Original Article

A TWO-YEAR COMPARATIVE STUDY ON SKELETAL STABILITY OF MONOBLOCK VERSUS ANTERIOR SEGMENT LE FORT I OSTEOTOMY

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ABSTRACT

Severe maxillary protrusion often requires Le Fort I osteotomy, either as a monobloc or two-piece segmental approach. Comparative evidence on their long-term skeletal stability remains limited. This study aimed to quantitatively compare the long-term skeletal stability of monoblock versus two-piece segmental Le Fort I osteotomy in patients with severe maxillary protrusion. A longitudinal comparative study was conducted on 70 patients (35 monoblock; 35 2-piece segmental). All subjects underwent virtual surgical planning (VSP) for maxillary setback and impaction. Skeletal stability was evaluated using lateral cephalograms at five standardized intervals over 24 months. Measurements focused on the horizontal and vertical positions of the A-point and maxillary central incisor. The results showed that the monoblock group followed a traditional recovery path, exhibiting a minor anterior relapse (+0.84 ± 0.38 mm at 2 years), with the jaw moving slightly forward toward its original position. The 2-piece segmental group demonstrated a pattern referred to here as "posterior drift", continuing to move backwards by an average of -0.52 ± 0.29 mm at the 2-year mark. Statistical testing showed a very large Time × Group interaction effect ($\eta_p^2 = 0.81$, $p < 0.001$), suggesting that surgical technique may be associated with differences in stability rather than random variation alone. The study indicates that two-piece Le Fort I segments are particularly prone to further posterior displacement after surgery, possibly due to compressive forces from the surrounding soft-tissue environment. These findings might inform clinicians to consider this tendency during treatment planning to minimize relapse risk.

Key words: Le Fort I osteotomy, Segmental osteotomy, Skeletal stability, Posterior drift, Biomechanics, Maxillary protrusion.

Introduction

Maxillary protrusion associated with excessive gingival display (vertical maxillary excess) is a prevalent craniofacial deformity, particularly characterizing the Asian population [1-3]. In Vietnam, cephalometric analyses reveal that patients frequently exhibit significantly greater dentoalveolar protrusion and lip prominence compared to Caucasian norms, often accompanied by a shorter cranial base and facial height [2, 4]. Such severe discrepancies necessitate substantial surgical posterior setback and superior repositioning (impaction) of the maxilla to optimize facial esthetics and oral health-related quality of life [5, 6]. While the conventional monoblock Le Fort I osteotomy remains the standard for maxillary repositioning [7-10], severe cases often require a 2-piece segmental Le Fort I osteotomy combined with bilateral premolar extractions during surgery. This segmental approach allows for maximal posterior retraction of the anterior maxillary segment directly into the extraction spaces, effectively resolving the prominent lip profile characteristic of this demographic [11-13].

According to Proffit's hierarchy of surgical stability, maxillary superior repositioning is considered highly stable [14-16]. However, dividing the maxilla into multiple segments raises valid concerns regarding the increased risk of postoperative relapse [17, 18]. A prospective analysis by Ismail *et al*. (2017) demonstrated that segmental Le Fort I osteotomies exhibit a higher relapse rate compared to monoblock procedures in patients with anterior open bite (AOB), primarily due to the continuous protrusive forces exerted by the tongue on the mobilized anterior segment [19, 20]. Conversely, the biomechanical environment in patients with maxillary protrusion is fundamentally different; the profoundly retracted anterior segment is subjected to significant compressive resistance from the circumoral musculature and the upper lip [21-23].

This gap in the literature formulates the core research question: Does the 2-piece segmental Le Fort I osteotomy with extractions provide comparable long-term skeletal stability to the conventional monoblock Le Fort I osteotomy in patients with maxillary protrusion, and can the observed differences be interpreted in relation to perioral soft tissue conditions? Therefore, this study aims to quantitatively compare the skeletal stability (sagittal and vertical relapse) between monoblock and 2-piece segmental Le Fort I osteotomies. Evaluations will be conducted at five standardised time points: preoperatively (T0), immediately postoperatively (T1), 6 month follow-up (T2), a year follow-up (T3) and at a 2-year follow-up (T4).

