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RESEARCH

Efficacy and outcomes of fixation methods in bilateral sagittal split ramus osteotomy: a comprehensive review of stability, neurosensory disturbances and TMJ disorders

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Introduction: Bilateral sagittal split ramus osteotomy (BSSO) is a commonly performed procedure for correcting mandibular prognathism and retrognathism. Numerous modifications to the technique along with the use of bicortical and monocortical screw fixation systems, have been developed to enhance stability, aesthetics and function. This review explores the stability, relapse rates, neurosensory disturbances (NSD) and temporomandibular joint (TMJ) dysfunction associated with different fixation methods in BSSO.

Methods: A comprehensive literature review of studies evaluating the outcomes of BSSO was performed. Factors such as skeletal stability, NSD, TMJ symptoms and the impact of fixation methods were examined. Comparative analyses of bicortical and monocortical screws were conducted to assess their efficacy and complications.

Results: Bicortical screw fixation demonstrated better long-term stability and cost-effectiveness compared to monocortical systems with relapse rates varying based on fixation type and surgical scenarios. NSD particularly inferior alveolar nerve (IAN) injury were the common complications. Recovery rates were influenced by patient age, surgical duration and nerve manipulation. TMJ dysfunction outcomes indicated improvement in symptoms for most patients postoperatively, though pre-existing conditions and specific anatomical factors increased risk.

Conclusion: BSSO remains a reliable procedure for addressing mandibular discrepancies. Bicortical screws offer enhanced stability but are associated with higher risks of neurosensory complications. Multidisciplinary approaches and individualized treatment planning can optimize functional and esthetic outcomes while minimizing complications such as relapse, NSD and TMJ dysfunction.

Keywords: bilateral sagittal split osteotomy, bicortical fixation, monocortical fixation, neurosensory disturbance, temporomandibular joint dysfunction, skeletal stability

Introduction

Bilateral sagittal split ramus osteotomy (BSSO) is one of the most widely employed surgical techniques for the correction of mandibular deformities including mandibular prognathism (forward positioning of the mandible) and retrognathism (backward positioning of the mandible). The procedure was first described by Schuchardt in 1942 (1) and subsequently refined by Trauner and Obwegeser in 1957 whose modifications laid the foundation for the modern approach. Further advancements were introduced by Dal Pont in 1961, Hunsuck in 1968 and Epker in 1977 (2).

In terms of fixation, bicortical screws are part of the rigid internal fixation system which engage both the buccal and lingual cortices, whereas monocortical screws used in semi-rigid fixation and engage only the buccal cortex. Bicortical screw fixation, however, often requires an extraoral stab incision for trocar and cannula insertion which may leave a visible scar and result in unesthetic appearance (3).

Postoperative complications of orthognathic surgery (OGS) may include injury to the inferior alveolar nerve (IAN), temporomandibular joint (TMJ) disorders and skeletal relapse (4). IAN is a branch of the trigeminal nerve may be damaged directly during osteotomy procedures involving the saw, drill or chisel or indirectly through compression from hematoma or edema within the mandibular canal. Since BSSO is most frequently performed in young adults seeking both functional improvement and optimal facial aesthetics, complications can significantly affect patient satisfaction (5).

Temporomandibular disorders (TMD) can manifest through limited mandibular movement, masticatory muscle and joint pain, audible joint sounds (clicking, popping or crepitus), myofascial pain and other functional impairments (5, 6). Similarly, skeletal relapse after surgery poses challenges to the long-term stability of treatment outcomes.

This review provides an in-depth analysis of stability and relapse, neurosensory disturbances (NSD) and TMJ disorders in relation to monocortical plate and bicortical screw fixation techniques used in BSSO.

Methods

This review was undertaken as a narrative synthesis of the literature on fixation methods in BSSO with a particular focus on skeletal stability, relapse, NSD and TMJ disorders. Relevant studies were identified through systematic searches of PubMed, Scopus, and Google Scholar using combinations of keywords including "bilateral sagittal split osteotomy," "bicortical fixation," "monocortical fixation," "stability," "relapse," "neurosensory disturbance," and "temporomandibular joint dysfunction."

Studies published in English between 1980 and 2024 were included. Eligible publications comprised prospective and retrospective clinical studies, randomized controlled trials, systematic reviews and meta-analyses. Case reports and conference abstracts were excluded unless they provided unique clinical insights. Additionally, the reference lists of relevant articles were screened to identify further sources.

