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

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Purpose: The purpose of this systematic review was to evaluate horizontal relapse and its causes in bilateral sagittal split advancement osteotomy (BSSO) with rigid internal fixation of different types.

Materials and Methods: A search of the literature was performed in the databases PubMed, Ovid, Cochrane Library, and Google Scholar Beta. From 488 articles identified, 24 articles were finally included. Six studies were prospective, and 18 were retrospective. The range of postoperative study records was 6 months to 12.7 years.

Results: The short-term relapse for bicortical screws was between 1.5% and 32.7%, for miniplates between 1.5% and 18.0%, and for bioresorbable bicortical screws between 10.4% and 17.4%, at point B. The long-term relapse for bicortical screws was between 2.0% and 50.3%, and for miniplates between 1.5% and 8.9%, at point B.

Conclusions: BSSO for mandibular advancement is a good treatment option for skeletal Class II, but seems less stable than BSSO setback in the short and long terms. Bicortical screws of titanium, stainless steel, or bioresorbable material show little difference regarding skeletal stability compared with miniplates in the short term. A greater number of studies with larger skeletal long-term relapse rates were evident in patients treated with bicortical screws instead of miniplates. The etiology of relapse is multifactorial, involving the proper seating of the condyles, the amount of advancement, the soft tissue and muscles, the mandibular plane angle, the remaining growth and remodeling, the skill of the surgeon, and preoperative age. Patients with a low mandibular plane angle have increased vertical relapse, whereas patients with a high mandibular plane angle have more horizontal relapse. Advancements in the range of 6 to 7 mm or more predispose to horizontal relapse. To obtain reliable scientific evidence, further short-term and long-term research into BSSO advancement with rigid internal fixation should exclude additional surgery, ie, genioplasty or maxillary surgery, and include a prospective study or randomized clinical trial design with correlation statistics.

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The major indication for the bilateral sagittal split osteotomy (BSSO) is the advancement of the mandible to correct a skeletal Class II. Moderate to severe mandibular retrognathism often requires a combined orthodontic and surgical approach for optimal function and best esthetic results. Despite the popularity of BSSO, new methods, such as segmental distraction of the anterior alveolar process and anterior apical base augmentation for the correction of the retrognathic mandible, have been proposed and performed successfully.[1,2]

A major concern in the surgical correction of a skeletal Class II is potential postsurgical relapse. To minimize relapse, careful selection of patients has been advocated, so that isolated mandibular advancement is not used for patients with high mandibular plane angles and open bites.[3] Trends for fixating the proximal to the distal segment intraoperatively show an increased use of rigid internal fixation (RIF) instead of wire fixation. The use of bicortical screws or mono-

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cortical screws, together with plates, is termed RIF, and was also called the most demanding fixation procedure of the craniofacial skeleton when used in mandibular advancement patients, because of the stretching of the musculature and paramandibular tissues, the bilateral compound joints, the masticatory forces, and occlusion.[4] Spiessl was the first to introduce RIF without maxillomandibular fixation (MMF) in 1974.[5] His method involved the use of 3 lag-screws at the osteotomy site (2 above the neurovascular bundle, and 1 below) to stabilize the bony fragment. Since then, many modifications of the screw osteosynthesis principle have been used, varying in relation to number, sites, sizes, placement patterns, and types (ie, stainless steel, titanium, biodegradable, or allogenic cortical bone) of screws.

Miniplates were introduced for fixation in BSSOs by Rubens et al.[6] Miniplates have several advantages compared with bicortical screw osteosynthesis. From a transoral approach, plate application obviates the need for transcutaneous puncture, with subsequent scarring, and the increased risk of facial-nerve damage. The removal of third molars and the preservation of a sufficient bulk of bone on the distal segment are not necessary for screw placement, and the risk of damaging adjacent teeth is also lower. Passive plate-bending helps maintain the axial condylar orientation within the fossa. Plates are easily removed under local anesthesia after 6 months.[6]

In a report on the hierarchy of stability in orthognathic surgery, Proffit et al[7] ranked isolated mandibular advancement in patients with normal to decreased facial height as the second most stable orthognathic surgical procedure after maxillary upward positioning. In their view, the order of importance begins with the direction of movement, the type of fixation used, and at the end, the surgical technique.

In their systematic review of BSSO setback surgery, Joss and Vassalli[8] found short-term relapse rates between 9.9% and 62.1%, and long-term relapse rates between 14.9% and 28.0%, at point B. However, since the very first studies published on BSSO with RIF in the late 1970s and early 1980s, no study has been undertaken to systematically review their relapse rates in BSSO advancement surgery.

The aim of this study was a systematic review of the literature on stability after BSSO to advance the mandible with different types of RIF. The specific research questions were:

1) What is the amount of relapse in short-term and long-term BSSO advancement surgery with different types of RIF?
2) What are the reasons for relapse?
3) When and where does relapse take place?

Materials and Methods

LITERATURE SEARCH

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

SELECTION CRITERIA

The following inclusion criteria were initially chosen 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 advancement.

Articles were ultimately selected on the basis of these final inclusion criteria:

1) No other surgical intervention (eg, Le Fort I) than BSSO for mandibular advancement with RIF (no wire fixation; genioplasty was accepted);
2) Lateral cephalograms used for horizontal skeletal stability, as measured on pogonion or point B;
3) Follow-up of 6 months or longer;
4) Adult patients;
5) Articles with more than 10 patients examined;
6) Articles published from January 1974 (first introduction of RIF into maxillomandibular surgery by Spiessl[5]) to August 2007;
7) No case reports, case series, descriptive studies, review articles, opinion articles, or abstracts.

