B)	Some patients with bi-maxillary surgery
Fujioka et al[20]	Plates or bicortical screws, no genioplasty, MMF for 3-4 w	15 (screws) 17 (plates)	6 m	7.0 mm (screws) 7.2 mm (plates)	—	No relapse values for point B and Pg
Edwards et al[19]	3 PLLA bicortical screws (Ø: 2 mm), 6% of patients with Le Fort I, no MMF	12	7.2 m	5.2 mm (point not specified)	—	No relapse values for point B and Pg Some patients with bimaxillary surgery
Bailey et al[18]	RIF in 44%, rest with WF, genioplasty in 22%	18	3.7 yr	Not published	3.83 mm (B) 3.9 mm (Pg)	Setback distance not specified RIF in only 44%
Hilbe and Puelacher[17]	Bicortical position screws, no MMF, no genioplasty	10	3.5 yr	7.44 mm (Wits-value)	1.13 mm, 15.2% (Wits-value)	Relapse measured on Wits-value No values for point B and Pg
Krekmanov et al[16]	2 or 3 screws, some patients with genioplasty	23	1 yr	6.3 mm (point not specified)	0.8 mm, 12.7% (point not specified)	Points for measurement of the initial setback and relapse not specified

Abbreviations: B, point B; MMF, maxillomandibular fixation; m, month(s); Pg, pogonion; PLLA, poly-L-lactic-acid; RIF, rigid internal fixation; Ti, titanium; w, weeks; WF, wire fixation; yr, year(s).

Joss and Vassalli. BSSO Setback With RIF. J Oral Maxillofac Surg 2008.

the percent of patients falling into this published cut-off value.[4,24,28]

WHAT IS THE REASON FOR RELAPSE?

Few reasons for relapse have been identified, with relapse varying drastically between patients and surgeons without any known reason. It is clear that good surgical training, profound experience in orthognathic surgery, and technical refinements by the surgeon are required to have good surgical results in regard to stability and esthetics. The orthodontist needs to prepare the patient before surgery in regard to a perfect coordination of both dental arcades in transverse width, correct decompensation of the incisors, and the control of the surgical splint and its newly defined occlusion to allow correct placement of the mandible during surgery.

Proffit et al[15] state in their article on the hierarchy of stability in orthognathic surgery, that the stability of the surgical repositioning of the jaws varies a lot depending on the procedure. In their view, the order of importance starts with the direction of movement, the type of fixation used, and in the end, the surgical technique that has been used.

WIRE FIXATION OR RIGID INTERNAL FIXATION?

RIF using bicortical screws or miniplates with monocortical screws was first described in orthognathic surgery in 1974 by Spiessl.[7] RIF is suspected to allow condylar positional changes that may be related to surgical relapse or temporomandibular dysfunction syndrome,[44] and it seems that precise determination of the condyle-fossa relationship is not possible.

According to Proffit et al,[4] RIF compared with WF could hold the condyles in a position of slight transverse rotation relative to the fossa, so that 1 pole of the condyle is too far posteriorly. Some kind of forward position of the mandible would then be the expected result. Ayoub et al[21] concluded that screws exert mediolateral torque on the condylar surface when they are being fixed. This causes considerable condylar remodeling, which will be transmitted to the distal segment of the mandible and result in anterior movement of the symphysis.

Most surgeons in this systematic review prefer to use bicortical screws to fixate the proximal to the distal segment.[24,27-30,32-34,36,38] The use of miniplates with monocortical screws is less frequent in BSSO setback surgery.[31,33-35] When using miniplates at the site of fixation, an osseous step can be formed into them, depending on the amount of setback. The plates should fit passively and be well adapted. Biodegradable plates (for instance PLLA plates) can be bent using forceps at room temperature and maintained in the desired position without use of a heating device.

The surgeon may tend to seat the condyles too far posteriorly. As RIF maintains the proximal segment in an upright position, the postsurgical changes are expressed horizontally without the local adaptation at the osteotomy site that would be possible if wire osteosynthesis were used.[37] The fact could already be confirmed that condylar displacement is greater after BSSO with RIF for advancement[44,45] and setback[45] surgery. In other words, the wire fixation allows the ramus to adjust its position itself post-surgically via movements at the osteotomy site. This will not happen when RIF is used.