Given the narrative design, no formal quality assessment or risk-of-bias scoring was applied. Instead, emphasis was placed on the clinical relevance, sample size and methodological clarity of the included studies. The findings were synthesized qualitatively, with comparative focus on monocortical versus bicortical fixation methods and their implications for stability, neurosensory recovery and TMJ function.

Discussion

Stability and relapse following BSSO

Stability after BSSO depends on the fixation method, amount of skeletal movement and the direction of correction (advancement or setback).

Brian C. Rubens et al. (7) evaluated 20 patients who underwent mandibular advancement using miniplates and monocortical screws. Postoperative assessment showed relapse at B-point in 10.7% and at pogonion in 18.7% of patients. The overall relapse rate was higher than average, at 16% for B-point and 24% for pogonion, with a slight reduction in mouth opening (0.47 mm) reported. These results highlighted the limitations of early monocortical fixation in maintaining long-term skeletal stability (7).

In comparison, more recent studies using bicortical rigid fixation or hybrid approaches (miniplates with positional screws) have reported lower relapse rates, particularly in mandibular advancements. Eggensperger et al. (8) reported a mean relapse of only 1.3 mm at both the B-point and pogonion after 1 year, increasing to approximately 2.3 mm after 12 years, primarily due to progressive condylar resorption rather than fixation failure. Similarly, Paunonen et al. (9) found mandibular advancement in Class II patients to be a stable procedure with relapse ranging between 10 and 25%, which was often clinically insignificant.

Overall, these comparisons suggest that while monocortical fixation in early studies showed higher relapse, advances in rigid fixation methods, case selection and orthodontic finishing have significantly improved long-term stability in BSSO procedures.

Comparison of fixation system: (**Table 1**)

- Bicortical screw fixation is widely considered more rigid, predictable and cost-effective. It provides stronger interfragmentary stability but carries higher risks of lingual nerve injury and greater intraoperative blood loss.
- Miniplates with monocortical screws are indicated in unfavorable splits or when large defects (e.g.,

following third molar removal) are present. They are easier to adapt intraorally and safer in certain anatomic scenarios.

- Long-term evidence indicates that bicortical screws provide superior skeletal stability, particularly beyond the 10-year follow-up; however, the differences in relapse compared with monocortical fixation are generally minimal and often clinically insignificant when orthodontic finishing is optimized.

Christopher A. Sorokolit et al. in 1990 conducted a study on mandibular setback using rigid fixation in 25 patients. Postsurgical relapse was observed in 16 patients, accounting for approximately 10% of the original surgical correction (mean setback: 5.1 ± 3.0 mm), corresponding to an average anterior movement of 0.51 ± 1.04 mm from the initial correction. Clinically stable results were found when using rigid fixation in sagittal osteotomy for mandibular setback surgeries (10).

The use of bicortical screws for fixation in sagittal split osteotomy has been shown to provide rigid, predictable and cost-effective stabilization. These screws are available in various designs and their application depends on factors such as angulation, anatomical location and the presence of bone contact or gaps. Miniplates with monocortical screws are typically indicated in cases of unfavorable splits or when large defects result from lower third molar removal. Knowledge of both the surgical procedure should be familiar to the surgeon depending on the intra operative surgical scenario (11). N. Eggensperger et al. analyzed the short and long term skeletal relapse for 12 years in 32 skeletal Class II malocclusions who underwent BSSO with rigid fixation followed by orthodontic treatment. 4.1 mm of mandibular advancement was effected at B point and 4.9 mm was noted at pogonion. A skeletal relapse of 1.3 mm was observed at both the B-point and pogonion by the end of the first year. After 12 years, due to progressive condylar resorption, the relapse increased to 2.3 mm, representing approximately 50% of the original advancement. No significant association was found between a high mandibular plane angle and long-term skeletal relapse, nor between the amount of initial surgical advancement and the degree of skeletal relapse. No significant association was found between a high mandibular plane angle and long-term skeletal relapse, nor between the amount of initial surgical advancement and the degree of skeletal relapse (8).

TABLE 1 | Comparison of fixation systems.

