Original Article

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# Correlation between vertical facial configuration and skeletal relapse at different time points after single-jaw BSSO mandibular setback in skeletal class III patients

Napatsorn Imerb[1], Warit Powcharoen[1], Chonatee Chinkrua[1], Nutchada Sriyaranya[1], Janya Apisariyakul[2], **Chayarop Supanchart**[1]

[1] *Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand*
[2] *Department of Orthodontics and Pediatric Dentistry, Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand*

**Objective:** To evaluate the correlation between MPA and skeletal stability after mandibular setback surgery in skeletal class III patients at the short-term and long-term post-operative time points.

**Materials and Methods:** Fifty-eight skeletal class III with mandibular prognathism patients who underwent the single-jaw mandibular setback surgery using bilateral sagittal split ramus osteotomy approach were divided into two subgroups based on their vertical skeletal configuration. The subjects were twenty-five patients with normal mandibular plane angle (21.22° ± 4.86°) and thirty-three patients with the high MPA (> 28.06°). To analyze the influence of two facial patterns on post-operative stability, the digital lateral cephalograms were computerized and analyzed on three cephalometric anatomical landmarks including B-point, SNB-angle, and mandibular plane (MP). The correlation between the amount of MPA and the percentage of skeletal relapse was analyzed with the Pearson Correlation Coefficient.

**Results:** The mean MPA in the hyperdivergent group (30.02° ± 1.65°) was significantly higher than in the normodivergent group (23.65° ± 1.16°). The correlation analysis found that there was a positive correlation between MPA and the percentage of skeletal relapse on the B-point in vertical axis and Mandibular plane (MP) at short-term follow-up. This positive correlation was also further shown on B-point in horizontal axis, SNB-angle, and MP at long-term follow-up.

**Conclusions and Relevance:** The skeletal relapse after mandibular setback surgery was positively correlated to the mandibular plane angle in skeletal Class III patients. An adjunctive surgical procedure may be needed to achieve the long-term successful outcome after orthognathic surgery in skeletal Class III malocclusion with high MPA.

**Keywords:** bilateral sagittal split osteotomy, high mandibular plane angle, skeletal relapse, skeletal stability

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## Background

Orthognathic surgery is the use of surgical procedures mainly to correct the dentofacial deformity and to improve the imbalanced relationship between maxilla and mandible [1]. This surgical procedure not only results in an improvement of facial appearance and masticatory function but also improves the patient's quality of life both physically and psychosocially. Epidemiologic studies found that bilateral sagittal split ramus osteotomy (BSSO) has been considered the most common surgical procedure used to correct the skeletal class III discrepancy mostly among the Asian population [2-4]. However, reducing the most prevalent postoperative complication despite producing satisfactory results is highly needed to achieve a successful outcome.

Corresponding author: Chayarop Supanchart
Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chiang Mai University
239 Huay Kaew Rd., Muang District, Chiang Mai 50200, Thailand.
Tel: +66 5394 4455; Fax: +66 5393 5368
E-mail: chayarop.supanchart@cmu.ac.th
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Accumulated evidence demonstrated that single-jaw mandibular setback is one of the problematic surgical procedures in terms of postoperative stability and is less predictable due to the posterior rotation of the condylar segment even in a rigid fixation [5-7]. Recent studies found that a higher risk of skeletal relapse after single-jaw mandibular setback robustly correlated with various factors i.e., high magnitude of setback distance, clockwise rotation of the mandible, skeletal open bite configuration, hyperactivity of masticatory muscle, and large tongue volume with the high position [8-10]. Mandibular plane angle (MPA) is one of three key angles used to determine the pattern of facial growth except a cranial base angle and facial axis angle [11]. The comparison of mandibular plane angle shown in those Asian samples was larger than in the Caucasian. According to Chatkupt's study revealed that the average of MPA in Thai people is 21.22 ± 4.86° [11]. In agreement with Kim's study found that an average MPA in Korean subjects with normal occlusions and well-balanced profiles is 23.87° ± 4.19° in males and 23.65° ± 5.19° in females [12]. Whereas, Tweed reported the standard or normal range of MPA in Caucasians was 22° to 28° projecting a skeletal pattern with a normal growth direction [13]. Moreover, Tweed suggested that a steeper mandibular plane angle results in a poor prognosis in relation to the facial esthetic [13].

The patient with class III high angle malocclusion is characterized by the prognathic mandible, steep mandibular plane, steep occlusal plane, larger gonial angle, lower face height, and hyperdivergent skeletal pattern. This complex skeletal discrepancy requires multiple directions of surgical movement to correct the maxillary-mandibular relationship which may create postsurgical skeletal relapse by causing the clockwise rotation of the distal segment and forward shifting of the mandible and condyle into a preoperative former position. In case of presenting normal maxilla position, treating the class III high angle patients has been a challenge for surgeons considering between single-, versus double-jaw surgery and concerning prognosis. Additional surgical approaches such as subapical osteotomy and genioplasty may be required in specific cases [1].