Articles which met the final inclusion criteria were separated, according to RIF method, into 3 groups: bicortical screws (short-term and long-term results), miniplates (short-term and long-term results), and bioresorbable screws (short-term results). The cutoff value of less than 1.5 years was chosen to separate short-term from long-term studies. In cases of more than one 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, ethnic background of patients, number of surgeons operating, type of RIF, use of MMF, use of genioplasty, mean advancement, mean relapse, correlations between relapse and different variables, percentage of patients with more than 2 mm of sagittal relapse, and authors' conclusions. Moreover, to document the methodologic soundness of each article, a quality evaluation, modified by the methods of Jadad et al[9] and Petrén et al,[10] was performed with respect to pre-established characteristics. The following characteristics were used: study design, sample size and previous estimate of sample size, selection descriptions, withdrawals (dropouts), valid methods, confounding factors considered (eg, genioplasty or the presence of a splint in the immediate postsurgical radiographs), method error analysis, blinding in measurements, and adequate statistics. Quality was categorized as low, medium, or high.

Results

RESULTS OF SEARCH

The final selection of articles, according to initial and final selection criteria, is presented in Table 1. The search strategy resulted in 488 articles on BSSO with advancement and setback surgery. After selection according to the inclusion/exclusion criteria, 43 articles qualified for the final review analysis/results report. All articles on BSSO advancement surgery were read in their entirety and studied, and 24 suitable studies were identified after consideration of all inclusion criteria. Nineteen articles[11-29] that met the first inclusion criteria were rejected because of final selection criteria. Reasons for rejection included lack of relapse rates for point B and pogonion in 10 studies,[11,19-21,23,24,26-29] patients with other types of surgery in 5 studies,[11,15,18,21,22] and lack of follow-up or follow-up of less than 6 months in 6 studies.[12-14,16,17,26]

QUALITY ANALYSIS

Most of the studies (n = 18) were retrospective,[4,30-46] and only a few (n = 6) were prospective.[6,47-51] All were clinical trials, one study was a multicenter, randomized clinical trial[48]; and another was a multicenter prospective study.[50] The ethnic background of treated patients was mainly Caucasian in all reviewed studies. No article on Asian subjects was found in the literature review.

The search showed that research quality or methodological soundness was low in 18 studies and of medium quality in 6 studies (Table 1). The most obvious findings included small sample sizes implying low power, lack of method of error analysis, blinding of measurements, and deficient or lacking statistical methods. Furthermore, no study contained any power analysis. The sample size of 8 studies[33,39,41,43,45,47,48,50] was judged adequate. Studies with inadequate sample size (≤10 patients) were excluded based on selection criteria. In all studies, the methods used to detect and analyze postoperative relapse were valid and well-known. However, 11 studies[6,30-33,35,38,39,41,45,48] did not include a method error analysis, and none of the studies used blinding in measurements. Correlation statistics were only used in 12 studies.[30,31,34,36,39,40,42,44,47,48,50,51]

Considering the confounding variable "genioplasty," 8 studies declared that additional genioplasty was performed in only a few patients.[30,31,33-35,45-47] In one study,[48] it was unclear whether patients with genioplasty were included or not. In another study, a mandibular template was used to eliminate the effect of genioplasty.[46]

Another confounding variable was the presence of a splint in the immediate postsurgical radiographs. Several studies did not compensate for or comment on the presence of a splint in the immediate postsur-

Table 1. ARTICLES INCLUDED IN REVIEW AND JUDGMENT OF QUALITY

Article	Study Design	Judgment of Quality
Joss and Thüer, 2008[51]	CT, P	Medium
Kahnberg et al, 2007[46]	CT, R	Low
Turvey et al, 2006[45]	CT, R	Low
Borstlap et al, 2004[50]	MCT, P	Medium
Ferretti and Reyneke, 2002[49]	CT, P	Medium
Mobarak et al, 2001[43]	CT, R	Low
Pangrazio-Kulbersh et al, 2001[44]	CT, R	Low
Van Sickels et al, 2000[48]	RCT, P	Medium
Kallela et al, 1998[42]	CT, R	Low
Blomqvist et al, 1997[40]	CT, R	Low
Bouwman et al, 1997[41]	CT, R	Low
Scheerlinck et al, 1994[39]	CT, R	Low
Thüer et al, 1994[47]	CT, P	Medium
Abeloos et al, 1993[38]	CT, R	Low
Lee and Piecuch, 1992[37]	CT, R	Low
Douma et al, 1991[36]	CT, R	Low
Jäger et al, 1991[34]	CT, R	Low
Mommaerts, 1991[4]	CT, R	Low
Watzke et al, 1991[35]	CT, R	Low
Kierl et al, 1990[31]	CT, R	Low
Moenning et al, 1990[32]	CT, R	Low
Watzke et al, 1990[33]	CT, R	Low
Rubens et al, 1988[6]	CT, P	Medium
Kirkpatrick et al, 1987[30]	CT, R	Low

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

Joss and Vassalli. BSSO Advancement Surgery With Rigid Internal Fixation. J Oral Maxillofac Surg 2009.

gical radiographs. Hence, the autorotation of the mandible caused by removal of the splint, depending on its thickness, would result in a relative anterior displacement of the mandible, which must be considered when assessing relapse.[22,31] Therefore, in some studies, a template of the mandible was made and rotated around the midcondylar point until the upper and lower incisors occluded, to compensate for the error that would otherwise occur.[30,43,46] Nonetheless, Rubens et al[6] did not observe any autorotation after splint removal, probably due to a splint design with 3-point occlusal contact, whereas others[44] designed a splint as thin as possible, without having any horizontal or vertical overcorrection. Some attributed the forward movement of point B and pogonion in their studies to removal of the splint.[33,38] Abeloos et al[38] showed further anterior movement in 25% of their patients. The forward rotation of pogonion was attributable to occlusal settling after the use of a 3-point occlusal contact (right and left molars, and incisors), to eliminate the deep bite in these patients.