Fixation method	Advantages	Disadvantages/risks
Bicortical screws	Rigid, predictable, cost-effective, long-term stability	↑ Lingual nerve injury, ↑ blood loss
Miniplates + monocortical screws	Easier intraoral adaptation, safer in unfavorable splits or third molar defects	Less rigid than bicortical, slightly higher relapse

The stability of miniplates and monocortical screws in BSSO advancement and mandibular setback was evaluated in a study involving 10 patients with 5 in each group. In the advancement group, the sella, nasion and cephalometric B point (SNB) angle demonstrated a statistically significant relapse of 2.4° at 12 months. However, anterior and posterior facial height, Frankfort–Mandibular Incisor Angle (FMIA) and overjet showed no significant changes. In the setback group, a statistically significant change of 1.4 mm was observed in posterior facial height, the angle between the lower incisor and mandibular plane and pogonion position, whereas the SNB angle, anterior facial height, interincisal angle and FMIA remained stable. Cephalometric analysis indicated that relapse began at the third month in advancement cases and from the sixth month onwards in setback cases (12).

Bilateral sagittal split ramus osteotomy advancement and setback procedures were performed in 16 patients, and long-term hard and soft tissue changes were evaluated using cephalometric analysis over a minimum follow-up period of 2 years post-surgery. He concluded that 7% was the mean difference in mandibular advancement between post-surgical and long term post-surgical patients, whereas in mandibular setback, it was 29%. So mandibular advancements were relatively stable over a longer period of time than mandibular setback procedures (13).

Other studies confirm that relapse patterns differ between advancement and setback. In mandibular advancement, SNB angle relapse of about 2–3° can occur, but linear relapse is usually minor and clinically acceptable. In mandibular setback, relapse rates are higher (up to 29% long term), partly due to muscular and soft-tissue rebound forces.

E. Ellis et al. reviewed the literature and evaluated the changes in both linear and angular measurements. He suggested that bicortical screw fixation is cost-effective, requires minimal hardware and demonstrates slightly better stability compared to miniplate fixation following BSSO setback procedures (14).

Postoperative stability was evaluated in 75 patients treated via an intraoral approach, comparing bicortical screw fixation (39 cases) with miniplate and monocortical screw fixation (36 cases). Both groups demonstrated statistically similar postoperative relapse at point B and menton; however, the incidence of lingual nerve injury and total blood loss was higher in the intraoral bicortical screw fixation group. In individuals devoid of facial asymmetry, intraoral miniplate with monocortical screw fixation was recommended over intraoral bicortical screw fixation (3).

Kristoffer Schwartz et al. examined 33 individuals with skeletal Class II malocclusion who underwent bimaxillary surgery to assess skeletal stability following mandibular advancement exceeding 10 mm. Stability was evaluated using lateral cephalogram with relapse measured at point

B and pogonion. Vertical facial type was assessed using the mandibular plane angle. Nineteen patients with a long-face pattern exhibited the greatest skeletal relapse, averaging −0.5 mm at point B and −1.9 mm at pogonion (15). Jaakko Paunonen et al. evaluated the long-term dental and skeletal stability as well as factors associated with relapse in 46 patients with mandibular retrognathia treated with BSSO. Patient records and preoperative (T1), postoperative (T2) and long-term follow-up (T3) radiographs were analyzed. The authors concluded that mandibular advancement in healthy Class II patients is generally a stable procedure. Although dental changes were clinically insignificant, a skeletal relapse of approximately 25% was observed (9).

Overall, the stability of BSSO is influenced by several interrelated factors including fixation technique, magnitude and direction of movement, facial type and long-term adaptive changes such as condylar resorption. While bicortical screw fixation offers rigidity and cost-effectiveness, miniplates with monocortical screws remain a safer option in certain clinical scenarios, particularly when unfavorable splits or large defects are encountered. Evidence consistently suggests that mandibular advancement procedures are generally more stable than setback surgeries in the long term. Nonetheless, skeletal relapse, although often clinically insignificant, remains a challenge that requires careful case selection, precise surgical execution and appropriate orthodontic support.

