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Original Article

Long-Term Outcomes of Surgery-First Mandibular Setback and Anterior Segmental Osteotomy in Skeletal Class III Malocclusion

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ABSTRACT

Severe skeletal Class III malocclusion often requires orthognathic surgery to achieve both functional stability and improved quality of life. This study aims to quantitatively evaluate the long-term (>3 years) three-dimensional skeletal stability and patient-reported quality of life (OQLQ) outcomes of a surgery-first approach (SFA) combining anterior segmental osteotomy with bilateral sagittal split osteotomy (SFA-ASO-BSSO) compared to conventional monobloc SFA-BSSO in patients with severe skeletal Class III malocclusion. This retrospective cohort study included 47 adult patients treated with SFA, divided into SFA-ASO-BSSO (n=22) and SFA-Monobloc (n=25). Skeletal displacement and stability were assessed using CBCT scans at four time points (T0–T3), and functional/psychosocial outcomes were evaluated with the 22-item OQLQ at T0, T2, and T3. Postoperatively, spatial displacements of mandibular basal landmarks (B-point, Pogonion, Menton) demonstrated equivalent setbacks in both groups ($p > 0.05$), but the SFA-ASO-BSSO group achieved significantly greater incisor retraction (-11.64 ± 2.85 mm vs -8.12 ± 2.25 mm, $p < 0.001$), reduced surgical compensation (ΔL1-MP: $-11.85 \pm 2.55°$ vs $-1.50 \pm 1.15°$, $p < 0.001$), and lower need for genioplasty (18.18% vs 56.00%, $p = 0.007$). Long-term evaluation confirmed strong skeletal stability in both groups ($p > 0.05$), with the SFA-ASO-BSSO group showing superior esthetic improvement and OQLQ scores at final evaluation ($p \leq 0.001$). Integrating an anterior segmental osteotomy into a surgery-first mandibular setback does not compromise long-term skeletal stability. Furthermore, it yields superior immediate surgical decompensation, aesthetic soft-tissue adaptation, and patient-reported outcomes compared to the conventional monobloc technique in severe Class III cases.

Keywords: Skeletal Class III malocclusion, Surgery-first approach (SFA), Anterior segmental osteotomy (ASO), Mandibular setback, Skeletal stability, Orthognathic quality of life (OQLQ)

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Introduction

Severe skeletal Class III malocclusion accompanied by dentoalveolar protrusion is a complex craniofacial deformity that profoundly impairs both masticatory function and psychosocial well-being. While the conventional orthodontics-first approach (OFA) has long been the standard, the surgery-first approach (SFA) has rapidly gained momentum as a paradigm-shifting option in modern orthognathic practice [1, 4]. By eliminating the presurgical orthodontic phase, SFA capitalizes on the regional acceleratory phenomenon (RAP) to reduce total treatment time and provides immediate resolution of facial aesthetics, thereby significantly enhancing early patient satisfaction [5-8]. In the management of standard mandibular prognathism, the single-piece (monobloc) bilateral sagittal split osteotomy (BSSO) setback is considered highly predictable and biomechanically stable [9-11]. However, in patients presenting with severe anterior mandibular protrusion and dental crowding, isolated BSSO is often insufficient to retract the prominent lower lip. Such cases necessitate multisegmental approaches, specifically the mandibular anterior segmental osteotomy (ASO) combined with BSSO and bilateral premolar extractions, to maximize posterior dentoalveolar retraction [12]. Historically, multisegmental osteotomies of the jaws have been viewed with surgical caution due to presumed increased risks of vascular compromise, fixation instability, and unpredictable sagittal relapse [13-16].