Harada and Enomoto[27] could not show any statistical difference in the stability between the use of titanium screws and Poly-L-lactic acid (PLLA, biodegradable) screws 12 months postoperatively. Nevertheless, they mentioned a greater relapse tendency in the PLLA-group, which they accounted for by the much lower physical strength of the PLLA screw compared with the titanium screw. The MMF was longer in the PLLA-group (14.6 days) than in the titanium-group (9.4 days). The appropriate indications for these PLLA-screws should be carefully selected; large setbacks and markedly asymmetrical cases should not be treated with these screws. They did not report any foreign body reaction like Bergsma et al.[46]

Choi et al[33,34] conducted 2 studies to evaluate the postsurgical change between the use of miniplates (with MMF for 6 weeks) and bicortical screws (without MMF, only Class III elastics and immediate masticatory function) at 6 weeks[33] and 24 months[34] after surgery. After the 6-week period, little difference regarding the stability occurred in the postsurgical change between the 2 groups. Twenty-four months after surgery, relapse was 13% in the miniplate and 12% in the screw group. They concluded that the omission of MMF in RIF has little influence on the stability. However, in his review article on bicortical screw fixation in BSSO, Ochs[47] concludes that 3 bicortical screws offer the most cost effective, rigid, and predictable way to fixate the proximal to the distal segment.

Fujioka et al[20] compared 2 groups (1 group with miniplates and 4 monocortical screws and another group with 2 lag screws) of BSSO with mandibular setback and RIF. They summarized their findings in the way that postoperative excessive shear force stress transforms the mandibular shape as the distal segment of the mandible rotated clockwise and the proximal segment rotated counterclockwise, so that the mandible was bent at the miniplates. The bicortical osteosynthesis is more rigid against this shearing stress than the monocortical osteosynthesis.

PROPER SEATING OF THE CONDYLES OR THE CONTROL OF THE PROXIMAL SEGMENT

It is obviously less difficult to obtain a stable result after surgical setback than after mandibular advancement. A possible explanation for this difference is that it is easier to set the condyles correctly in the fossa before rigid fixation when the soft tissues, as in the case of the setback, are not extensively stretched.[32] The simple adjustment of the condyle-fossa relationship as a correction for the condyles that were improperly (ie, retropositioned or clockwise) rotated at surgery is a possible explanation for relapse. The muscular sling exerts its influence when function resumes and tends to return the proximal segment to its original position that in turn moves the chin forward.[21]

Intercondylar width tends to decrease after BSSO setback and to increase after mandibular advancement. This trend becomes clearer with rigid fixation. A change in axial inclination involving either a medial or lateral rotation of the condylar axis occurs, with inward rotation more frequent with mandibular retropositioning and rigid-screw fixation.[48]

It is generally conceded that surgeons have better control of the condylar segment at surgery when BSSO is used compared with TOVRO.[49] With TOVRO, it can be difficult to position the condyles properly after the ramus osteotomy is completed.[4]

To achieve better control in positioning the proximal segment, several devices have been proposed and used.[27,50-52] Others proposed proper segment positioning by cephalometric prediction tracings that include the BSSO design and moving the mandibular distal tooth bearing segment into final occlusion while maintaining the ramal inclination and proximal segment position.[47] Proper positioning can be confirmed by comparison of the ramal border in the preoperative and immediate postoperative lateral cephalogram. Nevertheless, it is possible to present stable postsurgical results without using any appliance for repositioning the proximal segment as shown by Choi et al.[34] The surgeons positioned the proximal segment arbitrarily in their study, and bicortical screws were then passively inserted without distracting either the occlusion or the condyles.

Mobarak et al[28] found a significant correlation between the degree of surgical setback and the magnitude of surgical change in ramus inclination (angle made by the intersection of the line connecting posterior Go and Articulare and the x-axis), in the sense that the more the mandible is set back, the greater the resulting clockwise rotation of the proximal segment. It is obvious that there is a tendency of the proximal segment to return to its original inclination, and this probably contributed to the horizontal relapse observed in this study during the first 6 months after surgery. It seems that adaptation of the pterygomandibular muscle sling to lengthening and reorientation ultimately occurred because about 70% of the ramus inclination and 78% of the posterior movement of Go were maintained 3 years after surgery.