Neurosensory disturbances

T. Teerijoki-Oksa et al. investigated the risk of IAN injury in 20 patients undergoing mandibular advancement (BSSO) and its correlation with mandibular anatomy and surgical technique. The orthodromic sensory nerve action potential of the IAN was continuously recorded during the procedure. The results indicated that impaired IAN conduction was more frequently observed in mandibles with a low corpus height and when the mandibular canal was located close to the inferior border. In terms of nerve injury, no functional impairment was observed from mere manipulation or exposure of the IAN; however, conduction was significantly disrupted during lengthy procedures, surgeries involving the medial mandibular ramus and when nerve laceration occurred (16). Sensory impairement of IAN after BSSO studied in 60 patients by testing thermal sensations, nociception and two point discrimination. Results showed that spontaneous recovery happened within 6 months in minor injuries like neuropraxia and axonotmesis whereas major injury like neurotmesis is left with persistent anesthesia (17).

Further clinical studies on 60 patients using thermal sensation, nociception and two-point discrimination testing revealed that recovery depends on the type of nerve injury. Neuropraxia (a temporary conduction block without axonal injury) and axonotmesis (axonal disruption with preservation of connective tissue sheaths) typically resolve within 6–12 months, whereas neurotmesis (complete nerve transection) is usually associated with persistent anesthesia. Although some reports suggest recovery within 6 months for minor injuries, variability is common and follow-up beyond 1 year is often required to confirm outcomes (**Table 2**).

Aldo Bruno Gianni et al. developed a study protocol to evaluate NSD following genioplasty, sagittal split mandibular osteotomy and combined procedures. The results indicated that performing genioplasty in combination with sagittal split osteotomy had a greater negative impact on lip sensibility compared to either procedure performed alone. Additionally, thermal sensation was found to be less affected than tactile sensation, two-point discrimination and location tests (18).

T. Teerijoki Oksa et al. compared various clinical sensory with the electrophysiologic tests. Clinical sensory tests included touch detection threshold test, blink test, cold detection threshold test and nerve conduction study in 20 patients undergoing BSSO. The results demonstrated that nerve conduction studies were the most sensitive among clinical sensory tests, although their specificity was relatively low. All electrophysiological tests showed a clear association with objectively verified IAN damage. It was recommended that combining different sensory and electrophysiological tests would enhance diagnostic accuracy and facilitate the detection of various types of damage across different nerve fiber populations (19).

A retrospective study was conducted to assess the incidence of NSD following sagittal split osteotomy and to evaluate their association with patient age, gender, satisfaction and the effects of steroid use in 50 patients 1 year post-surgery. The results indicated that NSD were more prevalent in patients over 40 years of age and steroid administration appeared to have a beneficial effect in reducing these disturbances. Subjectively, patients placed greater emphasis on functional and aesthetic outcomes than on neurosensory discomfort (20). To determine the frequency of postoperative sensory disturbances, questionnaires were mailed to patients who had undergone BSSO (n = 84) and BSSO combined with genioplasty (n = 20). Results showed that 37 and 37% of operated sides were considered to be sensory disturbances, respectively.

TABLE 2 | Types of nerve injury and expected recovery timeline.

Nerve injury type	Definition	Typical recovery timeline
Neuropraxia	Conduction block, no axonal damage	6–12 months
Axonotmesis	Axon damage, connective sheath intact	6–12 months
Neurotmesis	Nerve completely transected	Rarely recovers; persistent numbness

Long - lasting sensory disturbances in were noticed in 36% of mandibular advancement and 40% in mandibular setback. 89% of patients were satisfied with BSSO and 85% with BSSO in combination with genioplasty. There was no statistically or clinically significant difference between the two groups regarding the incidence of sensory disturbances. Sensory disturbances was not primary factor for patient's satisfaction, but depends on function and aesthetics (21).

A retrospective study was conducted on 68 patients to assess the occurrence of neurosensory dysfunction in the lower lip and chin following bilateral sagittal split osteotomy and to evaluate its correlation with various factors. The study concluded that patient age, the perioperative position of the IAN and the method of fixation were the most significant factors influencing postoperative nerve function (22). The literature review aimed at evaluating neurosensory disturbance of IAN by subjective and objective methods and to comp are the sensitivity of these diagnostic tests. Results showed that objective methods provide the most sensitive diagnostic tests at early controls (within 3 months). Later on, sensitivity increases and the inter-rater reliability is satisfactory in control points (23).