FOLLOW-UP PERIOD

The range of follow-up period was 6 months[30,40,49] to 12.7 years.[51] Twelve studies were short-term,[4,30,32,33,35,36,40,41,44,45,47,49] and 5 were long-term,[31,43,46,48,51] in which bicortical screws of different types (lag and position) and materials (titanium or stainless steel) for RIF were used. Miniplates for RIF were applied in 5 short-term[6,34,37,38,40] and 3 long-term[39,46,50] studies. Only 3 short-term studies were found[42,45,49] in which bioresorbable material (PLLA, PLLA/PGA Lactosorb, or PLLDL) for RIF was used.

RELAPSE RATES WITH THE USE OF BICORTICAL SCREWS

Short-term relapse for bicortical screws (Table 2) was between 1.5% and 32.7% at point B,[32,47] and between 2.0% and 37.0% at pogonion.[45,47] Long-term relapse for bicortical screws (Table 3) was between 2.0% and 50.3% at point B,[48,51] and between 6.4% and 60.2% at pogonion.[51]

RELAPSE RATES WITH THE USE OF MINIPLATES

Short-term relapse for miniplates (Table 4) was between 1.5% and 18.0% at point B,[37,40] and between 1.4% and 18.7% at pogonion.[6,37] Long-term relapse for miniplates (Table 5) was between 1.5% and 8.9%[39,46] at point B, and between 1.6% and 16.1% at pogonion.[46,50]

RELAPSE RATES WITH THE USE OF BIORESORBABLE BICORTICAL SCREWS

Short-term relapse for bioresorbable bicortical screws (Table 6) ranged from 10.4% to 17.4% at point B,[42,45] and from 4.2% to 15.4% at pogonion.[42,45] No studies with long-term values were found.

RELAPSE DEFINED AS CUTOFF VALUE

The introduction[52,53] of a cutoff value of 2 to 4 mm, and the number of patients included, make sense, given that postsurgical orthodontic treatment can compensate for 2 to 4 mm of unfavorable changes. Hence it was suggested that skeletal relapse be defined as more than 2 mm of sagittal relapse. Unfortunately, few studies in this review contained the percentage of patients falling within this cutoff value.[30,37,38,41-43,50] The published values ranged from no patients[30,37] up to 46% of all patients.[43] No articles mentioned the frequency of necessary retreatment.

POSTOPERATIVE FORWARD MOVEMENT OF THE MANDIBLE

Further postoperative forward movement of the mandible in some patients was evident in almost all revised studies. However, further forward postoperative movement of the mandible was not mentioned in 5 studies.[4,30,32,35,36] The mean relapse as a forward instead of backward movement of point B and pogonion was described in studies that involved bicortical screws,[33,44] and in one study that involved miniplates.[34] An anterior movement of more than 3 mm is difficult to explain by mandibular autorotation alone as a result of splint removal and orthodontic finishing. Mandibular growth could explain this finding.[39]

CORRELATIONS

Preoperative Age

The mean age in all studies ranged between 19.3 and 34.0 years.[4,40] Indication of mean age was missing in 4 studies. Less postoperative relapse with increased age was shown in 1 study.[40] Patients above age 41 years had further postoperative changes in an anterior direction. It was concluded that older patients have a more mature, harder compact bone, and combined with decreased bone metabolism, this might provide more stable mechanical fixation when stability is more dependent on fixation than on actual bony consolidation. However, others did not show any correlation between age and relapse rate.[47]

Gender

None of the 24 studies in this systematic review showed any correlation between relapse and gender. It can be thus speculated that gender has little or no effect on the relapse rate. Seventy-one percent of all patients were female when evaluating the gender distribution of all reviewed articles. This shows that female patients, for the most part, seek orthognathic surgery for mandibular advancement.

Table 2. SUMMARIZED DATA OF 12 STUDIES WITH BICORTICAL SCREWS AND SHORT-TERM FOLLOW-UPS (<1.5 YEARS)