Applying the SFA concept to combined ASO-BSSO procedures amplifies these biomechanical concerns. The lack of presurgical dental decompensation creates a transitional, unstable occlusal interface immediately post-surgery, which theoretically increases the susceptibility of the mobilized anterior segment to postoperative muscular tension and occlusal forces [17, 18]. Although recent literature has begun to explore the outcomes of segmental osteotomies, robust longitudinal evidence remains remarkably scarce [19-21]. Furthermore, contemporary surgical literature increasingly demands the integration of objective anatomical stability with subjective Patient-Reported Outcome Measures (PROMs), such as the Orthognathic Quality of Life Questionnaire (OQLQ), to provide a holistic measure of clinical success [22-25].

Therefore, a fundamental research question remains: Does the integration of ASO into an SFA mandibular setback compromise long-term 3D skeletal stability and quality of life when compared to conventional monobloc SFA BSSO? This retrospective cohort study aimed to quantitatively evaluate the long-term skeletal stability (over 3 years of follow-up) and the OQLQ-based functional outcomes of patients undergoing SFA-ASO-BSSO versus SFA-monobloc BSSO for Class III correction. The study hypothesized that the segmental SFA approach yields comparable long-term skeletal stability and superior aesthetic satisfaction relative to the conventional monobloc technique.

Materials and Methods

Study design and ethical considerations

This retrospective cohort study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki: Independent Ethics Committee IEC, Tra Vinh University (Ref. no. 185/GCN.ĐC-HĐĐ); and the IEC of Van Hanh General Hospital (Ref. no. 01/2025/GCN-HĐĐ). The study protocol received formal approval from the Institutional Review Board. Following a Surgery-First Approach (SFA) protocol, the study aimed to evaluate the long-term (>3 years) skeletal stability and Patient-Reported Outcome Measures (PROMs) of two distinct surgical interventions.

Patient selection and allocation

The study population comprised adult patients with severe skeletal Class III malocclusion accompanied by dentoalveolar protrusion, treated consecutively at a single maxillofacial center. Patients were stratified into two cohorts based on the surgical intervention: the SFA-ASO-BSSO group (anterior segmental osteotomy combined with bilateral sagittal split osteotomy and bilateral lower premolar extractions) and the SFA-monobloc BSSO control group. To ensure adequate statistical power to detect clinically significant skeletal relapse (defined as a spatial deviation ≥ 1.0 mm), an a priori power analysis was conducted using G*Power (version 3.1.9). Based on a predetermined effect size of 0.80, an alpha error probability of 0.05, and a power of 90%, a minimum of 20 subjects per group was required. To account for potential data attrition over the long-term follow-up, the recruitment target was adjusted accordingly.

Inclusion criteria were defined as: (1) age $\geq$ 18 years; (2) severe skeletal Class III discrepancy (ANB < 0°); (3) treatment executed strictly via an SFA protocol without presurgical orthodontic decompensation; (4) availability of complete cone-beam computed tomography (CBCT) records up to a minimum of 3 years postoperatively; and (5) completed Orthognathic Quality of Life Questionnaire (OQLQ) assessments. Patients presenting with craniofacial syndromes, cleft lip/palate, active temporomandibular joint disorders (TMD), or previous facial trauma were strictly excluded to prevent anatomical confounding.

Surgical protocol and bias elimination

To eliminate the surgeon's experience as a confounding variable, all procedures were performed by the same senior surgical team utilizing identical virtual surgical planning (VSP) workflows. The BSSO was performed using the modified Hunsuck/Epker technique, and all osteotomies were stabilized with rigid internal fixation (RIF) using titanium miniplates to ensure uniform biomechanical resistance to muscular strain.

To isolate intrinsic surgical stability from extrinsic orthodontic interference, a standardized bias-elimination protocol was implemented during the immediate postoperative phase. Passive rectangular stainless steel archwires were maintained without active retraction forces or heavy intermaxillary elastics during the initial healing period, thereby neutralizing active orthodontic mechanics as a confounding variable for sagittal relapses.