Materials and Methods

A retrospective cohort study was conducted with Institutional Review Board approval, in accordance with the Declaration of Helsinki. The sample comprised adult Vietnamese patients diagnosed with maxillary protrusion and excessive gingival display. The inclusion criteria were: (1) treatment involving either a monoblock Le Fort I osteotomy or a 2-piece segmental Le Fort I osteotomy with bilateral premolar extractions; (2) rigid internal fixation (RIF) with titanium miniplates; and (3) availability of complete, high-quality lateral cephalograms at five standardized follow-up intervals. Patients with craniofacial syndromes, severe asymmetrical or previous facial trauma were excluded. To establish the comparative cohorts, eligible patients were assigned to two groups according to the surgical protocol indicated by clinical and orthodontic considerations; this non-randomised allocation may introduce selection bias:

- *Monoblock Group:* Patients who underwent a conventional single-piece Le Fort I osteotomy, typically following comprehensive preoperative orthodontic space closure.
- *2-Piece Segmental Group:* Patients who received a 2-piece segmental Le Fort I osteotomy accompanied by bilateral maxillary first premolar extractions during the surgical intervention, allowing for immediate and maximum posterior retraction of the anterior segment.

An a priori sample size estimation was performed using G*Power software (Version 3.1.9.4; Heinrich-Heine-Universität, Düsseldorf, Germany). Based on the primary outcome measure - horizontal maxillary relapse at A-point - derived from previous segmental stability reports, an anticipated large effect size of 0.8 (Cohen's d) was assumed. To achieve a statistical power of 80% at a 95% significance level ($\alpha = 0.05$) for a two-tailed independent t-test, a minimum of 26 participants per group was mathematically required. Accounting for a potential radiographic distortion or follow-up attrition rate of approximately 25%, the final sample size was upwardly adjusted to 35 patients per cohort (total N = 70), ensuring robust statistical validity to detect clinically meaningful biomechanical differences.

While the primary outcome measurements relied on 2D cephalometry, three-dimensional (3D) Cone-Beam Computed Tomography (CBCT) was utilised strictly for preoperative visualisation and Virtual Surgical Planning (VSP). The DICOM data were imported into surgical planning software to virtually simulate osteotomies, resolve bony interferences, and fabricate the intermediate and final CAD/CAM surgical splints. This protocol ensured surgical precision and execution without overcomplicating the longitudinal stability analysis. Radiographs were obtained at five standardised time points: T0 - Preoperative (within 1 month prior to surgery); T1 - Immediate postoperative (within 1 week after surgery); T2 - 6 months postoperative; T3 - 1 year postoperative; and T4 - 2 years postoperative.

To accurately quantify the skeletal displacements and longitudinal stability of the isolated maxillary segments, sequential 2D lateral cephalograms were analysed at five specific time points: preoperative (T0), immediate postoperative (T1), 6 months (T2), 1 year (T3), and 2 years (T4). A standardised Cartesian coordinate system was established to evaluate surgical movements and postoperative relapse. The horizontal reference plane (X-axis) was defined by the Frankfort Horizontal (FH) plane, passing through Porion (Po) and Orbitale (Or). The vertical reference plane (Y-axis) was constructed as a line perpendicular to the X-axis passing through the Sella (S) point. To assess the distinct biomechanical behaviours of the segmented maxilla, the following core anatomical landmarks were digitized:

- *Anterior Segment*: A-point, Anterior Nasal Spine (ANS), and the incisal edge of the upper central incisor (U1).
- *Posterior Segment*: Posterior Nasal Spine (PNS) and the mesiobuccal cusp of the maxillary first molar (UM).