This study compared masticatory function and neurosensory recovery patterns following BSSO for Class III malocclusion between bicortical screw fixation (n = 38) and monocortical miniplate fixation (n = 32). Postoperative assessments of masticatory function and neurosensory recovery were conducted at 1, 3, 6 and 12 months. The results indicated that patients with monocortical miniplate fixation demonstrated faster recovery in both masticatory function and neurosensory parameters compared to those with bicortical screw fixation (24). This study aimed to evaluate the development and recovery of NSD following Sagittal Split Ramus Osteotomy (SSRO) in 50 subjects, with particular attention to the surgical procedure and the anatomical and structural characteristics of the craniomaxillofacial skeleton. Manipulation of the IAN on the medial aspect of the mandibular ramus was associated with an increased risk of NSD. Conversely, limited periosteal degloving helped prevent excessive stretching of the nerve during SSRO, thereby reducing the incidence of NSD (25).

The effect of different mandibular splitting techniques are mallet and chisel versus spreading and prying on postoperative hypoesthesia following BSSO was evaluated. Fourteen studies were analyzed and categorized into three groups: (1) no use of chisel, (2) undefined use of chisel and (3) explicit use of chisel along the buccal cortex. The explicit use of a chisel along the buccal cortex was associated with the highest incidence of NSD (26). A study evaluated the extent of neurosensory disturbance and its impact on patients 1 year after BSSO as well as factors associated with NSD. The degree of intraoperative nerve manipulation was considered the predictor variable, while the outcome variable was the effect of NSD on patient satisfaction. Among 41 patients, 90.2% experienced NSD; however, 89.2% remained satisfied with their treatment and stated they would undergo the procedure again. Increased intraoperative manipulation of the nerve was associated with a higher incidence of NSD (27).

A retrospective evaluation of IAN function was conducted in 15 patients following BSSO. Both objective (cotton swab and pin-prick testing) and subjective (questionnaire) assessments were performed at 1 year postoperatively. Subjectively, NSD was reported in 22 operated sides during the immediate postoperative period, with 4 sides showing persistent NSD at 1 year. Objectively, NSD was observed in 20 operated sides immediately after surgery, with recovery noted in 18 sides and persistence in 2 sides after 1 year. These findings suggest that immediate postoperative NSD of the IAN is a common complication after BSSO; however, long-term recovery of nerve function typically occurs (1).

The incidence of NSD following BSSO was investigated and the probability of sensory recovery was assessed among patients stratified into three age groups: $<$19 years, 19–30 years and $>$30 years. Immediately after BSSO, hypoesthesia of the lower lip was assessed subjectively and objectively. In older patients, the frequency of NSD immediately after surgery was significantly higher with significant risk factor for permanent hypoesthesia. The incidence of permanent hypoesthesia observed was 4.8% per patient aged $<$19 years, 7.9% per patient aged 19–30 years and 15.2% per patient aged $>$30 years (28).

Neurosensory disturbance is one of the most frequent and clinically significant complications following BSSO, with its incidence and recovery influenced by multiple factors including patient age, surgical duration and technique, fixation method and the extent of IAN manipulation. While most cases of neuropraxia and axonotmesis recover spontaneously within 6–12 months, severe injuries such as neurotmesis may result in persistent anesthesia. Objective diagnostic methods especially electrophysiological testing, offer greater sensitivity for early detection, though combining them with clinical sensory tests enhances diagnostic accuracy. The choice of fixation method also appears to influence recovery with monocortical miniplates showing faster neurosensory recovery compared to bicortical screws in some studies. Importantly, despite the relatively high incidence of temporary NSD, long-term patient satisfaction after BSSO remains high, as functional and esthetic improvements often outweigh sensory impairments. Continued refinement of surgical technique, judicious handling of the IAN and individualized patient risk assessment are essential to minimize permanent deficits and optimize outcomes.

Temporomandibular joint dysfunction

A study assessed changes in intercondylar width (ICW) and intercondylar angle (ICA) in relation to temporomandibular symptoms, magnitude of advancement and mandibular form following BSSO advancement with rigid fixation. The results indicated that although individual variations were observed, there was no significant difference between pre- and postoperative ICA and ICW measurements, nor between pre- and postoperative temporomandibular pain or clicking. This suggests that condylar positional changes occurred within the range of clinical adaptability. Furthermore, no correlation was found between the magnitude of advancement and percentage change in ICA or ICW and mandibular form did not significantly influence ICA or ICW, even with changes in ICW and screw osteosynthesis (29).