Long-term outcome and stability

Skeletal stability and spatial displacements were quantified using high-resolution CBCT scans acquired at four specific intervals: T0 (preoperative), T1 (immediate postoperative, within 1 week), T2 (1 year postoperative), and T3 (long-term follow-up, >3 years). Voxel-based regional superimposition was performed on the stable anterior cranial base utilizing Dolphin 3D imaging software. To precisely evaluate the directional movements of the mandibular segments, a standardized spatial coordinate reference system was established. The X-axis (anteroposterior dimension) was defined as a plane parallel to the Frankfort Horizontal (FH) plane. The Y-axis (superoinferior dimension) was constructed as a line perpendicular to the X-axis (FH plane) passing through the Sella (S) point.

The exact spatial displacements (T0–T1) and subsequent long-term relapse patterns (T1–T3) of key distal mandibular landmarks-specifically B-point, Pogonion (Pog), Menton (Me), and the lower incisor tip (L1)-were computed along these defined X and Y coordinates. Additionally, the lower incisor to mandibular plane (L1-MP) angle was measured to assess the extent of surgical dentoalveolar decompensation and postoperative orthodontic tipping.

Quality of life assessment (OQLQ)

Functional and psychosocial outcomes were evaluated using the validated 22-item OQLQ. Patients completed the survey at T0 and T3. The questionnaire assessed four distinct domains: social aspects of deformity, facial aesthetics, oral function, and awareness of facial deformity. Responses were recorded on a 4-point Likert scale, with lower summary scores indicating a superior oral health-related quality of life (OHRQoL).

Statistical analysis

All statistical analyses were executed using SPSS (version 25.0). To evaluate intra-examiner and inter-examiner reliability in anatomical landmark identification, 20 randomly selected CBCT scans were retraced after a 2-week interval, and the Intraclass Correlation Coefficient (ICC), alongside Dahlberg's formula, was calculated.

The Shapiro-Wilk test confirmed the normality of continuous variables. Baseline demographic and surgical magnitude equivalences between the two cohorts were assessed using independent Student's T-tests or Mann-Whitney U tests. To analyze the longitudinal trajectory of skeletal stability and OQLQ scores across time points, repeated-measures Analysis of Variance (ANOVA) and Generalized Estimating Equations (GEE) were employed, adjusting for covariates such as the magnitude of surgical setback and initial occlusal parameters. The significance level was strictly set at $p < 0.05$.

Results and Discussion

The baseline data analysis **(Table 1)** demonstrated high homogeneity in skeletal characteristics and psychosocial status between the two study cohorts. Mean age and long-term follow-up duration were statistically equivalent between the SFA-ASO-BSSO and SFA-Monobloc groups ($p > 0.05$). Regarding the severity of the Class III skeletal discrepancy, no statistically significant intergroup differences were recorded across core cephalometric indices, including SNA, SNB, and ANB angles ($p > 0.05$). Correspondingly, the degree of preoperative psychosocial impairment was comparable, as evidenced by the total Orthognathic Quality of Life Questionnaire (OQLQ) scores (58.42 vs 56.95, p = 0.534) and the Facial Aesthetics domain scores (24.15 vs 23.85, $p = 0.764$). The dataset revealed a highly significant divergence ($p < 0.001$) within the anterior dentoalveolar region. The SFA-ASO-BSSO cohort exhibited substantially more severe lower incisor proclination, characterized by a markedly increased L1-MP angle *(104.25 ± 4.12°)* compared to the SFA-Monobloc cohort *(92.14 ± 3.84°)*. This pronounced dental inclination precipitated consequent soft-tissue alterations, wherein the lower lip protrusion relative to the E-line (LL–E-line) in the ASO group *(5.85 ± 1.55 mm)* was more than twice that of the conventional monobloc BSSO group *(2.65 ± 1.34 mm)*.