Study	Surgery (eg, Type of RIF, Genioplasty, MMF)	Number of Surgeons	Number of Patients	Mean Age and Range (yr)	Follow-Up	Mean Setback (mm)	Relapse (mm)
Turvey et al, 2006[45]	Group with 4 Ti position screws (diameter: 2.0 mm), genioplasty in 9 patients.	1 in 60%	35	26.8 (SD, 11.2)	1 yr	4.96 (B) 6.89 (Pg)	0.33 (B), 6.7% 0.14 (Pg), 2.0%
Ferretti and Reyneke, 2002[49]	3 Ti screws (diameter: 2.0 mm), no MMF, no genioplasty, condylar positioning device.	1	20	-	6 m	4.7 (B)	0.25 (B), 5.3%
Pangrazio-Kulbersh et al, 2001[44]	Bicortical screws, no genioplasty, splint, MMF.	1	20	24.4 (16.7-39.4)	1 yr	4.2 (B) 4.2 (Pg)	0.1 (B), 2.4% 0.1 (Pg),*2.4%*
Blomqvist et al, 1997[40]	Group S1 (Boden) and S2 (Halmstad): 3 noncompression screws (diameter: 2.0 mm); no splint, no genioplasty, MMF for 7-10 d.	—	Group 1: 15 Group 2: 15	33 (20-61) 33 (17-50)	6 m	5.6 (B) 4.9 (Pg) 6.5 (B) 5.6 (Pg)	0.9 (B), 16.1% 0.9 (Pg), 18.4% 0.3 (B), 4.6% 0.6 (Pg), 10.7%
Bouwman et al, 1997[41]	3 self-tapping screws (diameter: 2.0 mm), no genioplasty, splint, no MMF.	—	45	28.5 (17.8-50.9)	1 yr	4.44 (B)	0.07 (B), 1.6%
Thüer et al, 1994[47]	3 Ti lag screws (diameter: 3.5 mm), 2 with genioplasty, no splint, MMF for 4-6 d.	4	30	20 yr 5 m (17-32.5)	13 m	4.9 (B) 4.6 (Pg)	1.6 (B), 32.7% 1.7 (Pg), 37.0%
Douma et al, 1991[36]	Compression screws, splint, no genioplasty.	2	16	30.68 (14-50)	11.15 m	5.6 (Pg)	1.4 (Pg), 31.4%
Mommaerts, 1991[4]	3 or 2 ss AO-lag screws (diameter: 3.5 mm), no genioplasty, no MMF.	—	13	19.3 (± 8.5)	1.02 yr	6.1 (Pg)	0.7 (Pg), 11.5%
Watzke et al, 1991[35]	Lag-group with 3 lag screws (diameter: 2.0 mm) and pos-group with 3 positioning screws (diameter: 2.0 mm), genioplasty in 20 (pos) and 4 (lag).	4	30 (pos) 26 (lag)	24.9 (± 10.3) 29.0 (± 11.0)	1 yr	5.4 (B) 5.3 (B)	0.6 (B), 11.1% 0.3 (B), 5.7%
Moenning et al, 1990[32]	2 or 3 lag screws, no genioplasty, MMF for 7-10 d.	2	14	—	10.6 m	4.68 (B) 4.36 (Pg)	0.07 (B), 1.5% 0.14 (Pg), 3.2%
Watzke et al, 1990[33]	21 patients with positional (diameter: 2.0 mm), 14 with lag (diameter: 2.0 mm) or compression screws (diameter: 3.5 mm), genioplasty in 9 patients.	1 surgeon for 21 patients, and 5 for 14 patients	35	26.8 (SD, 11)	1 yr	5.0 (B) 6.9 (Pg)	0.33 (B),* 6.6%* 0.14 (Pg),*2.0%*
Kirkpatrick et al, 1987[30]	3 Synthes ss screws (diameter: 2.0 mm), 7 patients with genioplasty, splint.	3	20	24 (17-46)	6 m	5.7 (B)	0.4 (B), 7.3%

Abbreviations: MMF, maxillomandibular fixation; B, point B; Pg, pogonion; pos, position screws; lag, lag screws; d, days; m, months; yr, years; Ti, titanium; ss, stainless steel; —, not reported.

*Relapse in anterior direction.

Joss and Vassalli. BSSO Advancement Surgery With Rigid Internal Fixation. J Oral Maxillofac Surg 2009.

Table 3. SUMMARIZED DATA OF 5 STUDIES WITH BICORTICAL SCREWS AND LONG-TERM FOLLOW-UPS (≥1.5 YEARS)

Study	Surgery (eg, Type of RIF, Genioplasty, MMF)	Number of Surgeons	Number of Patients	Mean Age and Range (yr)	Follow-Up	Mean Setback (mm)	Relapse (mm)
Joss and Thüer, 2008[51]	3 Ti lag screws (diameter: 3.5 mm), no splint, no genioplasty, MMF for 4-6 d.	4	16	21.4 (17.0-31.1)	12.7 yr	4.81 (B) 5.33 (Pg)	2.42 (B), 50.3% 3.21 (Pg), 60.2%
Kahnberg et al, 2007[46]	Lag screws, splint, and some patients with genioplasty.	—	17	31 (21-42)	1.5 yr	6.5 (B) 7.8 (Pg)	0.8 (B), 12.3% 0.5 (Pg), 6.4%
Mobarak et al, 2001[43]	3 Salzburg Ti lag screws (diameter: 2.0 mm), no genioplasty, with or without splints, no MMF.	7	61	28.2 (16.2-50.9)	3 yr	5.92 (B) 5.88 (Pg)	1.84 (B), 31.1% 1.94 (Pg), 33.0%
Van Sickels et al, 2000[48]	3 screws (diameter: 2.0 mm), MMF for 5-7 d, splint, genioplasty.	4	62	—	2 yr	5.1 (B)	0.1 (B), 2%
Kierl et al, 1990[31]	3 Synthes ss screws (diameter: 2.0 mm), 6 patients with genioplasty.	3	19	26.6 (14-47)	3 yr, 4 m	6.7 (B)	1.3 (B), 19.4%

Abbreviations: MMF, maxillomandibular fixation; B, point B; Pg, pogonion; d, days; m, months; y, years; Ti, titanium; ss, stainless steel; —, not reported.