Although the postoperative stability after mandibular setback surgery has been reported in many studies over the past decade. However, the influence of the post-operative period on skeletal stability following mandibular setback in skeletal class III patients with different vertical facial pattern are not well known. The purpose of this study was to evaluate the correlation between the MPA and skeletal stability after mandibular setback surgery in skeletal class III patients at the short-term and long-term post-operative time points. We hypothesize that under controlling the magnitude of setback movement in the horizontal axis, the skeletal relapse in single-jaw mandibular setback surgery in skeletal class III patients is strongly correlated to the preoperative high MPA configuration.

## Materials and Methods

### Study design and sample

To address the research purpose, the investigators designed and implemented The Human Experimentation Committee, Office of Research Ethics, Faculty of Dentistry, Chiang Mai University approved retrospective study by investigating orthodontic, surgery, and medical records. The study population consisted of all patients presenting for evaluation and who underwent single-jaw mandibular setback surgery between 2013 and 2015. To be included in the study sample, patients had to be: 1) non-growing adults (>15 years old female and >18 years old male); 2) diagnosed with a skeletal Class III with mandibular prognathism that preoperative SNB

angle is more than 84.61°with normal or high MPA (Figure 1a); 3) treated with mandibular setback surgery involving BSSO followed by rigid internal fixation without additional surgery (including any types of maxillary surgery, subapical osteotomy, and genioplasty); 4) have diagnostic quality lateral cephalograms at the indicated time points. Both digital and analogue lateral cephalograms were taken at time points: immediately or less than 3-month before surgery (T0), at immediately or less than 2 weeks after surgery (T1), 6 months after surgery (T2), and 2-year after surgery (T3) the analogue cephalograms were converted to the digital format by computerize scanning.

## Cephalometric evaluation

All the lateral cephalogram analyses and measurements were performed by using ImageJ® software as described in the previous study [14]. Briefly, ImageJ was used to calculate area and pixel value statistics or measure distances and angles of user-defined selections as well as to calibrate an unequal magnification to be equal (Figure 1b), to eliminate the dimensional error of all cephalograms produced from different x-ray sources. All measurements were performed by one examiner in a dark room with an appropriate environment. All cephalograms were computerized analysis, orientated with the horizontal plane at 7°