Table 1. Baseline demographic, cephalometric characteristics, and OQLQ presurgery (T0)

Variable	SFA-ASO-BSSO (n = 22) Mean ± SD	SFA-Monobloc (n = 25) Mean ± SD	*p*-value
Age (years)	24.15 ± 4.21	23.82 ± 3.95	0.781
Follow-up duration (months)	46.12 ± 5.84	44.25 ± 5.41	0.254
SNA (°)	80.45 ± 3.12	80.68 ± 2.94	0.795
SNB (°)	84.72 ± 2.85	84.15 ± 3.01	0.528
ANB (°)	-4.27 ± 1.45	-3.47 ± 1.62	0.082

L1-MP Angle (°)	104.25 ± 4.12	92.14 ± 3.84	*<0.001**
LL- E-line (mm)	5.85 ± 1.55	2.65 ± 1.34	*<0.001**
OQLQ: Facial Aesthetics	24.15 ± 3.42	23.85 ± 3.55	0.764
Total OQLQ Score	58.42 ± 8.15	56.95 ± 7.82	0.534

* Data are presented as Mean ± Standard Deviation (SD).
p-values were derived from independent Student's t-tests. $p < 0.05$ indicates statistical significance.
L1-MP: Lower incisor to mandibular plane angle; LL- E-line: Lower Lip to E-line.

The immediate postoperative evaluation (T0-T1) **(Table 2)** showed that the displacements of the mandibular basal landmarks, including B-point, Pogonion (Pog), and Menton (Me), were statistically equivalent between the two cohorts in both the X-axis (anteroposterior) and Y-axis (superior-inferior) dimensions (*p* > 0.05). Both groups achieved a comparable posterior setback ranging from *-8.12 mm* to *-8.95 mm*, accompanied by a slight inferior displacement of approximately *1.15 mm to 1.65 mm*. In contrast, a significant divergence was observed at the dentoalveolar level. The SFA-ASO-BSSO group exhibited a substantially greater posterior retraction of the lower incisors *(L1 tip X-axis: -11.64 ± 2.85 mm)* compared to the SFA-Monobloc group *(-8.12 ± 2.25 mm, p < 0.001)*. The ASO cohort experienced a massive reduction in the lower incisor inclination *(Change in L1-MP Angle: -11.85 ± 2.55°)*, effectively up righting the teeth, whereas the Monobloc group presented minimal angular alteration *(-1.50 ± 1.15°, p < 0.001)*. Parallel to these dentoalveolar trends, the incidence of adjunctive genioplasty to optimize the final facial contour varied notably; only *18.18%* of patients in the ASO group required this concurrent procedure, which was significantly lower than the *56.00%* recorded in the Monobloc group (*p* = 0.007).

Table 2. Surgical Displacements (T0-T1) and Genioplasty Incidence

Variable	SFA-ASO-BSSO (n = 22)	SFA-Monobloc (n = 25)	*p*-value
Adjunctive Genioplasty, n (%)	4 (18.18%)	14 (56.00%)	*0.007**
B-point (X-axis, mm)	-8.45 ± 2.15	-8.12 ± 2.08	0.584
B-point (Y-axis, mm)	1.15 ± 0.95	1.25 ± 0.88	0.705
Pogonion (Pog) (X-axis, mm)	-8.72 ± 2.45	-8.35 ± 2.31	0.592
Pogonion (Pog) (Y-axis, mm)	1.35 ± 1.05	1.42 ± 1.12	0.825
Menton (Me) (X-axis, mm)	-8.95 ± 2.50	-8.62 ± 2.41	0.648
Menton (Me) (Y-axis, mm)	1.55 ± 1.15	1.65 ± 1.25	0.776
L1 tip Retraction (X-axis, mm)	-11.64 ± 2.85	-8.12 ± 2.25	*<0.001**
Change in L1-MP Angle (°)	-11.85 ± 2.55	-1.50 ± 1.15	*<0.001**

Negative X-axis values indicate posterior displacement; Positive Y-axis values indicate inferior displacement.
*Genioplasty rate evaluated via Pearson Chi-square test: $p < 0.05$ indicates statistical significance