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Amount of Advancement

A positive correlation between amount of advancement and relapse rate was found in several studies.[31,36,40,47,48,50,51] Nevertheless, others could not show any such positive correlation.[6,32,42] Kallela et al[42] did not include patients with more than 7-mm advancement, which could have influenced their findings. In a multicenter, randomized clinical trial, Van Sickels et al[48] showed that advancements with RIF of more than 5.2 mm are prone to relapse.

Scheerlinck et al[39] found that the amount of advancement correlated positively with progressive condylar resorption (PCR) evaluated on orthopantomograms after BSSO advancement with miniplates. The risk of experiencing PCR was 5.2 times higher for those with a mandibular advancement between 5 and 10 mm than for those with an advancement of 5 mm or less. For 10 mm or more, the risk was as much as 20 times higher, compared with 5 mm or less. The incidence of PCR can be as high as 7%. It usually manifests during the second half of the year after the BSSO procedure, and can amount to total relapse.[39]

Low Angle and High Angle

The influence of mandibular plane angle on horizontal[34,36,41,43,50] or vertical[34,40] relapse was shown in several studies, in the sense that the steeper the mandibular plane angle (high-angle patients), the more often that horizontal relapse can be expected,[34,36,41,43,50] and the smaller the mandibular plane angle (low-angle patients), the more often that vertical relapse can be expected.[34,40]

Proper Seating of the Condyles and Control of the Proximal Segment

In a randomized clinical trial, Van Sickels et al[48] showed that relapse correlated significantly with the change in ramus inclination and thus with the control of the proximal segment. Mobarak et al[43] also demonstrated condylar distraction in the surgical and early postsurgical movements of gonion. A forward movement of gonion and counterclockwise rotation of the proximal segment was seen in the low-angle and high-angle groups, but was more pronounced in the high-angle groups.

Discussion

A lack of randomized clinical trials and prospective studies makes the realization of a meta-analysis impossible in this field at present. To increase the power of this systematic review, it would be necessary to include only randomized, clinical trials, prospective multicenter articles, or prospective clinical trials. Further, an exclusion of patients with genioplasty, evaluation of the error of the method, standardization in superimposing the lateral cephalograms (eg, the sella-

Table 4. SUMMARIZED DATA OF 5 STUDIES WITH MINIPLATES AND SHORT-TERM FOLLOW-UPS (<1.5 YEARS)

Study	Surgery (eg, Type of RIF, Genioplasty, MMF)	Number of Surgeons	Number of Patients	Mean Age and Range (yr)	Follow-Up	Mean Setback (mm)	Relapse (mm)
Blomqvist et al, 1997[40]	P1 (Boden) and P2 (Halmstad): plates with monocortical Ti screws (diameter: 2.0 mm).	—	Group 1: 15	34 (20-53)	6 m	5.3 (B) 4.6 (Pg)	0.5 (B), 9.4% 0.5 (Pg), 10.1%
	No genioplasty, MMF for 7-10 d, no splint.		Group 2: 15	26 (17-56)		6.1 (B) 6.1 (Pg)	1.1 (B), 18.0% 1.1 (Pg), 18.0%
Abeloos et al, 1993[38]	Miniplates, no MMF, no genioplasty.	—	20	22.0 (15-36)	11.8 m	5.0 (Pg)	0.3 (Pg), 6.0%
Lee and Piecuch, 1992[37]	Miniplates (Luhr Vitallium compression), 2 cases with a second smaller unilateral plate, 3 with a single bicortical position screw, splint, no genioplasty, no MMF.	1	15	33.3 (15-46)	11.8 m	4.8 (B) 4.9 (Pg)	0.1 (B), 1.5% 0.1 (Pg), 1.4%
Jäger et al, 1991[34]	Miniplates (Luhr), splint, genioplasty in 8 patients, condyle positioning device.	—	21	25.1 (16.3-44.9)	16 m	2.6 (Pg)	0.2 (Pg),*7.7%*
Rubens et al, 1988[6]	Champy miniplates, MMF for 5.2 d, splint, miniplates removed after 6 m, no genioplasty.	—	20	—	8.85 m	6.07 (B) 5.39 (Pg)	0.65 (B),10.7% 1.01 (Pg),18.7%

Abbreviations: MMF, maxillomandibular fixation; B, point B; Pg, pogonion; d, days; m, months; yr, years; Ti, titanium; —, not reported.
*Relapse in an anterior direction.

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nasion line minus 7°), and a listing of all essential patient data would be necessary. Focusing a systematic review on only the most evidence-based articles would mostly limit our conclusions to only 6 studies, ie, 2 on miniplates,[6,50] and 4 on bicortical screws.[47-49,51] Moreover, 2 of these studies include the same patient population,[47,51] and 1 involves bioresorbable bicortical screws.[49] The huge number of possible articles was reduced because of inclusion and exclusion criteria that were thought to promote the possibility of comparing short-term and long-term relapse rates between 3 groups of different RIF techniques (bicortical screws, miniplates, and bioresorbable bicortical screws). Furthermore, the huge variation in short-term and long-term postsurgical relapse in this systematic review was very impressive, and makes it rather difficult to draw conclusions.

WHEN AND WHERE DOES RELAPSE OCCUR?