SOFT TISSUE AND MUSCLES

Another possible explanation of relapse is muscular pull as function resumes. Muscular pull after readaptation of elevator muscles after BSSO could also lead to forward relapse of the mandible after BSSO.[37] The more the ramus (proximal) segment is moved posteriorly, the more the muscular orientation would be altered, and the more the mandible might be expected to move forward. Unbalanced tension resulting from a surgically modified stomatognathic system can be an important factor for skeletal relapse in mandibular setback. By moving the distal segment, the neuromuscular balance is altered by stretching the connective tissues within the muscle and tendinous attachments to the bone. RIF is regarded to provide enough resistance to counteract this tension.[34]

Kim et al[29] showed that postoperative relapse could be prevented more effectively by applying the distal ostectomy technique. This might be due to reduction of tension in the pterygomasseteric sling that applied force in the posterior mandible. Another advantage was to achieve a more esthetic profile in the gonial angle area and less airway constriction postoperatively than in conventional techniques.

Some surgeons prefer to detach the masseter and pterygoid muscle from the proximal segment to avoid any stretching after repositioning of the main fragment to overcome inadvertent or intentional rotation of the proximal segment. Others are afraid of avascular necrosis of the bone and do not carry out this step.

The tongue and its adaptation to the new environment of the shortened mandible could play an important role for relapse as well. The position and the size of the tongue without any tongue resection will be the same after surgery and could lead to increased pressure in a forward direction of the mandible.[36]

It seems that there could be a significant correlation between the facial type and the relapse pattern. According to the study done by Yoshida et al,[53] the movement of the distal segment in the brachiofacial pattern is in a backward and clockwise direction. This movement causes shortening of posterior facial height. In such cases, a pattern of anterior relapse was noted. In mesio- and dolichofacial patterns the osteotomy is carried out to decrease facial height. This produces a counterclockwise rotation of the distal segment and necessitates elongation of the posterior

facial height with rotation around a fulcrum at the molars and a clockwise pattern of relapse.

GENDER

Correlations between relapse and gender were shown in only 2 studies.[28,36] Although females had a relatively greater relapse during the first 6 months after surgery, males had a more pronounced relapse from 1 year to 3 years postoperatively in the study by Mobarak et al.[28] They still concluded that gender differences in postoperative response were small. Joss and Thüer[36] showed that gender correlated very significantly ($P = .002$, $r = -0.691$) with the relapse at point B, ie, women in contrast to men showed further posterior movement of the mandible instead of anterior relapse 12.7 years after surgery.

AGE

None of the 14 studies included in this systematic review showed any correlation between relapse and age. The mean age in all studies was between 20.0 and 32.1 years.[30,37] The mean age indication was only missing in 1 study.[24] Despite the fact that almost all research groups included few patients younger than 20 years of age, further remaining growth of the mandible cannot be excluded.

AMOUNT OF SETBACK

Compared with mandibular advancement BSSO, the amount of setback was correlated less frequently with the amount of relapse.[24,28,32] The question remains if the lack of different findings could be due to the fact that in all other reviewed studies, no correlation statistics were carried out.

Mobarak et al[28] found the amount of setback at Pg correlated significantly to the relapse at Pg 3 years postsurgically. Franco et al[24] found that the amount of setback was the only predictor for relapse in their study. One explanation of this is that the further the distal segment is setback, the greater the tendency for the proximal segment to rotate.

GROWTH AND REMODELING

It is likely that remaining growth will cause relapse. For this reason, surgery should be provided mainly to patients where the end of growth is at least radiographically confirmed to minimize relapse due to remaining growth.