A study evaluated pre- and postoperative TMJ symptoms in 480 patients who underwent surgery for dysgnathia. Preoperatively, 16.2% of patients presented with TMJ symptoms and among them, 66.6% reported fewer or no symptoms postoperatively. TMJ symptoms were more prevalent in low and normal-angle patients compared to high-angle patients, with a greater likelihood of symptom improvement observed in cases of low and normal-angle mandibular retrognathism (30). A study on 54 patients assessed TMJ function preoperatively and up to 1 year postoperatively using condylar path tracings, which provide both quantitative and qualitative data. Internal derangements were identified in 72% of joints. Functional adaptation of the TMJ was more favorable in mandibular reduction and maxillary impaction procedures compared to mandibular advancement or combined surgeries. Condylar tracings proved to be a valuable non-invasive tool for detecting and monitoring TMJ status after surgery (31).

The effects of rigid and non-rigid fixation were assessed in 40 patients who had undergone BSSO with mandibular advancement on TMJ dysfunction symptoms and were divided into two groups (20 in each). He concluded that the difference was not statistically significant between two groups (32). In a study of 53 patients undergoing OGS, the incidence of disc displacement and TMJ symptoms was evaluated clinically and bilaterally using TMJ arthrography. Disc displacement was identified unilaterally or bilaterally in 57% of patients, while TMJ pain was reported in 53%. He concluded that in patients with dentofacial anomalies, disc displacement was more common, but that there was no connection between the symptoms of the TMJ and the form of dentofacial anomaly (33).

A retrospective study was conducted on 143 patients with normal or low mandibular angles and 53 patients with high absolute mandibular retrognathism, treated with mandibular advancement and bimaxillary surgery respectively. The study confirmed earlier findings that the incidence of TMJ symptoms preoperatively in patients with low or normal mandibular angles as well as in the overall group, was significantly higher compared to postoperative TMJ symptoms. TMJ symptoms are decreased postoperatively in low or normal angle than high angle group (34). Alterations in the signs and symptoms of TMJ disorders were evaluated in patients undergoing OGS and compared with a healthy control group. The study found that OGS can improve the functional status of the TMJ; however, no correlation was observed between the presence of TMD symptoms and the type of dentofacial deformity (35).

Retrospective study was carried out to evaluate the TMJ dysfunction in 25 patients with known presurgical TMJ internal derangement who underwent bimaxillary surgery. Signs and symptoms of TMJ dysfunction such as range of mandibular motion, pain and presence or absence of TMJ sounds were evaluated subjectively as well as objectively. He concluded that patients with pre-existing TMJ dysfunction undergoing BSSO with mandibular advancement are found to have significant worsening of the TMJ dysfunction postoperatively (36).

Cecilia Abrahamsson et al. evaluated the prevalence of TMD in individuals referred for OGS compared to a control group using a questionnaire. The results showed a higher occurrence of myofascial pain without limited opening, disc displacement with reduction and arthralgia (based on Research Diagnostic Criteria for Temporomandibular Disorders [RDC/TMD] criteria) in the patient group. They concluded that patients referred for OGS exhibited more signs and symptoms of TMD and a higher frequency of diagnosed TMD compared to the control group (37).

The improvements in TMJ disorders before and after OGS were analysed and retrospectively assessed the possibility of new symptoms of TMJ in 176 patients. This study supports the viewpoint that routine OGS can improve TMJ internal derangement with a long - term stability of the orthognathic surgical procedures performed. No statistically significant difference was found in the prevalence of TMJ symptoms between Class II and Class III patients when comparing preoperative and postoperative assessments (38). A review of 148 studies identified several factors practitioners should consider during treatment planning including pre-existing TMJ disc displacement, crepitus, counterclockwise mandibular rotation, the extent of mandibular advancement and the rigidity of fixation, all of which can influence TMJ position and increase the risk of condylar resorption. The authors concluded that young adult females with mandibular retrognathism and an increased mandibular plane angle are particularly prone to painful TMJ symptoms, demonstrate less postoperative improvement and are more susceptible to condylar resorption (5).