Schendel and Epker[11] distinguished between early relapse, or what occurs in the first few months after surgery, and later relapse. They attributed early relapse to surgical technique. Later relapse would be the result of unbalanced forces in the stomatognathic system, and would occur more slowly. Later published studies show a tendency to a common consent on which location early and late relapse appear. Possible sites for relapse include osteotomies, through intersegmental movement, and the temporomandibular joint, through condylar distraction, rotation of the ramus (proximal) segment, and morphologic changes in the condyle.

Condylar distraction implies that the condyle is positioned inferiorly or anteriorly to the glenoid fossa seated position. The condyle is therefore unable to support the mandible in the new advanced position defined by the surgeon. Intraoperative distraction of the condyles from their seated position should result in an immediate skeletal relapse when the condyles return to their preoperative position. This kind of relapse can be masked postoperatively by MMF, Class II elastics, or habituation.[43] Another form of condylar distraction is the counterclockwise (anterior) rotation of the proximal segment. This can lead to instability because of altered muscular orientation, length, and insertion. The muscular pull tends to return the proximal segment to its original inclination, resulting in posterior movement of the chin.[7,43] Counterclockwise rotation of the proximal segment should also lead to early relapse, soon after function resumes.

Progressive condylar resorption is related to long-term relapse.[43,54] The target groups for condylar resorption are young women with a high mandibular plane angle.[55,56] Scheerlinck et al[39] showed that 7% of all BSSO advancement patients appear to undergo

Table 5. SUMMARIZED DATA OF 3 STUDIES WITH MINIPLATES AND LONG-TERM FOLLOW-UPS (≥1.5 YEARS)

Study	Surgery (eg, Type of RIF, Genioplasty, MMF)	Number of Surgeons	Number of Patients	Mean Age and Range (yr)	Follow-Up	Mean Setback (mm)	Relapse (mm)
Kahnberg et al, 2007[46]	Miniplates (6-hole plate for marginal part and another 3-hole or 4-hole plate inferior to the first plate), splint, some patients with genioplasty.	—	15	28 (18-67)	1.5 yr	6.5 (B) 6.4 (Pg)	0.1 (B), 1.5% 0.1 (Pg), 1.6%
Borstlap et al, 2004[50]	Ss or Ti miniplates (additional plates in bad splits), splint, no genioplasty, plates removed after 6 m.	—	222	25.2 (13-53) (SD, 8.2)	2 yr	5.6 (Pg)	0.9 (Pg), 16.1%
Scheerlinck et al, 1994[39]	Miniplates, no genioplasty, splint, MMF for 1-3 d.	—	103	23.7 males (15.0-44.8) 25.8 females (14.1-43.3)	32 m	5.9 (B)	0.5 (B), 8.9%

Abbreviations: MMF, maxillomandibular fixation; B, point B; Pg, pogonion; d, days; m, months; yr, years; Ti, titanium; Ss, stainless steel; —, not reported.

Joss and Vassalli. BSSO Advancement Surgery With Rigid Internal Fixation. J Oral Maxillofac Surg 2009.

PCR, and the amount of advancement correlates positively with PCR.

If the condyle is forcefully pushed in the fossa, or the condyle is torqued as a result of type of fixation (bicortical screws), localized compressive or tensile forces may predominate in different areas of the condyle.[37,41] It was suggested that excessive compressive loading of the condyles leads to a decrease in nutrition from the synovial fluid, resulting in possible condylar resorption.[57]

WHAT IS THE REASON FOR RELAPSE?

Relapse seems to be a multifactorial phenomenon affected by many different variables. Possible factors promoting relapse in the reviewed articles are shown in Figure 1. Good surgical training, lengthy experience in orthognathic surgery, and technical refinements by the surgeon are necessary for good postoperative results in regard to stability and esthetics. Presurgical orthodontics is another important factor for stable results which allows, when performed correctly, good interdigitation after surgery.

No difference was found between short-term relapse rates in bicortical screws and miniplates. A higher number of studies with larger skeletal long-term relapse rates involved patients treated with bicortical screws instead of miniplates. One explanation could involve longer follow-up periods in long-term studies on bicortical screws compared with miniplates. In general, there is a trend toward increase in relapse from short-term to long-term studies when bicortical screws are used. Only small differences between short-term and long-term relapse rates in miniplates were evident.

Only 1 study[46] compared relapse rates in miniplates with relapse rates of bicortical screws. Kahnberg et al[46] found slightly higher skeletal relapse rates in patients with bicortical screws than with miniplates. Nonetheless, they concluded that for both methods, only minor skeletal relapses and small differences were evident 1.5 years postoperatively.

Bioresorbable or biodegradable osteosynthesis material for RIF included self-reinforced poly-L-lactide,[42] relapse rates PGA Lactosorb,[49] and PLLDL bicortical screws.[45] Two studies compared the skeletal stability of titanium with that of bioresorbable bicortical screws.[45,49] They did not find any statistical difference between these 2 types of bicortical screws. Nevertheless, bioresorbable bicortical screws had higher short-term relapse rates compared with bicortical screws.[45,49] Long-term studies on bioresorbable bicortical screws were not found.