Surgical movement was calculated as the coordinate difference between T1 and T0. Postoperative skeletal relapse was defined as geometric alterations at subsequent time points (T2-T1, T3-T1, and T4-T1). Sagittal relapse was determined by the changes in the perpendicular distance from the landmarks to the Y-axis (X-coordinate), whereas vertical relapse was measured by the changes in the perpendicular distance to the X-axis (Y-coordinate).

Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Intra-examiner reliability was assessed using the Intraclass Correlation Coefficient (ICC) and Dahlberg's formula. Data normality was verified via the Shapiro-Wilk test. Baseline categorical variables (e.g., gender) were compared using the Chi-square test. Independent Student's t-tests were used to compare the magnitude of surgical movements and skeletal relapses between the monoblock and 2-piece segmental groups at specific time points, with effect sizes reported as Cohen's d. To evaluate the longitudinal relapse trajectory from T1 to T4, Repeated-Measures ANOVA with a Greenhouse-Geisser correction was employed. The primary focus was the Time × Group interaction to determine if the relapse patterns differed significantly between the two surgical techniques. The magnitude of this interaction was quantified using Partial Eta Squared (η_p^2). A p-value < 0.05 was considered statistically significant.

Results and Discussion

Table 1 summarises the baseline demographic and cephalometric parameters of the 70 enrolled patients (35 in the Monoblock group and 35 in the 2-Piece Segmental group). The mean age was 24.12 ± 4.38 years in the

Monoblock cohort and 23.67 ± 3.92 years in the 2-Piece cohort, with no significant difference (p = 0.651). Gender distribution was also comparable between the two surgical groups (p = 0.584). Regarding the skeletal and dental patterns, both cohorts showed broadly comparable preoperative morphologies characteristic of severe maxillary protrusion. Specifically, the severity of the malocclusion was demonstrated by a markedly increased mean overjet (8.76 ± 1.92 mm vs. 9.04 ± 2.18 mm; p = 0.572) and a steep ANB angle (8.41 ± 2.16° vs. 8.68 ± 2.34°; p = 0.614). Statistical evaluation using independent Student's t-tests yielded p-values greater than 0.47 for all continuous craniofacial variables (SNA, ANB, overjet, overbite, and U1-SN), indicating no statistically significant differences between the two groups at T0.

Table 1. Preoperative Demographic and Cephalometric Characteristics of the Study Population (T0)

Variables	Monoblock Le Fort I (n=35)	2-Piece Segmental (n=35)	Mean Diff. (95% CI)	p-value	Cohen's d
Age (years)	24.12 ± 4.38	23.67 ± 3.92	0.45 (-1.53 to 2.43)	0.651	0.11
Gender (M/F)	11 / 24	9 / 26	N/A	0.584*	N/A
SNA (°)	86.84 ± 3.27	87.31 ± 3.52	-0.47 (-2.09 to 1.15)	0.562	0.14
ANB (°)	8.41 ± 2.16	8.68 ± 2.34	-0.27 (-1.34 to 0.80)	0.614	0.12
Overjet (mm)	8.76 ± 1.92	9.04 ± 2.18	-0.28 (-1.26 to 0.70)	0.572	0.14
Overbite (mm)	4.82 ± 1.64	5.11 ± 1.76	-0.29 (-1.10 to 0.52)	0.478	0.17
U1 to SN (°)	115.63 ± 6.41	116.38 ± 6.72	-0.75 (-3.88 to 2.38)	0.633	0.11

Values are presented as Mean ± Standard Deviation (SD).
CI: Confidence Interval; SNA: Sella-Nasion-A point angle; ANB: A point-Nasion-B point angle.
p-values for continuous variables were derived from independent Student's t-tests.
* p-value for categorical data (gender) was calculated using the Chi-square test. Effect sizes are expressed as Cohen's d (small: 0.2, medium: 0.5, large: 0.8). Statistical significance was set at $p < 0.05$.