Behrents[54,55] demonstrated that late growth in a certain extent and remodeling processes in the aging skeleton are possible. He showed that point B moved downward in both genders. Males presented a nonclockwise rotation (anterior and downward) of the mandible, whereas females showed a clockwise rotation (posterior and downward). Behrents' findings indicate that there would be a worsening of the profile in male setback patients with age, but in females neither an improvement nor a worsening. The initial growth of the patient's face and continuous remodeling processes may lead to an advantageous or disadvantageous change of the position of the mandible after BSSO.[36,37]

Mobarak et al[28] suggested that some of the anterior relapse might be a manifestation of late growth, because 7 of their male patients (between 17.8 and 22.3 years of age) had a relapse greater than 3 mm 3 years after surgery. In their study 12.7 years after surgery, Joss et al[36] concluded that growth and remodeling processes in females showed an improvement of the initial result after surgery but in males a deterioration. Factors that could contribute to this relapse are further growth as well as mandibular remodeling.

Condylar remodeling occurs in untreated as well as in treated patients. Long-term remodeling at the condyles with shortening of the mandible is of particular concern after mandibular advancement. It is interesting that the same percentage of patients seem to show this pattern of mandibular shortening when the mandible is setback.[18] If the presence of pressure on the condyles due to soft tissue stretch has any impact on condylar remodeling, it needs to be elucidated.

The aim of this study was to systematically review the literature on the stability after BSSO to setback the mandible with different types of RIF.

On the basis of the analysis of 14 retrieved articles, it can be concluded that:

- BSSO for mandibular setback is an effective treatment of skeletal Class III and a stable procedure in the short- and long-term.
- Short- compared with long-term relapse rates are quite similar. This means that neither large increase nor decrease of relapse between short- and long-term follow-ups need to be expected.
- The etiology of relapse is multifactorial: the proper seating of the condyles, the amount of setback, the soft tissue and muscles, remaining growth and remodeling, and gender were identified. No study could show any correlation with age.
- To obtain reliable scientific evidence, further short- and long-term research of BSSO setback with RIF should exclude additional surgery, ie, genioplasty or maxillary surgery, and include correlation statistics.

Acknowledgments

The authors thank Prof Dr Roberto Brusati, Department of Maxillo-Facial Surgery, Ospedale San Paolo, University of Milano, Italy,

for his kind help with the review of this paper and Mrs Ingrid A. Beutler-Thornburn for the revision of the English language.