The prevalence of temporomandibular disorders was recorded in patients scheduled for OGS, with documentation of TMD development and symptoms throughout the entire course of treatment. 76 patients had undergone surgical treatment. TMJ status were assessed using the RDC/TMD criteria. The data indicated that both functional status and pain levels associated with TMDs can be significantly improved through a multidisciplinary approach. The authors concluded that surgical intervention should be modified in patients presenting with presurgical TMJ disorders (39). A retrospective cohort study examined the need for TMJ surgery following orthognathic procedures in 630 consecutive patients undergoing Le Fort I or bilateral sagittal split osteotomy. Clinical, surgical, and radiographic outcomes were analyzed. Of the 630 patients, 10 required additional arthroscopic TMJ surgery due to internal derangements resistant to conventional therapy, with good outcomes observed in four patients. One patient underwent open TMJ surgery after failed arthroscopy which was unsuccessful in relieving pain and movement restriction. Additionally, five patients required further treatment for bilateral postoperative condylar resorption; a conservative approach proved sufficient for TMJ management in these cases (40).

The effect of OGS on the three-dimensional position of the condyle was investigated in a surgery-first treatment approach without a positioning device, with both quantitative and qualitative assessments of positional changes. Le Fort I osteotomy and bilateral sagittal split osteotomy were performed. Prospective analysis was conducted using CT scans of patients over 18 years of age presenting with anterior open bite. The study concluded that condylar position and TMJ anatomy had no significant impact on surgical outcomes (41).

A prospective study at Lille University Hospital assessed the impact of various fixation techniques on TMJ health following BSSO in 183 patients with dentofacial deformities. Patients underwent osteosynthesis either with monocortical miniplates (n = 42) or a hybrid method combining miniplates with bicortical retromolar screws (n = 141). TMJ health was assessed using the RDC/TMD and the Jaw Pain Function questionnaire, both preoperatively and 1 year postoperatively. The findings revealed no significant difference between the two fixation methods regarding TMD signs, symptoms or functional outcomes. The authors concluded that the hybrid technique, while offering practical surgical advantages, does not adversely affect TMJ health compared with conventional miniplate fixation (42).

A retrospective analysis of 99 patients assessed mandibular condyle positional changes following BSSO and bimaxillary OGS performed between 2013 and 2022. Condylar position was evaluated using preoperative and 6–12 month postoperative CT scans in both axial and sagittal planes. Significant postoperative changes were observed bilaterally in the AB angle ($p < 0.001$). Comparison between advancement and setback procedures revealed that the setback group had significantly lower ABL angle values (p = 0.0113) while the advancement group showed significantly higher facial deformity rehabilitation (FDR) values (p = 0.0058). No significant differences were noted between BSSO-only and bimaxillary procedures. These findings indicate that OGS induces moderate changes in condylar position, particularly affecting condylar rotation along the transverse axis (43).

A retrospective study of 20 patients evaluated postoperative condylar position stability following BSSO using either monocortical miniplates or bicortical lag screws for fixation. Preoperative and 7-day postoperative CT scans revealed no significant differences in condylar height, length or width between the two fixation groups. Although a marginally significant increase in left condylar angulation was observed in the lag screw group (p = 0.04), overall condylar position remained stable in both groups. The findings suggest that both fixation methods such as miniplates and lag screws are equally effective in maintaining condylar position, allowing choice of technique to be based on surgeon preference and clinical considerations (44).

A finite element analysis study compared stress distribution and stability among three fixation methods following BSSO setback are two bicortical screws, three bicortical screws and a miniplate. Simulated occlusal loading showed that stress concentrated mainly on the fixation units. While bicortical screws provided greater rigidity, they also produced higher stress and displacement. In contrast, miniplates demonstrated the most favorable biomechanical performance, offering effective stabilization with lower stress values. The study concludes that miniplates with monocortical screws represent an appropriate and efficient fixation method for BSSO setback surgery (45).

This retrospective study assessed the clinical and radiographic outcomes of BSSO setback in Class III skeletal patients, with particular focus on TMJ changes. Twenty-five patients aged 18–30 years were assessed before and 6 months after surgery. Although reductions were observed in condylar axial angle, inclination, maximum mouth opening and mandibular movements, these changes were not statistically significant. Radiographically, anterior joint space decreased while posterior joint space increased bilaterally, with significance noted only on the right side. Overall, BSSO setback did not produce significant alterations in condylar position within the glenoid fossa or lead to notable TMJ symptoms, suggesting that the procedure is stable with minimal impact on TMJ function (46).