Following the immediate postoperative changes, the longitudinal assessment **(Table 3)** revealed distinct patterns of skeletal stability, soft-tissue adaptation, and patient satisfaction over the >3-year follow-up period. Within-group analyses using paired t-tests indicated that the vast majority of hard-tissue relapses occurred during the first postoperative year (T2–T1). There was no statistically significant progressive relapse from year 1 to the final follow-up (T3–T1) across all X-axis (anteroposterior) and Y-axis (superoinferior) spatial coordinates for both the SFA-ASO-BSSO and SFA-Monobloc groups (*p* > 0.05). The L1-MP angle, lower lip position, and OQLQ scores similarly demonstrated robust intra-group stability over time, with no significant deterioration occurring after the first year. Despite the equivalent hard-tissue stability, highly significant inter-group divergences were observed in soft-tissue and subjective outcomes. The SFA-ASO-BSSO group exhibited a significantly superior and sustained reduction in lower lip position relative to the E-line (*p* < 0.001) compared to the conventional BSSO group. Concordantly, the ASO cohort consistently reported significantly better (lower) scores in both the OQLQ Facial Aesthetics domain and Total OQLQ Score at all respective follow-up intervals *(p < 0.001)*.

Table 3. Comparison of Intra-group Relapse Progression and Inter-group Long-Term Outcomes

Parameter	SFA-ASO-BSSO (n = 22)	SFA-Monobloc (n = 25)	Between-Group *p*-value**

	T2–T1	T3–T1	*p*-value*	T2–T1	T3–T1	*p*-value*	T2–T1	T3–T1
B-point (X-axis, mm)	0.55 ± 0.35	0.65 ± 0.42	0.412	0.62 ± 0.30	0.71 ± 0.38	0.358	0.475	0.612
B-point (Y-axis, mm)	-0.25 ± 0.20	-0.32 ± 0.25	0.320	-0.22 ± 0.18	-0.28 ± 0.21	0.285	0.598	0.556
Pogonion (X-axis, mm)	0.68 ± 0.40	0.78 ± 0.45	0.435	0.75 ± 0.38	0.85 ± 0.41	0.374	0.542	0.584
Pogonion (Y-axis, mm)	-0.32 ± 0.28	-0.41 ± 0.32	0.334	-0.28 ± 0.24	-0.35 ± 0.28	0.342	0.605	0.489
Menton (X-axis, mm)	0.72 ± 0.38	0.81 ± 0.40	0.456	0.78 ± 0.42	0.88 ± 0.44	0.418	0.620	0.565
Menton (Y-axis, mm)	-0.38 ± 0.30	-0.45 ± 0.35	0.481	-0.31 ± 0.26	-0.38 ± 0.31	0.389	0.408	0.468
L1-MP Angle (°)	0.75 ± 0.48	0.85 ± 0.52	0.505	0.58 ± 0.41	0.65 ± 0.45	0.562	0.204	0.165
Lower Lip to E-line (mm)	-1.75 ± 1.10	-1.65 ± 1.15	0.772	0.35 ± 0.85	0.45 ± 0.90	0.685	*<0.001**	*<0.001**
OQLQ: Facial Aesthetics	-12.70 ± 2.85	-12.91 ± 2.90	0.804	-9.73 ± 2.40	-10.00 ± 2.55	0.710	*<0.001**	*0.001**
Total OQLQ Score	-23.05 ± 5.42	-23.26 ± 5.60	0.825	-17.45 ± 4.81	-17.75 ± 4.95	0.781	*<0.001**	*0.001**

*p-values derived from paired t-tests comparing T2–T1 vs. T3–T1 changes within the same group.
** p-values derived from independent Student's t-tests comparing SFA-ASO-BSSO and SFA-Monobloc groups at respective follow-up intervals.
$p < 0.05$ indicates statistical significance.