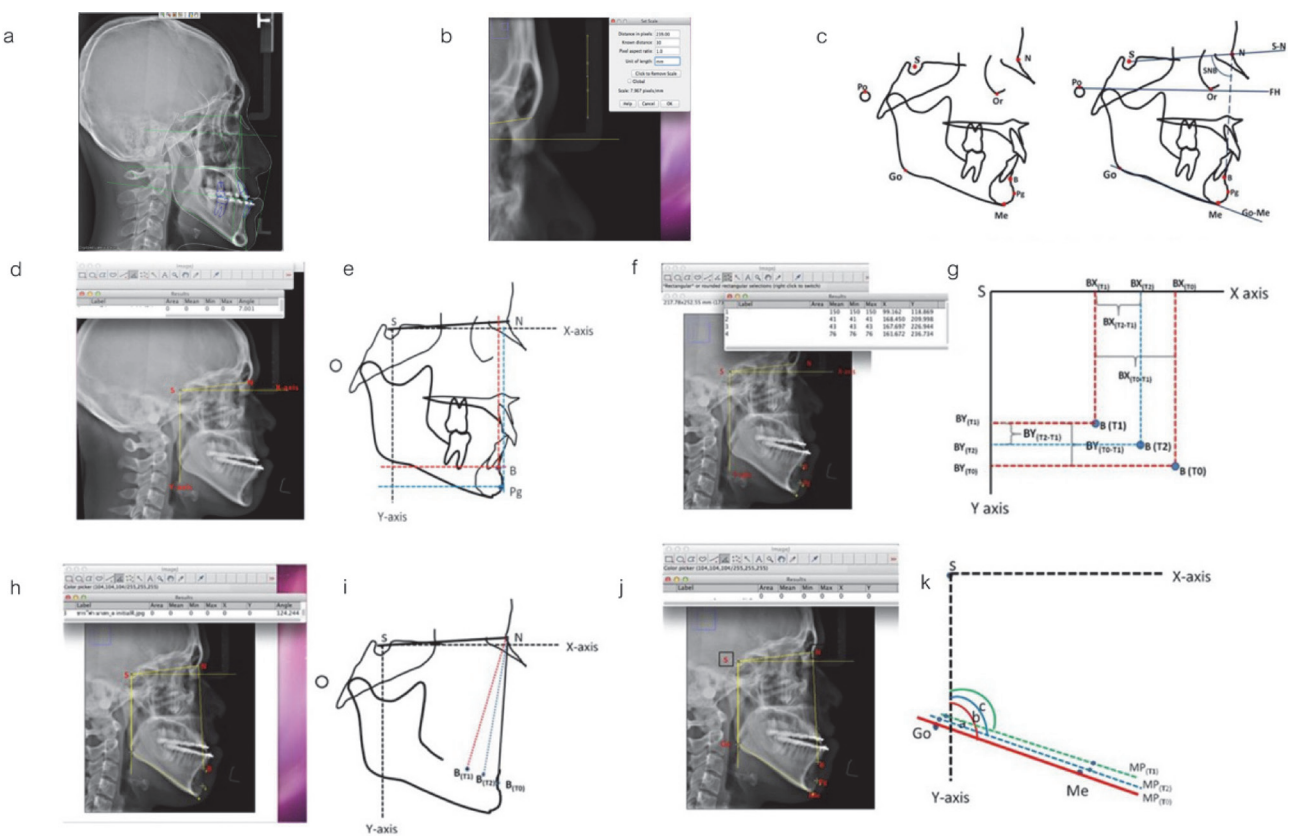


Figure 1 Cephalometric evaluation using ImageJ® software. (a) A lateral cephalogram of skeletal class III patient (MPA>26.09°); (b) Setting the pixel aspect ratio by using set scale function of ImageJ®; (c) Cephalometric landmarks, lines, angles, and planes used in this study; (d, e) The cephalogram was rotated by using ImageJ® to establish an angulation of S-N line to be 7°, B-point in horizontal axis and vertical axis were measured in millimeters perpendicular to X and Y axis, respectively; (f, g) Measurement of B-point on X-Y cranial base coordinate system. (h-k) Angular measurement of SNB-angle and mandibular plane.

to the Sella-Nasion line [15]. Four cephalometric landmarks of hard tissue including B-point, Pg-point, SNB-angle, and mandibular plane (MP) were identified in Table 1 and Figure 1c [16].

In order to locate the position of B and Pg points, the X-Y cranial base coordinate system was constructed on the radiograph system [17]. An X-axis as a horizontal reference line was drawn 7° to the sella-nasion line (SN) and a Y-axis as a vertical reference line was drawn perpendicular to the X-axis at the sella point (Figures 1d-e) then B and Pg points were measured in millimeters (mm) perpendicular to X and Y axis respectively (Figures 1d-1e).

### Presurgical evaluation

The subjects were divided into 4 subgroups to study stability and relapse according to their presurgical MPA and follow-up time point as follows:

*Group A1*: skeletal Class III patients with high MPA (≥ 26.09°) who are able to obtain high-quality lateral cephalograms at T0, T1, and T2.

*Group A2*: skeletal Class III patients with high MPA (≥ 26.09°) who are able to obtain high-quality lateral cephalograms at T0, T1, and T3.

*Group B1*: skeletal Class III patients with normal MPA (21.22° ± 4.86°) who are able to obtain high-quality lateral cephalograms at T0, T1, and T2

*Group B2*: skeletal Class III patients with normal MPA (21.22° ± 4.86°) who are able to obtain high-quality lateral cephalograms at T0, T1, and T3

Table 1 The definition of cephalometric landmarks, lines, angles, and planes used in this study.

| Landmark | Definition |
|---|---|
| Sella (S) | The center of sella turcica. |
| Nasion (N) | A point at the anterior limit of the nasofrontal suture. |
| B-point (B) | The most posterior point on contour of mandible between incisor tooth and body of chin. |
| Menton (Me) | The most inferior midline point on mandibular symphysis. |
| Gonion (Go) | The midpoint of the angle of mandible. |
| Porion (PO) | The midpoint of the line connecting the most superior point of the radiopacity generated between by the two ear rods of the cephalostat. |
| Orbitale (Or) | A point located at the lowest point on the external border of the orbital cavity. |
| Sella-Nasion plane (S-N) | Sella-Nasion plane (S-N) The line between Sella and Nasion. |
| Go-Me, Tweed's mandibular plane (MP) | The line between Gonion and Menton. |
| Frankfurt horizontal plane (FH) | The line between Orbitale and Porion. |
| SNB Angle (SNB) | The angle between SN plane and NB line. |
| Mandibular plane angle (FMA/MPA) | The angle between FH plane and MP plane. |

Table 2 Demographic data of all subjects.

| Group | Number of subjects | Age (years) | | Mean age (years) |
|---|---|---|---|---|
| | | Min | Max | |
| A (High MPA, mean MPA = 30.02 ± 1.64) | | | | |
| Male | 9 | 17.2 | 30.7 | 24.79 ± 2.49 |
| Female | 24 | 17.8 | 35.56 | 26.68 ± 2.76 |
| B (Normal MPA, mean MPA = 23.35 ± 1.16) | | | | |
| Male | 11 | 18.2 | 26.02 | 22.11 ± 1.63 |
| Female | 14 | 16.4 | 32.6 | 24.5 ± 2.78 |