Table 2 details the magnitude and direction of the surgical displacements (T0-T1) to verify that comparable surgical vectors were applied to both cohorts. The data reveal a uniform pattern of substantial posterior setback and superior impaction required to resolve the severe maxillary protrusion, with the Monoblock and 2-Piece Segmental groups experiencing an anterior retraction at A-point of -6.42 ± 1.34 mm and -6.78 ± 1.51 mm, respectively, alongside pronounced vertical impactions of -4.27 ± 1.18 mm and -4.41 ± 1.23 mm. At the dentoalveolar level, the maxillary central incisor (U1) tips underwent massive retractions exceeding 7 mm in both groups (-7.21 ± 1.48 mm vs. -7.63 ± 1.62 mm; p = 0.263) to effectively reduce the prominent lip profile.

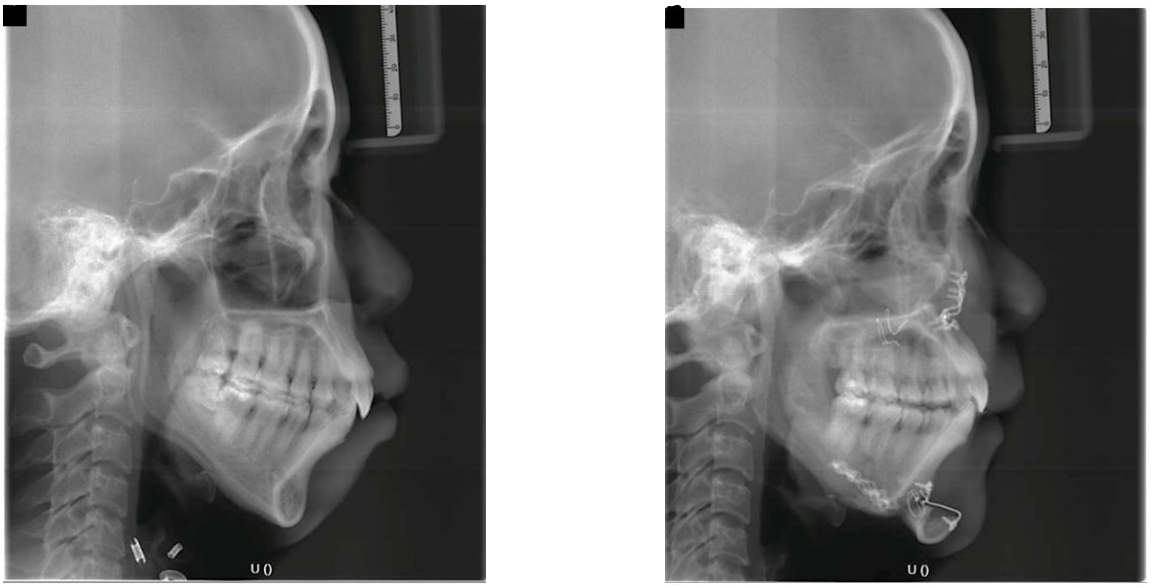
Clinically, in the illustrative case (**Figures 1 and 2**), this skeletal retraction directly translated into a dramatic aesthetic improvement in the facial profile, successfully resolving severe soft-tissue protrusion and excessive gingival display. Statistical evaluation utilising independent Student's t-tests confirmed no significant differences in the surgical movements across all assessed landmarks, including the posterior nasal spine (PNS) and the maxillary first molar (UM) (all $p > 0.26$). Furthermore, the calculated Cohen's d effect sizes were uniformly small ($d < 0.30$), validating that the magnitude of surgical intervention was highly consistent across the two techniques. This quantitative equivalence is methodologically crucial, as it minimises the influence of surgical magnitude as a confounder, suggesting that subsequent disparities in long-term skeletal stability may be associated with the inherent biomechanical properties of the segmented versus non-segmented constructs.