Six studies that evaluated differences between groups with RIF and wire fixation (WF) were included in this systematic review.[4,32,33,36,41,48] Watzke et al,[33] Douma et al,[36] and Bouwman et al[41] did not find any

Table 6. SUMMARIZED DATA OF 3 STUDIES WITH BIORESORBABLE BICORTICAL SCREWS

Study	Surgery (eg, Type of RIF, Genioplasty, MMF)	Number of Surgeons	Number of Patients	Mean Age and Range (yr)	Follow-Up	Mean Setback (mm)	Relapse (mm)
Turvey et al, 2006[45]	4 self-reinforced polylactate (PLLDL 70/30) biodegradable bicortical screws, genioplasty in 7 patients.	1	34	27.5 (SD, 13.0)	1 yr	5.20 (B) 6.19 (Pg)	0.54 (B), 10.4% 0.26 (Pg), 4.2%
Ferretti and Reyneke, 2002[49]	3 copolymer (PLLA/PGA Lactosorb) screws (core-diameter: 2.0 mm, thread-diameter: 2.5 mm), no MMF, no genioplasty, condylar positioning device.	1	20	—	6 m	5.5 (B)	0.83 (B), 15.1%
Kallela et al, 1998[42]	3 self-reinforced PLLA screws (diameter: 2.7 mm), no genioplasty, splint.	—	25	27 (18-38)	1 yr	4.6 (B) 3.9 (Pg)	0.8 (B), 17.4% 0.6 (Pg), 15.4%

Abbreviations: MMF, maxillomandibular fixation; B, point B; Pg, pogonion; d, days; m, months; yr, years; —, not reported.

Joss and Vassalli. BSSO Advancement Surgery With Rigid Internal Fixation. J Oral Maxillofac Surg 2009.

significant difference regarding stability and relapse between the groups with RIF and WF, whereas others[4,32,48] found that RIF was more stable than WF in preventing skeletal relapse.

Two studies compared different screw systems,[35,40] and found only small differences regarding skeletal stability. It was stated that larger screws, plates, skeletal suspension wires together with RIF, and MMF after surgery in combination with RIF may be better in preventing relapse.[20] However, individual anatomic variations may result in less than ideal ramal splits, leading to splintering of the osseous segments. In this situation, finding an area for the placement of fixation screws would be difficult at best, and would affect the stability of the osteotomy site.[31] The variability of osseous segments could be a factor in the differences pertaining to relapse. Rubens et al[6] showed that 4 patients with a buccal bone plate fracture had a slightly greater degree of relapse than was seen in their main group of patients. This may be attributable to a potential loss of condylar control during plate fixation, and thus a longer period of MMF in these cases may be advisable, because there is more potential for displacement.

Changes in condylar position after BSSO and mandibular advancement with RIF are frequent findings.[58] The importance of correct positioning of the condyles before fixation is well-known. Improper positioning of the condyle in the glenoid fossa at time of surgery, when the soft tissue undergoes considerable stretching, can cause relapse. It is believed that the magnitude of advancement is a factor in the proper seating of condyles.[47] Thüer et al[47] showed that it was easier to manipulate the proximal segment in patients with small advancement who had their condyles set a bit too far posteriorly, with subsequent anterior relocation after surgery. 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 setbacks, are not extensively stretched.[8]

When RIF is used, it is possible to check passive condylar function and occlusion intraoperatively, before incisor closure. This should help reduce the incidence of condylar distraction.[12] As a consequence of intraoperative swelling and inflammation within the joint because of manipulation of the proximal segment, an increase in vertical joint space is a common finding. When assessing condylar distraction, Gassman et al[19] showed about twice the amount of gonial arc displacement in their relapse group (more than 25% of relapses) versus their control group with no relapses.

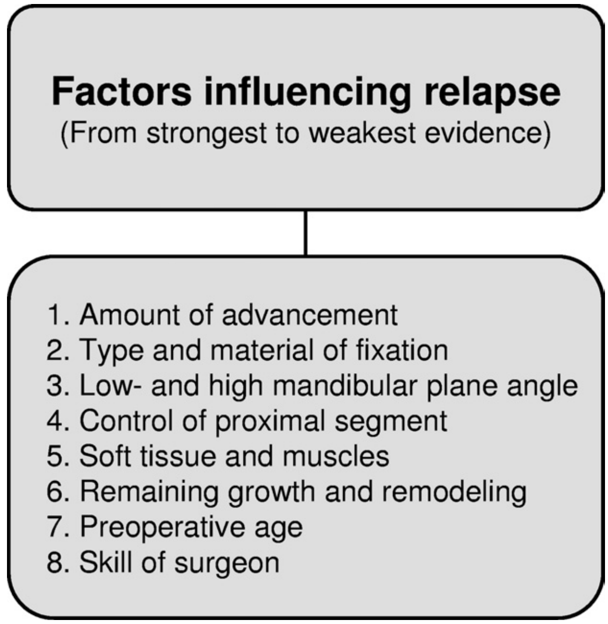

FIGURE 1. Factors influencing relapse after BSSO for mandibular advancement.

Joss and Vassalli. BSSO Advancement Surgery With Rigid Internal Fixation. J Oral Maxillofac Surg 2009.

The use of positioning appliances remains controversial in the literature. Gerressen et al[59] concluded that the importance of condyle position is generally overestimated. They believe that the use of a positioning appliance in their study did not result in an accurate reproduction of the preoperative condyle position, a therapeutically favorable position for the proximal segments, or an improvement in skeletal stability. Nevertheless, others[34] found that controlling the position of the proximal segment by means of a device was the most important factor in posttreatment stability.