### Evaluation of the surgical technique and initial surgical movement

The medical and treatment records of all subjects were evaluated. Nasoendotracheal intubation was performed in all subjects who underwent a single-jaw mandibular setback surgery without additional surgery (including any types of maxillary surgery, subapical osteotomy, and genioplasty). Rigid fixation was accomplished by two four-holes titanium plates. All subjects were hospitalized overnight without a record of serious complications. At the time of discharge, they were instructed for a one-week in-office follow-up appointment to obtain a physical and radiographic examination. All subjects received a four-week period of intermaxillary fixation, and they were advised to follow a high-protein liquid diet. The initial surgical movement distance in each group was measured at B-point as a linear change (measurement at T0 - measurement at T1) in both horizontal and vertical axes on an X-Y cranial base coordinated system (Figures 1d-1e).

### Postoperative skeletal relapse evaluation

Postsurgical skeletal relapse was defined as a shifting of landmarks of interest into the opposite direction of the surgical direction correction. The postsurgical positional change greater than 2 mm is clinically significant and is considered a skeletal relapse as previously described in a previous study [18]. The position B-point, Pg-point, SNB-angle, and MP of all subjects were located on the X-Y cranial base coordinate system at each time point (Figures 1d-1k) before use for assessment of skeletal relapse relative to their initial surgical movement as follows:

(1) In group A1 and B1, a percentage of skeletal relapse regarding all reference landmarks were determined by measurement of the different position between T2-T1in relative to T0-T1.

2) In group A2 and B2, a percentage of skeletal relapse regarding all reference landmarks were determined by measurement of the different position between T3-T1in relative to T0-T1.

### Statistical analysis

All data were expressed as mean ± standard error of the mean (SEM). All statistical analyses were performed by using GraphPad Prism software version 8.2.1 for macOS. The correlation between the degree of MPA and the percentage of relapse was investigated by Pearson's correlation coefficient *(r)*. *P*-value less than 0.01 was considered as a statistically significant difference.

### Reliabilities of measurements

All cephalogram measurements were repeated for correction of systematic and accidental errors. An intra-examiner calibration of all lateral cephalograms was performed. The inter-

examiner reproducibility was conducted by the other four examiners within two-week to one-month after the first investigation, as suggested in the previous study [19]. All five investigations showed high correlations with Pearson's product-moment correlation coefficients of 0.847 to 0.933 ($p$<0.001). This indicated that the cephalometric landmarks measurements of the investigator were satisfied with a very high reproducibility.

## Results

### Demographic data and preoperative cephalometric assessment at T0

Demographic data of all subjects were reported in Table 2. A total of 58 patients; 38 females and 20 males who were identified as having undergone a single-jaw mandibular setback were included in this study. All subjects were obviously separated into two different facial types on the basis of MPA. Of the 58 patients, 33 patients presented high MPA configuration (group A, mean MPA = 30.02 ± 1.64), and 25 patients presented normal MPA (group B, mean MPA = 23.35 ± 1.16).

### Correlation between MPA and the percentage of skeletal relapse at short-term post-operative time point (6-month)

The correlation analysis found that a large positive correlation between MPA and the percentage of skeletal relapse was shown on the B-point in vertical axis (Figure 2b, $p$<0.001, r = 0.8030) and MP (Figure 2d, $p$< 0.001, r = 0.8538) at short-term post-operative time point. However, there was no correlation between MPA and the percentage of skeletal relapse found on the B-point in the horizontal axis (figure 2a) and SNB-angle at this time point (Figure 2c).