A highly significant Time and Group interaction was observed in the sagittal dimension for the anterior segment ($p < 0.001$, $\eta_p^2 = 0.81$) from **Table 3**. The Monoblock cohort demonstrated a conventional pattern of minor anterior relapse by T4, evidenced by an anterior drift at the A-point (+0.84 ± 0.36 mm) and the U1 tip (+1.02 ± 0.45 mm). Conversely, the 2-Piece Segmental group exhibited a distinctly different trajectory; the anterior segment underwent a continuous posterior drift, moving counter to the expected relapse vector (A-point: -0.52 ± 0.28 mm; U1 tip: -0.76 ± 0.38 mm at T4). In contrast, vertical stability at A-point, as well as the spatial stability of the posterior segments (PNS and UM), remained statistically comparable between the two surgical techniques across all intervals (p = 0.482, $\eta_p^2 = 0.06$ for A-point vertical relapse; p = 0.615, $\eta_p^2 = 0.04$ for the posterior segment). Ultimately, data from **Table 3** confirm that while anterior segmentation fundamentally alters the sagittal biomechanical response potentially influenced by soft tissue factors, it does not compromise the vertical stability of the maxillary impaction.

Table 2. Magnitude of Surgical Displacements (T0-T1)

Landmark Coordinate	Monoblock Group (n=35)	2-Piece Group (n=35)	Mean Diff. (95% CI)	p-value	Cohen's d
A-point Sagittal (X-coord, mm)	-6.42 ± 1.34	-6.78 ± 1.51	0.36 (-0.32 to 1.04)	0.291	0.25
A-point Vertical (Y-coord, mm)	-4.27 ± 1.18	-4.41 ± 1.23	0.14 (-0.43 to 0.71)	0.624	0.12
U1 Tip Sagittal (X-coord, mm)	-7.21 ± 1.48	-7.63 ± 1.62	0.42 (-0.32 to 1.16)	0.263	0.27
PNS Vertical (Y-coord, mm)	-2.58 ± 0.92	-2.71 ± 1.04	0.13 (-0.34 to 0.60)	0.578	0.13
UM Sagittal (X-coord, mm)	-5.94 ± 1.22	-6.12 ± 1.36	0.18 (-0.43 to 0.79)	0.556	0.14

Negative (-) values denote posterior (X-axis) or superior (Y-axis) surgical movements; positive (+) values denote anterior or inferior movements.
SD: Standard Deviation; CI: Confidence Interval.
Inter-group comparisons were performed using independent Student's t-tests. Statistical significance was set at $p < 0.05$.



a) b)

Figure 1. Lateral cephalograms of a 22-year-old female with skeletal Class II malocclusion characterised by mandibular retrusion, excessive gingival display, and maxillary protrusion. (a) Preoperative radiograph. (b) Lateral cephalogram after bimaxillary surgery, including posterior retraction of the anterior maxillary segment and BSSO mandibular advancement with genioplasty.

a) b)

c) d)

e) f)

Figure 2. Facial photographs of a 22-year-old female with skeletal Class II malocclusion characterised by mandibular retrusion, excessive gingival display, and maxillary protrusion. (A, B) Frontal view preoperatively (left) and postoperatively (right). (C, D) Frontal view with smile preoperatively (left) and postoperatively (right); (E, F) 90-degree profile preoperatively (left) and postoperatively (right).
*The use and publication of all participant images in this study were explicitly authorized through written informed consent.