The influence of fixation technique on TMJ outcomes remains debated. Comparisons between rigid (bicortical) and semi-rigid (monocortical) fixation in BSSO advancement have demonstrated no statistically significant differences in the incidence of postoperative TMJ dysfunction (**Table 3**). However, some reviews suggest that rigid bicortical fixation may exert greater condylar seating forces, theoretically increasing the risk of joint strain whereas monocortical fixation may allow a degree of passive adaptation. Clinically, the difference in symptom outcomes is generally small and preoperative TMJ status appears to be the stronger predictor of prognosis.

Meta-analyses and systematic reviews highlight that OGS can improve TMD symptoms in a substantial proportion of patients but may exacerbate dysfunction in those with established internal derangements, high mandibular plane angles or condylar resorption tendencies. The choice of fixation technique should be individualized are bicortical fixation offers superior skeletal stability whereas monocortical fixation may be preferable in patients with significant pre-existing TMJ pathology to reduce joint loading.

Overall, the relationship between BSSO and TMJ outcomes is complex and influenced by multiple factors. Evidence indicates that while OGS may improve pre-existing TMJ symptoms in a substantial proportion of patients particularly those with low or normal mandibular angle retrognathism, it may also exacerbate dysfunction in individuals with established internal derangements or anatomical predispositions. The role of fixation type, magnitude of mandibular advancement, condylar positioning and individual skeletal morphology continues to be debated, with most studies suggesting that postoperative adaptations generally occur within a clinically acceptable range. Importantly, preoperative TMJ status appears to be a critical determinant of prognosis and patients with symptomatic internal derangements or high mandibular plane angle may remain at risk of persistent dysfunction or condylar resorption despite corrective surgery.

Conclusion

Bilateral sagittal split ramus osteotomy continues to be a cornerstone surgical technique for the correction of mandibular prognathism and retrognathism. Advances in fixation methods have significantly shaped clinical outcomes. Both monocortical and bicortical screw fixation systems offer distinct advantages in terms of stability, cost-effectiveness and intraoperative adaptability. Bicortical screws provide rigid and predictable fixation, whereas monocortical screws are particularly useful in cases with unfavorable splits, large bony defects or when minimizing the risk of condylar torque is critical.

TABLE 3 | Influence of fixation method on temporomandibular joint (TMJ) outcomes after bilateral sagittal split ramus osteotomy.

Fixation method	Advantages	Disadvantages	Implications for TMJ
Bicortical screws	Stronger skeletal stability, lower relapse risk, long-term predictability	More rigid and may transfer stress to condyles	May reduce postoperative condylar displacement, but risk of overloading joints with pre-existing dysfunction
Monocortical miniplates	Allows minor adaptive movements, less stress on condyle, technically easier removal	Slightly higher relapse risk, less rigid fixation	Permits micro-adaptations in condylar position, potentially beneficial in patients with pre-existing TMJ issues

Postoperative stability is a major concern: mandibular advancements generally show better long-term stability than setback, though relapse remains a challenge influenced by factors such as skeletal pattern, magnitude of movement and fixation technique. NSD especially involving the IAN are frequent complications. Minor deficits often recover spontaneously; however, recovery is not always predictable, and persistent deficits may occur, with outcomes influenced by factors such as patient age and the extent of nerve injury. Importantly, patient satisfaction is typically more dependent on functional and aesthetic improvements than on sensory symptoms.

Although the procedure can improve pre-existing TMJ dysfunction, certain patients particularly young adult females and those with a high mandibular plane angle are at an increased risk of postoperative TMJ complications. Careful preoperative assessment and individualized planning are therefore essential.

Recommendations for the surgeon

- Fixation Choice:
  - Prefer bicortical screw fixation for cases requiring rigid stability, especially in advancements or when relapse risk is high.
  - Use monocortical screw fixation in situations with unfavorable splits, large defects, or where condylar seating needs to be preserved.
- Relapse Prevention: Anticipate greater relapse potential in setback procedures and high-angle cases; consider overcorrection or additional stabilization strategies.
- Nerve Safety: Counsel patients that neurosensory recovery is variable and not fully predictable. Younger patients may show better recovery, but severe injuries can lead to long-term deficits.
- TMJ Considerations: Evaluate preoperative TMJ carefully; recognize that patients with pre-existing TMJ dysfunction or risk factors (female sex, high-angle mandibles) may need closer monitoring.
- Patient-Centered Outcomes: Emphasize that overall satisfaction is largely tied to functional bite correction and aesthetic results, rather than minor sensory changes.

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