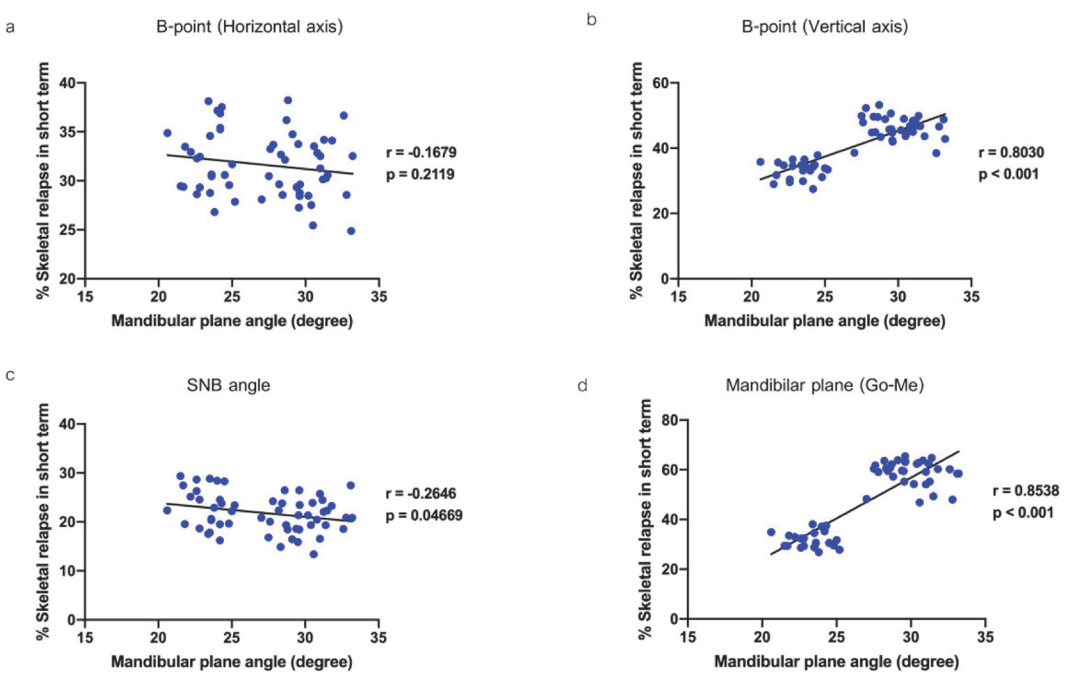


Figure 2 Correlation between the degree of mandibular plane angle and the percentage of skeletal relapse on different cephalometric landmarks at short-term postoperative time point (6-month). (a) B-point in the horizontal axis; (b) B-point in the vertical axis; (c) SNB-angle; (d) mandibular plane.

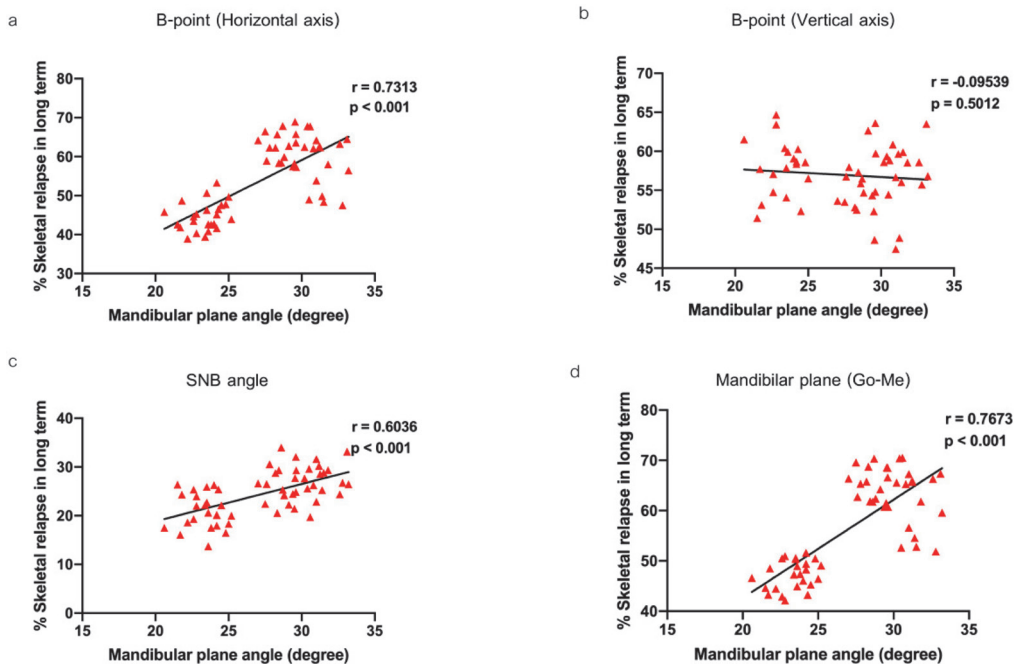


**Figure 3** Correlation between the degree of mandibular plane angle and the percentage of skeletal relapse on different cephalometric landmarks at long-term postoperative time point (24-month). (a) B-point in the horizontal axis; (b) B-point in the vertical axis; (c) SNB-angle; (d) Mandibular plane.

### Correlation between MPA and the percentage of skeletal relapse at long-term postoperative time point (24-month)

The correlation analysis found that a large positive correlation between MPA and the percentage of skeletal relapse was shown on the B-point in the horizontal axis (Figure 3a, $p<0.001$, $r = 0.7313$), SNB angle (Figure 3c, $p<0.001$, $r = 0.6036$), and MP (Figure 3d, $p < 0.001$, $r = 0.7673$) at long-term postoperative time point. However, there was no correlation between MPA and the percentage of skeletal relapse found on the B-point in vertical axis (Figure 3b) at this time point.