Table 3. Longitudinal Skeletal Relapse Trajectory

Spatial Dimension / Time Point	Monoblock Group (Mean ± SD)	2-Piece Group (Mean ± SD)	Inter-group Mean Diff.	Inter-group p-value*
A. ANTERIOR SEGMENT - SAGITTAL RELAPSE (X-coordinate)				
A-point at T2 (6 months)	+0.48 ± 0.27 mm	-0.24 ± 0.19 mm	0.72 mm	< 0.001
A-point at T3 (1 year)	+0.71 ± 0.32 mm	-0.41 ± 0.24 mm	1.12 mm	< 0.001
A-point at T4 (2 years)	+0.84 ± 0.36 mm	-0.52 ± 0.28 mm	1.36 mm	< 0.001
U1 Tip at T4 (2 years)	+1.02 ± 0.45 mm	-0.76 ± 0.38 mm	1.78 mm	< 0.001
Intra-group trend (p-value)†	< 0.001	< 0.001	Interaction:	$p < 0.001$, $\eta_p^2 = 0.81$
B. ANTERIOR SEGMENT - VERTICAL RELAPSE (Y-coordinate)				
A-point at T2 (6 months)	+0.28 ± 0.21 mm	+0.31 ± 0.24 mm	-0.03 mm	0.572
A-point at T3 (1 year)	+0.41 ± 0.28 mm	+0.46 ± 0.32 mm	-0.05 mm	0.481
A-point at T4 (2 years)	+0.51 ± 0.34 mm	+0.58 ± 0.39 mm	-0.07 mm	0.416
Intra-group trend (p-value)†	0.072 (NS)	0.061 (NS)	Interaction:	$p = 0.482$, $\eta_p^2 = 0.06$
C. POSTERIOR SEGMENT - VERTICAL RELAPSE (Y-coordinate)				
PNS at T4 (2 years)	+0.42 ± 0.29 mm	+0.45 ± 0.31 mm	-0.03 mm	0.671
UM Cusp at T4 (2 years)	+0.56 ± 0.33 mm	+0.61 ± 0.38 mm	-0.05 mm	0.554
Intra-group trend (p-value)†	0.088 (NS)	0.079 (NS)	Interaction:	$p = 0.615$, $\eta_p^2 = 0.04$

Positive (+) values signify anatomical relapse (anterior/inferior drift); negative (-) values indicate a continuous drift counter to the expected relapse vector (posterior/superior drift).
NS: Not Significant.
* p-values derived from independent Student's t-tests comparing the Monoblock and 2-Piece cohorts at each respective time point.

† p-values derived from Repeated-Measures ANOVA (Greenhouse-Geisser corrected) evaluating the longitudinal trajectory within each group from T1 to T4. η_p^2 (Partial Eta Squared) quantifies the magnitude of the Time × Group interaction effect.

The potential confounding effect of concomitant mandibular surgeries (BSSO advancement, BSSO setback, and BSSO advancement with genioplasty) on the sagittal relapse trajectory of the maxilla is presented in **Table 4**. Subgroup analysis utilising one-way ANOVA revealed no statistically significant differences in the magnitude of maxillary relapses at T4 within the Monobloc cohort ($p = 0.882$) or the 2-Piece Segmental cohort ($p = 0.795$) based on the specific mandibular surgical vector. The data demonstrate a highly consistent pattern independent of the mandibular procedure: the Monoblock group uniformly exhibited anterior relapse ranging from +0.81 ± 0.39 mm to +0.88 ± 0.38 mm, whereas the 2-Piece group consistently demonstrated posterior drift ranging from -0.49 ± 0.26 mm to -0.55 ± 0.31 mm at the 2-year follow-up. Independent t-tests confirmed that the inter-group differences between the Monoblock and 2-Piece constructs remained highly significant ($p < 0.001$) across all mandibular subgroups. These statistical findings confirm that the divergent sagittal stability patterns observed at the maxillary level appear to be primarily associated with the chosen maxillary surgical technique and did not demonstrate a statistically significant association with the opposing mandibular mechanical forces.