Relapse has been attributed largely to increased soft tissue and muscular tensions because of the advancement of the mandible.[60] Simply put, the greater the advancement, the greater the stretching of the soft tissue. To find evidence of this topic in the reviewed articles was rather difficult. Strong evidence can be found where a positive correlation between the amount of advancement and the relapse rate was shown. This was demonstrated in several studies.[31,36,40,47,48,50,51]

The influence of skeletal pattern, ie, of the mandibular plane angle on horizontal and vertical skeletal stability, was shown in several studies. High-angle patients undergo more horizontal relapse than low-angle patients,[34,36,41,43,50] whereas low-angle patients undergo more vertical skeletal relapse[34,40] than high-angle patients. Wolford et al[61] described 3 types of mandibular movements in cases of advancement. Types I and II undergo a clockwise and forward movement and a straightforward movement, respectively. Type III mandibular movements (counterclockwise) are also associated with a high mandibular plane angle. These cases were found to have a high incidence of relapse, because the muscles of mastication are lengthened in the ramus area. As these muscles attempt to return to their original positions, they rotate the mandible in a clockwise movement, open the bite, and cause relapse. On the other hand, low-angle patients, representing those with a Class II deep bite, are believed to manifest increased vertical relapse.

Different surgical techniques have been promoted to prevent skeletal relapse. Steinhäuser[62] first described the concept of suprahyoid myotomy, which involves the detachment of the geniohyoid and anterior digastric muscles. After an experimental study, Wessberg et al[63] reported that suprahyoid myotomies were a possible way to prevent relapse, but they failed to prove this in their clinical material. They concluded that suprahyoid myotomy is probably not indicated when digastric and geniohyoid muscles are stretched less than 30% after surgical advancement of the mandible. Schendel and Epker[11] also could not show any statistical difference between the application and nonapplication of suprahyoid osteotomies in different mandibular advancement procedures (BSSO, C, inverted-L, or arcing osteotomies). The technique described by Epker[64] allows the muscles of mastication (ie, the masseter, temporalis, and medial pterygoid muscles) to remain in their original position on the proximal segment, and allows the distal segment to be advanced, with potential positive effects on relapse. Nonetheless, a shortening of these muscles, in response to surgical intervention, will tend to rotate the segment superiorly and anteriorly.

Surgery should mainly be provided to patients when the end of growth is at least radiographically confirmed, to minimize relapse due to continuous growth. On the other hand, it is likely that remodeling and remaining growth could be a cofactor for relapse in older patients. The initial growth of the patient's face and continuous remodeling processes may lead to an advantageous or disadvantageous change of position of the mandible after BSSO.

Since the studies of Behrents,[65,66] late growth to a certain extent and remodeling processes in the aging skeleton have become well-known. He examined 113 untreated subjects, from 17 to 80 years of age, and showed that point B moved downward in both genders. Males presented nonclockwise rotation (anterior and downward) of the mandible, whereas females presented clockwise rotation (posterior and downward). These findings indicate that there would be an improvement of the profile in male advancement patients with age, but in females, there would be neither improvement nor worsening.

The number of long-term studies was rather low. This may be why little is known about the effect of growth on relapse. Mobarak et al[43] speculated that some of the late relapse 3 years after surgery in their high-angle patients could be attributable to late growth or to morphologic changes in the condyles. These late changes in the condyles would lead to their shortening and upward seating, with concomitant rotation of the mandible around a fulcrum at the molars. Joss and Thüer[51] also attributed some of their late relapses 12.7 years after surgery to the initial growth direction and ongoing remodeling processes of the hard tissue. Condylar remodeling or changes in the glenoid fossa may contribute to relapse. Perhaps more remodeling occurs over a longer period in some patients treated with RIF compared with WF because the rotation of the condyles is more rigidly maintained, which can cause more long-term changes in jaw position.[33]

Since the multicenter study from Schendel and Epker,[11] who reported differences in the amount of relapse found by different surgeons after mandibular advancement with MMF and WF, the influence of surgical skill and technique has become very important. Although some multicenter studies were recently performed,[48,50] and although most studies include patients operated upon by different surgeons, the influence of the skill of the surgeon on relapse has not widely been reported. However, Kirkpatrick et al[30] could not show any differences between their 3 operating surgeons, and concluded that RIF seems to compensate for such variations regarding surgical skill.

The aim of this study was a systematic review of the literature on stability after BSSO to advance the mandible with different types of RIF. On the basis of our analysis of 24 articles, it can be concluded that:

- BSSO for mandibular advancement is a good treatment option for skeletal Class II, but seems to be a less stable procedure than BSSO setback in the short term and long term.
- Bicortical screws (titanium, stainless steel, or bioresorbable) show only slight differences regarding skeletal stability compared with miniplates in the short term. A greater number of studies with higher skeletal long-term relapse rates were seen in patients treated with bicortical screws instead of miniplates.
- The etiology of relapse is multifactorial: the proper seating of the condyles, the amount of advancement, the soft tissue and muscles, the mandibular plane angle, the remaining growth and remodeling, the skill of the surgeon, and preoperative age. Gender does not seem to be of any importance in relapse.
- High-angle patients undergo more horizontal relapse than low-angle and normal-angle patients. Patients with a low mandibular plane angle, compared with high-angle and normal-angle patients, undergo increased vertical relapse.
- Advancements in the range of 6 to 7 mm or more predispose patients to horizontal relapse.
- To obtain reliable scientific evidence, further short-term and long-term research of BSSO advancement with RIF should exclude additional surgery, ie, genioplasty or maxillary surgery, and include a prospective study or randomized clinical trial design with correlation statistics.

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