## Discussion

Accumulated evidence indicated that postoperative skeletal stability is affected by different facial patterns [18]. Thus, the correlation between vertical facial configuration and postoperative stability in skeletal class III patients was determined in this study. The results of this study showed that high MPA was positively correlated with the degree of skeletal relapse in both short-term and long-term, postoperatively. Moreover, the skeletal relapse was remarkably shown in the vertical axis as similarly found in the previous study [20]. Our findings suggested that Skeletal Class III malocclusion with high MPA would have a higher risk in postoperative skeletal relapse after a single-jaw mandibular setback surgery than those who have a normal MPA especially in the vertical axis.

The subjects in this study showed a female predominance (65.52%), indicating a sample bias in gender distribution. Based on the esthetic purposes, a higher proportion of subjects who underwent orthognathic surgery were seen in females than in males and this concept has been demonstrated by the observed gender distribution in previous studies of orthognathic surgery patients [21]. To eliminate the effect of growth on mandibular position,

the ages of subjects in each group should be similar. Our results as shown in demographic data confirm that all subjects were non-growing adults with a mean age of 25.73 years old as comparable found in the previous study [20]. According to the findings of this study, the overall skeletal relapse rate after mandibular setback of our 58 subjects in this study was found by 42.24% similar to previous studies which reported a skeletal relapse of 38.9 – 51.4% [22-25]. A variety of factors affecting postoperative skeletal relapse have been demonstrated in previous studies including vertical facial pattern, occlusal plane and type of occlusion, condylar remodeling, mandibular growth, and the differences in the time of follow-up [20, 26]. Regarding the postoperative period, a smaller skeletal relapse rate was reported in the short-term than in the long-term as similarly found in our present study [27]. Many subjects tend to get more relapse of hard tissue when time passes due to the condylar resorption, especially in high-angle patients [28]. In contrast with the previous studies [5, 24, 29] reported main relapse mostly takes place immediately after surgery within the first 6 months while our present study found a greater skeletal relapse rate in long term follow-up at 24-month than 6-month after surgery at both types of facial pattern. Regarding our results, these findings proposed that the causes of preferred stability in the short term after surgery may associated with early management of postoperative stabilization such as proper seating of condyle in glenoid flossa to avoid a condylar sag, the optimal splinting and intermaxillary fixation period, routine postoperative follow up and patient compliance to instructions [18].

In accordance with previous reports, there may be subtypes of Class III malocclusion that have specific and different responses to the surgical treatment [30]. Our results confirmed that there is a significant correlation between facial type and relapse pattern. Our findings revealed that the highest relapse rate of either normal MPA or high MPA group was found on mandibular plane alteration. On the other hand, the most stable parameter was SNB angle, and the minimum value was found 6 months after the surgery period. From these results, a surgical movement direction should be considered. A larger movement or surgical movement in a subject with a more obtuse mandibular plane angle would be more likely to result in an initial stretch of the muscle itself because the greater the direction and amount of movement, the greater the likelihood that the limits of extensibility of the connective tissues will be exceeded [18]. Consistently, our present found a vertical movement in the high MPA group was nearly double that in the normal MPA group, whereas horizontal movement displayed a relatively similar pattern between the two groups. Our results indicate that a vertical relapse is more obvious than a horizontal relapse, especially in the high MPA group at long-term time point. These findings are significant in understanding the long-term stability of orthognathic surgical outcomes and may have important clinical implications. Our results support the notion that the evaluation of long-term stability should consider the patient's vertical facial configuration as a crucial factor. Vertical relapse appears to be more conspicuous in individuals with high MPA, highlighting the importance of post-operative follow-up and potential interventions to mitigate vertical changes. These findings also emphasize the necessity of individualized treatment planning, including the possibility of adjunctive surgical procedures such as intentional ostectomy of the posterior part of the distal segment or simultaneous mandibular angle resection and BSSRO to enhance the stability of surgical outcomes after mandibular setback which have been proven in previous studies [31, 32]. Conducting further studies to explore modifications in surgical techniques and other innovative approaches is a critical step toward improving the long-term stability after mandibular setback in skeletal class III patients with high MPA.

### Limitation

Some of the lateral cephalograms in this study were from the patient file and taken without randomization. In addition, the lateral cephalograms in this study were taken from different x-ray machines and technicians. Although no patient in this study experienced a second operation to correct an unexpected outcome, there is still no determining patient satisfaction in this study. A patient's perceived satisfaction and quality of life after definitive treatment should be concerned in further study.