Table 4. Influence of Concomitant Mandibular Surgeries on Maxillary Sagittal Relapse (A-point X-coordinate) at Follow-up Intervals

Concomitant Mandibular Surgery	T2 - T1 (6 months)	T3 - T1 (1 year)	T4 - T1 (2 years)	p-value (T4 Inter-group)
BSSO Advancement only (n = 29)				
Monoblock Group (n = 15)	+0.46 ± 0.25	+0.73 ± 0.31	+0.86 ± 0.35	
2-Piece Group (n = 14)	-0.22 ± 0.17	-0.38 ± 0.21	-0.49 ± 0.26	< 0.001
Intra-procedure p-value	< 0.001	< 0.001	< 0.001	
BSSO Setback only (n = 16)				
Monoblock Group (n = 8)	+0.42 ± 0.28	+0.68 ± 0.35	+0.81 ± 0.39	
2-Piece Group (n = 8)	-0.26 ± 0.20	-0.44 ± 0.26	-0.55 ± 0.31	< 0.001
Intra-procedure p-value	< 0.001	< 0.001	< 0.001	
BSSO Advancement + Genioplasty (n = 25)				
Monoblock Group (n = 12)	+0.51 ± 0.29	+0.76 ± 0.34	+0.88 ± 0.38	
2-Piece Group (n = 13)	-0.25 ± 0.19	-0.42 ± 0.25	-0.54 ± 0.29	< 0.001
Intra-procedure p-value	< 0.001	< 0.001	< 0.001	

BSSO: Bilateral Sagittal Split Osteotomy.
Values are presented as Mean ± Standard Deviation (SD) in millimeters.
* Inter-group p-values at the 2-year follow-up (T4) were calculated using independent Student's t-tests.
† One-way ANOVA confirmed no significant differences in the magnitude of maxillary sagittal relapse within the Monoblock group ($p = 0.882$) or the 2-Piece group ($p = 0.795$) based on the specific mandibular surgical vector. Concomitant mandibular procedures did not act as a confounding factor.

Multisegmental maxillary osteotomies have been viewed with caution due to presumed increased risks of instability and relapse, as highlighted in comprehensive reviews by Haas Junior *et al*. [17, 24-26]. To contextualize our findings, it is essential to contrast the present sample with segmental osteotomies typically performed for anterior open bite (AOB) correction. In AOB cases, such as those investigated by Ismail *et al*., the anterior maxillary segment often exhibits a tendency for anterior and superior relapse. This instability is widely hypothesised to be driven by the continuous, unopposed protrusive forces of the tongue during resting posture and deglutition [20, 27, 28].

Conversely, the morphological starting point and surgical vectors in our cohort of severe maxillary protrusion present a distinctly different biomechanical environment. Following bilateral premolar extractions, the substantial posterior retraction of the anterior dentoalveolar segment (mean U1 retraction >7.2 mm) significantly modifies regional soft-tissue tension. It is plausible to hypothesise that the retracted upper lip, in its attempt to re-establish physiological resting length, may exert a sustained compressive resistance, although this was not directly measured against the mobilised anterior segment. This concept is supported by Ueki *et al*. who demonstrated significant postoperative alterations in maximum lip closing forces and perioral muscle dynamics following orthognathic correction [29-31]. Rather than facing outward lingual pressure, the segment in a 2-piece setback procedure may be subjected to a sustained soft-tissue compressive effect from the orbicularis oris complex. This continuous posterior vector might partially counteract typical anterior relapse tendencies and

potentially contribute to the subtle posterior drift observed over the 24-month follow-up. While Hichijo *et al*. and Rahpeyma *et al*. have noted the restrictive nature of soft-tissue tension and facial expression muscle adaptation on surgical outcomes [13, 21, 32]. This study's longitudinal data suggest this restriction could translate into a dynamic mechanical force acting upon the isolated bony segment. However, studies evaluating maxillary setbacks, such as those by Baek *et al*. indicate varying degrees of anteroposterior stability depending on surgical movement [33]. This suggests that such localised posterior drift patterns should be interpreted with caution and highlight the need for further physiological validation.