References

1. Bailey LTJ, Haltiwanger LH, Blakey GH, et al: Who seeks surgical-orthodontic treatment: A current review. Int J Adult Orthod Orthognath Surg 16:280, 2001
2. Ellis E, McNamara JJ: Components of adult Class III malocclusion. J Oral Maxillofac Surg 42:295, 1984
3. Steinhäuser EW: Historical development of orthognathic surgery. J Cranio Maxillofac Surg 24:195, 1996
4. Proffit WR, Phillips C, Dann IV C, et al: Stability after surgical-orthodontic correction of skeletal Class III malocclusion. I. Mandibular setback. Int J Adult Orthod Orthognath Surg 6:7, 1991
5. Trauner R, Obwegeser H: Zur Operationstechnik bei der Progenie und anderen Unterkieferanomalien. Dtsch Zahn-, Mund- und Kieferheilk 23:1, 1955
6. Obwegeser H: The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. J Oral Surg 10:677, 1957
7. Spiessl B: Osteosynthese bei sagittaler Osteotomie nach Obwegeser/Dal Pont, *in* Schuchardt K (eds): Fortschritte in Kiefer-und Gesichtschirurgie. Thieme, Stuttgart, XVIII: 1974
8. Dal Pont G: Retromolar osteotomy for the correction of prognathism. J Oral Surg Anesth Hosp Dent Serv 19:42, 1961
9. Hunsuck EE: A modified intraoral sagittal splitting technique for correction of mandibular prognathism. J Oral Surg 26:250, 1968
10. Gallo W, Moss M, Gaul J: Modification of the sagittal split ramus osteotomy for retrognathia. J Oral Surg 34:178, 1976
11. Epker B: Modifications in the sagittal osteotomy of the mandible. J Oral Surg 35:157, 1977
12. Bell WH, Jacobs JD, Quejada JG: Simultaneous repositioning of the maxilla, mandible, and chin. Am J Orthod 89:28, 1986
13. Sinclair PM, Profitt WR: Class III problems: Mandibular excess/maxillary deficiency, *in* Profitt WR, White RP (eds): Surgical-Orthodontic Treatment. Mosby, St Louis, 1990, p 428
14. Bailey LTJ, Proffit WR, White RP: Trends in surgical treatment of Class III skeletal relationships. Int J Adult Orthod Orthognath Surg 10:108, 1995
15. Proffit WR, Turvey TA, Phillips C: Orthognathic surgery: A hierarchy of stability. Int J Adult Orthod Orthognath Surg 11:191, 1996
16. Krekmanov L, Lilja J, Ringqvist M: Sagittal split osteotomy of the mandible without postoperative intermaxillary fixation. A clinical and cephalometric study. Swed Dent J Suppl 61:1, 1989
17. Hilbe M, Puelacher W: Die Stabilität nach sagittaler Unterkieferosteotomie zur Korrektur distaler und progener Bisslagen. Inf Kieferortho 26:63, 1994
18. Bailey LTJ, Duong LH, Proffit WR: Surgical Class III treatment: Long-term stability and patient perceptions of treatment outcome. Int J Adult Orthod Orthognath Surg 13:35, 1998
19. Edwards RC, Kiely KD, Eppley BL: Resorbable PLLA-PGA screw fixation of mandibular sagittal split osteotomies. J Craniofac Surg 10:230, 1999
20. Fujioka M, Fujii T, Hirano A: Comparative study of mandibular stability after sagittal split osteotomies: Bicortical versus monocortical osteosynthesis. Cleft Palate Craniofac 37:551, 2000
21. Ayoub AF, Millett DT, Hasan S: Evaluation of skeletal stability following surgical correction of mandibular prognathism. Br J Oral Maxillofac Surg 38:305, 2000
22. Ueki K, Nakagawa K, Takatsuka S, et al: Plate fixation after mandibular osteotomy. Int J Oral Maxillofac Surg 30:490, 2001
23. Busby BR, Bailey LTJ, Proffit WR, et al: Long-term stability of surgical Class III treatment: A study of 5-year postsurgical results. Int J Adult Orthod Orthognath Surg 17:159, 2002
24. Franco JE, Van Sickels JE, Trash WJ: Factors contributing to relapse in rigidly fixed mandibular setbacks. J Oral Maxillofac Surg 47:451, 1989
25. Sorokolit CA, Nanda RS: Assessment of the stability of mandibular setback procedures with rigid fixation. J Oral Maxillofac Surg 48:817, 1990
26. Schatz JP, Tsimas P: Cephalometric evaluation of surgical-orthodontic treatment of skeletal Class III malocclusion. Int J Adult Orthod Orthognath Surg 10:173, 1995
27. Harada K, Enomoto S: Stability after surgical correction of mandibular prognathism using the sagittal split ramus osteotomy and fixation with Poly-L-Lactic Acid (PLLA) screws. J Oral Maxillofac Surg 55:464, 1997
28. Mobarak KA, Krogstad O, Espeland L, et al: Long-term stability of mandibular setback surgery: A follow-up of 80 bilateral sagittal split osteotomy patients. Int J Adult Orthod Orthognath Surg 15:83, 2000
29. Kim M-J, Kim S-G, Park Y-W: Positional stability following intentional posterior ostectomy of the distal segment in bilateral sagittal split ramus osteotomy for correction of mandibular prognathism. J Cranio Maxillofac Surg 30:35, 2002
30. Chou J, Fong H, Kuang S, et al: A retrospective analysis of the stability and relapse of soft and hard tissue change after bilateral sagittal split osteotomy for mandibular setback of 64 Taiwanese patients. J Oral Maxillofac Surg 63:355, 2005
31. Kim C-H, Lee J-H, Cho J-Y, et al: Skeletal stability after simultaneous mandibular angle resection and sagittal split ramus osteotomy for correction of mandible prognathism. J Oral Maxillofac Surg 65:192, 2007
32. Ingervall B, Thüer U, Vuillemin T: Stability and effect on the soft tissue profile of mandibular setback with sagittal split osteotomy and rigid internal fixation. Int J Adult Orthod Orthognath Surg 10:15, 1995
33. Choi B-H, Min Y-S, Yi C-K, et al: A comparison of the stability of miniplate with bicortical screw fixation after sagittal split setback. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 90:416, 2000
34. Choi B-H, Zhu S-J, Han S-G, et al: The need for intermaxillary fixation in sagittal split osteotomy setbacks with bicortical screw fixation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 100:292, 2005
35. Borstlap WA, Stoelinga PJ, Hoppenreijs TJ, et al: Stabilization of sagittal split set-back osteotomies with miniplates: A prospective, multicenter study with 2-year follow-up. Int J Oral Maxillofac Surg 34:487, 2005
36. Joss CU, Thüer UW: Stability of hard tissue profile after mandibular setback in sagittal split osteotomies: A longitudinal and long-term follow-up study. Eur J Orthod 30:16, 2008
37. Schatz J-P, Tsimas P: Cephalometric evaluation of surgical-orthodontic treatment of skeletal Class III malocclusion. Int J Adult Orthod Orthognath Surg 10:173, 1995
38. Sorokolit CA, Nanda RS: Assessment of the stability of mandibular setback procedures with rigid fixation. J Oral Maxillofac Surg 48:817, 1990
39. de Villa GH, Huang CS, Chen PK, et al: Bilateral sagittal split osteotomy for correction of mandibular prognathism: Long-term results. J Oral Maxillofac Surg 63:1584, 2005
40. Reyneke JP, Johnston T, Van der Linden WJ: Screw osteosynthesis compared with wire osteosynthesis in advancement genioplasty: A retrospective study of skeletal stability. Br J Oral Surg 35:352, 1997
41. Huang CS, de Villa GH, Liou EJ, et al: Mandibular remodeling after bilateral sagittal split osteotomy for prognathism of the mandible. J Oral Maxillofac Surg 64:167, 2006
42. Schendel SA, Epker BN: Results after mandibular advancement surgery: An analysis of 87 cases. J Oral Surg 38:265, 1980
43. Vasir NS, Thompson RT, Davies TM: Dental and skeletal changes following sagittal split osteotomy for correction of mandibular prognathism. Eur J Orthod 13:134, 1991
44. 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
45. Kundert M, Hadjianghelou O: Condylar displacement after sagittal splitting of the mandibular rami. J Maxillofac Surg 8:278, 1980
46. Bergsma EJ, Rozema FR, Bos RR, et al: Foreign body reactions to resorbable poly(L-lactide) bone plates and screws used for the fixation of unstable zygomatic fractures. J Oral Maxillofac Surg 51:666, 1993