## Conclusion

Postoperative skeletal stability is affected by different facial patterns. Understanding the stability and relapse patterns associated with single-jaw mandibular setbacks is crucial for both clinicians and patients, as it helps inform treatment planning and expectations. Skeletal Class III malocclusion with high MPA would have a higher risk of postoperative skeletal relapse after a single-jaw mandibular setback surgery than those who have a normal MPA, especially in the vertical axis. Our study thus contributes valuable information to the field, enabling a more comprehensive assessment of treatment options for patients with high mandibular plane angle. An adjunctive surgical procedure and other innovative approaches may be needed to achieve the long-term successful outcome.

## Conflict of interest

The authors declare that they have no conflict of interests.

## Author contributions

**N.I.**: Investigation, manuscript writing – Original Draft; **J.A.**: data analysis, criticism and conclusion, manuscript writing - Original Draft, review and editing; **W.P., C.C., N.S.**: investigation; **N.S., C.S.**: elaboration of concept, manuscript writing - review and editing, supervision, acquisition of funds.

## Abbreviations

B, B-point; BSSO, bilateral sagittal split ramus osteotomy; FH, Frankfurt horizontal plane; Go-Me, Tweed's mandibular plane; Go, Gonion; Me, Menton; MP, Mandibular plane; MPA, Mandibular plane angle; N, Nasion; Or, Orbitale; PO, Porion; S-N, Sella-Nasion plane; SEM, standard error of the mean; SNB, Angle between sella-nasion and B-point.

## References


1. Yan A, Chen YR. Orthognathic surgery to enhance the smile. ***Clin Plast Surg.*** 2023 Jan;50(1):81-89. doi: 10.1016/j.cps.2022.07.001.
2. Ngan P, Moon W. Evolution of Class III treatment in orthodontics. ***Am J Orthod Dentofacial Orthop.*** 2015 Jul;148(1):22-36. doi: 10.1016/j.ajodo.2015.04.012.
3. Proffit WR, Phillips C, Dann C 4th. Who seeks surgical-orthodontic treatment? ***Int J Adult Orthodon Orthognath Surg.*** 1990;5(3):153-160.
4. Mousoulea S, Tsolakis I, Ferdianakis E, Tsolakis AI. The Effect of Chin-cup Therapy in Class III Malocclusion: A Systematic Review. ***Open Dent J.*** 2016 Dec;10: 664-679. doi: 10.2174/1874210601610010664.
5. Joss CU, Vassalli IM. Stability after bilateral sagittal split osteotomy setback surgery with rigid internal fixation: a systematic review. ***J Oral Maxillofac Surg.*** 2008 Aug; 66(8):1634-1643. doi: 10.1016/j.joms.2008.01.046.
6. Cho HJ. Long-Term Stability of Surgical Mandibular Setback. ***Angle Orthod.*** 2007 Sep;77(5):851-856. doi: 10.2319/052306-209.1.
7. Proffit WR, Phillips C, Turvey TA. Stability after surgical-orthodontic corrective of skeletal Class III malocclusion. 3. Combined maxillary and mandibular procedures. ***Int J Adult Orthodon Orthognath Surg.*** 1991;6(4):211-225.
8. Choi TH, Kim SH, Yun PY, Kim YK, Lee NK. Factors related to relapse after mandibular setback surgery with minimal presurgical orthodontics. ***J Oral***