Despite the observed divergent sagittal behaviours, the vertical positional changes in both cohorts appeared to be relatively well-maintained and statistically comparable over time (interaction p = 0.482, η_p^2 = 0.06). At two years postoperatively, vertical alterations at A-point were limited to +0.51 mm for the monobloc group and +0.58 mm for the 2-piece group. These minor deviations align with Proffit's established hierarchy of surgical stability, which categorises isolated maxillary superior repositioning as a highly predictable and stable orthognathic procedure [34-37]. While some studies expressed concerns regarding the inherent instability of multisegmental maxillary surgery [15, 38, 39], recent systematic reviews, such as those by Haas Junior *et al*. suggest that vertical movement in the anterior region rarely causes a complete loss of bone contact, rendering the vertical dimension reasonably stable over time [17, 40]. Furthermore, investigations by Kretschmer *et al*. into segmental Le Fort I osteotomies found that rigid internal fixation (RIF) with titanium miniplates may provide adequate resistance to vertical relapse forces [24, 41]. The present data appear to corroborate these reports, supporting the hypothesis that the anatomical division of the maxilla into multiple segments - provided that adequate bone contact and osteosynthesis are achieved - does not appear to substantially compromise the structural integrity of a superior impaction.

When evaluating stability in bimaxillary procedures, a frequent clinical consideration is the potential confounding effect of concomitant mandibular movements on maxillary positioning [15, 42-45]. In the present study, subgroup analysis **(Table 4)** indicated no statistically significant differences in maxillary sagittal relapse patterns based on the specific mandibular surgical vector (BSSO advancement, BSSO setback, or adjunctive genioplasty; p > 0.79). Interestingly, the 2-piece maxillary segment maintained its subtle posterior drift trajectory (-0.49 to -0.55 mm) across all opposing mandibular movements. The literature presents a complex picture of maxillomandibular interaction; for instance, studies by Han *et al*. and Yin *et al*. demonstrated that BSSO procedures can introduce unique rotational changes, perioperative condylar displacement, and subsequent structural remodeling [46, 47]. Moreover, comprehensive reviews by Al-Moraissi and Ellis have noted varying degrees of soft-tissue and muscular adaptation between mandibular advancement and setback procedures. Given this context, one might expect varying mandibular kinematics to exert differential occlusal and muscular forces on the maxilla, potentially altering its stability. However, our localized findings imply that the subtle sagittal drift of the anterior maxillary segment in this specific cohort might be predominantly influenced by regional soft-tissue tension—such as the circumoral musculature - rather than by the broader, variable occlusal forces transmitted from the healing mandible. Alternative explanations should also be considered, including differences in segmental stability, fixation mechanics, and bone healing patterns, which were not directly evaluated in the present study. While this provides a plausible biomechanical explanation for the observed independence of the maxillary segments from mandibular vectors, these results should be interpreted cautiously, as dynamic functional habits and masticatory muscle adaptations were not directly measured.

This study has several limitations. First, its retrospective design introduces potential selection bias, as the choice of surgical technique was based on clinical indications rather than randomization. Second, no direct measurements of soft tissue forces or muscle activity were performed, limiting the ability to confirm the proposed biomechanical mechanisms. Third, the use of two-dimensional cephalometry restricts the evaluation of three-dimensional skeletal and soft-tissue interactions. Finally, the study population consisted exclusively of Vietnamese patients, which may limit the generalizability of the findings to other populations.

Conclusion

The study revealed that while both techniques achieve successful clinical outcomes, the 2-piece segmental Le Fort I construct is uniquely susceptible to further posterior displacement after surgery. This "posterior drift" may be associated with compressive forces from the upper lip complex, although this mechanism was not directly measured in the present study. This effect may reflect a sustained soft-tissue compressive influence on the mobilized anterior segment after a significant setback, although this mechanism was not directly measured in the present study. These findings suggest that surgeons may consider this potential additional backward movement during treatment planning to avoid potential over-correction in segmental cases.

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