47. Ochs MW: Bicortical screw stabilization of sagittal split osteotomies. J Oral Maxillofac Surg 61:1477, 2003
48. Ueki K, Nakagawa K, Marukawa K, et al: Changes in condylar long axis and skeletal stability after bilateral sagittal split ramus osteotomy with poly-L- lactic acid or titanium plate fixation. Int J Oral Maxillofac Surg 34:627, 2005
49. Phillips C, Turvey TA, McMillian A: Surgical orthodontic correction of mandibular deficiency by sagittal osteotomy: Clinical and cephalometric analysis of 1-year data. Am J Orthod Dentofacial Orthop 96:501, 1989
50. Epker BN, Wylie GA: Control of the condylar-proximal mandibular segments after sagittal split osteotomies to advance the mandible. Oral Surg Oral Med Oral Pathol 62:613, 1986
51. Raveh J, Vuillemin T, Lädrach K, et al: New techniques for reproduction of the condyle relation and reduction of complications after sagittal ramus split osteotomy of the mandible. J Oral Maxillofac Surg 46:751, 1988
52. Luhr HG, Kubein-Meesenburg D, Schwestka-Polly R: Bedeutung und Technik der Kiefergelenkspositionierung bei der sagittalen Spaltung des Unterkiefers. Fortschr Kieferortho 52:66, 1991
53. Yoshida K, Rivera G, Matsuo N, et al: Long-term prognosis of BSSO mandibular relapse and its relation to different facial types. Angle Orthod 70:220, 2000
54. Behrents RG: An atlas of growth in the aging craniofacial skeleton, *in* McNamara JA (ed). Monograph 18, Craniofacial Growth Series. Ann Arbor, MI, University of Michigan, 18:1985, p 1
55. Behrents RG: Growth in the aging craniofacial skeleton, *in* McNamara JA (ed). Monograph 17, Craniofacial Growth Series. Ann Arbor, MI, University of Michigan, 17:1985, p 1