*Maxillofac Surg.* 2019 May;77(5):1072.e1-1072.e9. doi: 10.1016/j.joms.2018.12.030.
9. Tseng YC, Wu JH, Chen CM, Hsu KJ. Correlation between change of tongue area and skeletal stability after correction of mandibular prognathism. *Kaohsiung J Med Sci.* 2017 Jun;33(6):302-307. doi: 10.1016/j.kjms.2017.03.008.
10. Wolford LM, Karras SC, Mehra P. Considerations for orthognathic surgery during growth, Part 1: Mandibular deformities. *Am J Orthod Dentofacial Orthop.* 2001 Feb;119(2):95-101. doi: 10.1067/mod.2001.111401.
11. Chatkupt S Sl, Patanaporn V, Bundech A, Apisariyakul S, Jotikasthira D. Cephalometric study in Northern Thai people. Research submitted to the Faculty of Dentistry, Chiang Mai: Chiang Mai University. 1987:1-84;
12. Kim JH, Gansukh O, Amarsaikhan B, Lee SJ, Kim TW. Comparison of cephalometric norms between Mongolian and Korean adults with normal occlusions and well-balanced profiles. *Korean J Orthod.* 2011 Feb;41(1):42-50. doi: 10.4041/kjod.2011.41.1.42.
13. Tweed CH. The Frankfort-mandibular plane angle in orthodontic diagnosis, classification, treatment planning, and prognosis. *Am J Orthod Oral Surg.* 1946 Apr; 32(4):175-230. doi: 10.1016/0096-6347(46)90001-4.
14. Linjawi AI, Afify AR, Baeshen HA, Birkhed D, Zawawi KH. Mandibular symphysis dimensions in different sagittal and vertical skeletal relationships. *Saudi J Biol Sci.* 2021 Jan;28(1):280-285. doi: 10.1016/j.sjbs.2020.09.062
15. Burstone CJ, James RB, Legan H, Murphy G, Norton LA. Cephalometrics for orthognathic surgery. *J Oral Surg.* 1978 Apr;36(4):269-277.
16. Athanasiou AE. Orthodontic Cephalometry: Mosby-Wolfe; 1995.
17. Espeland L, Stenvik A. Long-term outcome of orthognathic surgery. Naretto DS, editor: In Tech; 2011. 584p. doi: 10.5772/22574.
18. Proffit WR, Turvey TA, Phillips C. The hierarchy of stability and predictability in orthognathic surgery with rigid fixation: an update and extension. *Head Face Med.* 2007 Apr;3:21. doi: 10.1186/1746-160X-3-21.
19. Houston WJ. The analysis of errors in orthodontic measurements. *Am J Orthod.* 1983 May;83(5):382-390. doi: 10.1016/0002-9416(83)90322-6.
20. Kuo JJ, Lin CH, Ko EW. Relapse patterns of two-jaw surgical correction in patients with skeletal Class III malocclusion and different vertical facial types. *Int J Oral Maxillofac Surg.* 2022 Dec;51(12):1587-1595. doi: 10.1016/j.ijom.2022.05.016.
21. Joss CU, Thüer UW. Stability of the hard and soft tissue profile after mandibular advancement in sagittal split osteotomies: a longitudinal and long-term follow-up study. *Eur J Orthod.* 2008 Feb;30(1):16-23. doi: 10.1093/ejo/cjm080.
22. Phillips C, Zaytoun HS Jr, Thomas PM, Terry BC. Skeletal alterations following TOVRO or BSSO procedures. *Int J Adult Orthodon Orthognath Surg.*1986 Summer;1(3): 203-213.
23. Franco JE, Van Sickels JE, Thrash WJ. Factors contributing to relapse in rigidly fixed mandibular setbacks. *J Oral Maxillofac Surg.* 1989 May;47(5):451-456. doi: 10.1016/0278-2391(89)90276-0.
24. Proffit WR, White RP. Surgical-orthodontic treatment: Mosby-Year Book; 1991.
25. Schatz JP, Tsimas P. Cephalometric evaluation of surgical-orthodontic treatment of skeletal Class III malocclusion. *Int J Adult Orthodon Orthognath Surg.* 1995;10(3):173-180.
26. de Villa GH, Huang CS, Chen PK, Chen YR. Bilateral sagittal split osteotomy for correction of mandibular prognathism: long-term results. *J Oral Maxillofac Surg.* 2005 Nov;63(11):1584-1592. doi: 10.1016/j.joms.2005.03.031.
27. Halvorsen ET, Beddari IY, Schilbred Eriksen E, Boe OE, Wisth PJ, Loes S, *et al.* Relapse and Stability After Mandibular Setback Surgery One Year Postoperatively: A Retrospective Study. *J Oral Maxillofac Surg.* 2014 Jun; 72(6):1181.e1-1181e11. doi: 10.1016/j.joms.2014.02.033.
28. Moore KE, Gooris PJ, Stoelinga PJ. The contributing role of condylar resorption to skeletal relapse following mandibular advancement surgery: Report of five cases. *J Oral Maxillofac Surg.* 1991 May;49(5):448-460. doi: 10.1016/0278-2391(91)90166-J.
29. Jakobsone G, Stenvik A, Sandvik L, Espeland L. Three-year follow-up of bimaxillary surgery to correct skeletal Class III malocclusion: stability and risk factors for relapse. *Am J Orthod Dentofacial Orthop.* 2011 Jan;139(1):80-89. doi: 10.1016/j.ajodo.2009.03.050.
30. Morrill LR, Baumrind S, Miller D. Surgical correction of mandibular prognathism: I. A cephalometric report. *Am J Orthod.* 1974 May;65(5):503-518. doi: 10.1016/0002-9416(74)90032-3.
31. Kim MJ, Kim SG, Park YW. Positional stability following intentional posterior ostectomy of the distal segment in bilateral sagittal split ramus osteotomy for correction of mandibular prognathism. *J Oral Maxillofac Surg.* 2002 Feb;30(1):35-40. doi: 10.1054/jcms.2001.0272.
32. Kim CH, Lee JH, Cho JY, Lee JH, Kim KW. Skeletal stability after simultaneous mandibular angle resection and sagittal split ramus osteotomy for correction of mandible prognathism. *J Oral Maxillofac Surg.* 2007 Feb;65(2): 192-197. doi: 10.1016/j.joms.2005.12.064.