The core clinical challenge in severe skeletal Class III patients is the natural dentoalveolar compensation, characterized by severe lower incisor retroclination (acute L1-MP angle) [24, 26, 27]. In a conventional monobloc SFA setback, this acute angulation physically restricts the magnitude of posterior mandibular displacement and leaves the lower lip protrusive, often necessitating an adjunctive reduction genioplasty for camouflage [9, 19, 28]. The biomechanical advantage of the ASO lies in its capacity for immediate surgical decompensation. By isolating and posteriorly retracting the anterior dentoalveolar segment (evidenced by the massive L1 tip retraction of -11.64 mm in **Table 2**), surgeons can upright the lower incisors (L1-MP angle correction of -11.85°) and maximize lower lip retraction independently of the basal bone [29-32]. This mechanism directly explains the significantly reduced reliance on adjunctive genioplasty in the SFA-ASO-BSSO cohort (18.18%) compared to the monobloc group (56.00%). This aligns with the long-term retrospective data by Yong *et al*. (2023), which emphasized the indispensable role of mandibular ASO in maximizing lower lip retraction for protrusive Southeast Asian profiles without over-relying on chin-contouring adjuncts [19].

Multisegmental mandibular osteotomies have raised concerns about fixation instability and unpredictable sagittal relapse [33]. However, the long-term anterior drift (X-axis relapses) at key basal landmarks (B-point, Pogonion, and Menton) in this study ranged from +0.65 to +0.81 mm and was statistically equivalent between the segmental and monobloc cohorts. Intra-group analyses demonstrated that the vast majority of hard-tissue relapses occurred within the first 12 months post-surgery (T1–T2), with robust stability maintained through the >3-year mark (T2–T3). When compared with the existing literature on conventional monobloc SFA BSSO, the segmental approach demonstrates superior mechanical stability. For instance, Kim *et al*. (2014) reported a significantly greater mean anterior relapse of 2.4 mm in patients undergoing conventional SFA mandibular setback without segmentation [34]. Furthermore, a comprehensive meta-analysis by Wei *et al*. (2018) and Barone *et al*. highlighted that standard SFA BSSO procedures yield a pooled horizontal relapse of 1.50 mm, predominantly driven by postoperative counterclockwise mandibular rotation and muscular strain [35-37]. The SFA-ASO-BSSO cohort restricted long-term sagittal relapse to under 1.0 mm, markedly lower than the 1.50–2.40 mm range frequently reported for monobloc SFA setbacks, which proves that structurally segmenting the anterior mandible does not weaken the overall BSSO construct [38].

The ultimate determinant of orthognathic success is the patient's psychosocial recovery. The SFA inherently bypasses the prolonged phase of facial deterioration associated with presurgical orthodontic decompensation, providing immediate aesthetic benefits [24]. While both surgical modalities substantially improved the total OQLQ scores, the SFA-ASO-BSSO group reported significantly better (lower) scores in the "Facial Aesthetics" domain (-12.91 vs. -10.00 at T3) and achieved superior Lower Lip to E-line reduction. This subjective superiority is the direct clinical translation of the optimized soft-tissue draping achieved by the segmental technique [24, 30, 39].

Several limitations must be acknowledged. The retrospective design introduces an inherent selection bias, as surgical allocation was determined by baseline severity of dentoalveolar decompensation (L1-MP angle). Additionally, while distal segment stability was confirmed, this study did not evaluate the rotational alterations of the proximal segments or temporomandibular joint (TMJ) condylar remodeling, which are critical variables influencing late skeletal relapse. Future prospective, randomized controlled trials incorporating voxel-based 3D condylar volumetric analysis and long-term pharyngeal airway space evaluations are essential to map the physiological impact of the SFA-ASO-BSSO protocol comprehensively.

Conclusion

The findings of this long-term retrospective cohort study validate our primary hypothesis: the integration of an anterior segmental osteotomy into SFA BSSO does not compromise long-term skeletal stability. Furthermore, it yields superior aesthetic and functional outcomes (as measured by OQLQ) compared with the conventional monobloc SFA BSSO in patients with severe skeletal Class III malocclusion and dentoalveolar compensation.

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