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Original Article

Critical factors to ensure stable occlusion in Class III patients following surgical-orthodontic treatment

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Logistic regression

Abstract *Background/purpose:* Achieving coordination between maxillary and mandibular arches is critical for establishing stable occlusion. This study evaluated posterior occlusal intercupation and identified predictive factors for normal posterior buccal overjet in skeletal Class III patients following surgical-orthodontic treatment.
Materials and methods: A retrospective analysis was conducted on 51 Class III patients (24 males, 27 females) who underwent bimaxillary surgery and orthodontic treatment. Cone-beam computed tomography (CBCT) scans were obtained at three time points: pre-treatment (T0), pre-surgery (T1), and post-treatment (T2). Maxillary transverse discrepancies and buccolingual inclinations of maxillary and mandibular molars were assessed using Amira® 3D Pro software. Patients were categorized according to posterior buccal overjet at T2 into two groups: Group 1 (normal occlusion) and Group 2 (defective occlusion). Intergroup comparisons and logistic regression were conducted to determine predictive factors.
Results: At T0, Group 2 exhibited significantly narrower maxillary arch widths, more maxillary crowding, greater facial divergence, more pronounced maxillary transverse discrepancy (MTD), and increased molar inclinations on the menton non-deviation side compared to Group 1. At T1, molar inclinations were similar between the two groups. At T2, Group 2 continued to exhibit greater facial divergence, a narrower maxillary arch width, and residual MTD. Logistic regression identified the Wits appraisal at T0 and MTD at T1 as significant predictors of post-treatment occlusion.

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Conclusion: A logistic regression model incorporating the pre-treatment Wits appraisal and pre-surgical MTD could predict posterior occlusal outcomes after surgical-orthodontic treatment in Class III patients.

Introduction

Surgical-orthodontic intervention is frequently required to address the dentofacial deformities in patients presenting with moderate to severe skeletal Class III malocclusion.[1,2] Maxillary deficiency and mandibular prognathism contribute not only to sagittal but also to transverse skeletal discrepancies observed in this patient population.[3]

Appropriate buccolingual crown inclination of maxillary and mandibular posterior teeth is fundamental for achieving and maintaining stable occlusion.[4] Patients with a constricted maxilla and an expanded mandible often present with posterior crossbite. However, even in the absence of a posterior crossbite, maxillary transverse discrepancy may be masked by transverse dental compensation.[5] Therefore, pre-surgical evaluation of dental decompensation is essential for achieving a stable posterior occlusion following surgical-orthodontic treatment.[6,7]

Cone-beam computed tomography (CBCT) is increasingly utilized for evaluating transverse discrepancies between the maxilla and mandible.[8–11] However, some commonly used landmarks, such as the antegonial and jugular points, are distant from dental roots and may be less reliable in assessing occlusion-relevant maxillomandibular transverse discrepancies. Alternatively, measuring maxillomandibular basal arch width differences at the estimated centers of resistance of first molars via CBCT provides a more accurate reflection of skeletal discrepancies pertinent to occlusion.[12] Moreover, the estimated centers of resistance of maxillary and mandibular molars, i.e. the root trifurcation and bifurcation points respectively, remain largely unaffected by buccolingual tipping movement.

Skeletal asymmetries and dental compensations in Class III patients complicate diagnosis, treatment planning, and clinical outcomes. Accordingly, this study analyzed CBCT-derived data from skeletal Class III patients before and after surgical-orthodontic treatment to identify critical factors associated with achieving stable occlusion.

Materials and methods

Patient selection

This retrospective study included patients who underwent surgical-orthodontic treatment at National Taiwan University Hospital between January 2019 and December 2024. Institutional review board approval was obtained from the National Taiwan University Hospital Research Ethics Committee (IRB No. 201511037RINA). Inclusion criteria were: age 18 years or older, skeletal Class III malocclusion (ANB $<0°$), Class I canine relationship with normal overjet and overbite after completion of bimaxillary orthognathic surgery combined with orthodontic treatment. Exclusion criteria included of previous orthodontic treatment, history of maxillofacial trauma, and congenital craniofacial anomalies such as cleft lip or palate.

All patients underwent pre-surgical orthodontic decompensation followed by two-jaw surgery, consisting of a Le Fort I osteotomy of the maxilla and bilateral sagittal split osteotomy (BSSO) of the mandible, with internal fixation using titanium plates. Surgeries were performed by two experienced oral and maxillofacial surgeons. CBCT scans were obtained at three time points: T0 (pre-treatment), T1 (pre-surgery), and T2 (post-treatment, within three months following orthodontic appliance removal). Posterior occlusion at T2 was independently evaluated by two orthodontic specialists using the American Board of Orthodontics Objective Grading System.[13] Left and right occlusal relationships were evaluated separately. Normal occlusion was defined as the mandibular buccal cusps fitting well into the fossae of the maxillary teeth. Defective occlusion was characterized by a buccal overjet of less than half the distance from cusp tip to fossa, with the mandibular buccal cusps occluding on the lingual inclines of the maxillary buccal cusps (Fig. 1).

CBCT imaging protocol

CBCT images were acquired using a 3D Accuitomo 170 scanner (J. Morita MFG. Corp., Kyoto, Japan) with the following parameters: tube voltage 60–90 kVp, tube current 4–6 mA, focal spot size 0.5 mm, source-to-sensor distance 744 mm, source-to-patient distance 540 mm, voxel size 0.25 mm, field of view (FOV) 170 mm $\times$ 120 mm, and scanning time 17.5 s. Patients were positioned with the dentition in centric occlusion. Two scans were obtained, one for the upper and one for the lower facial region, and subsequently merged using OnDemand3D software. Images were exported in DICOM format for analysis.

Three-dimensional image superimposition

Three-dimensional image analysis was performed using Amira® 3D Pro software (Thermo Fisher Scientific, Waltham, MA, USA; version 2022.1). CBCT scans were reoriented according to three anatomical reference planes: the Frankfort horizontal plane (bilateral Porion and Orbitale), the midsagittal plane (Nasion and Basion, perpendicular to Frankfort plane), and the coronal plane (passing through Basion and

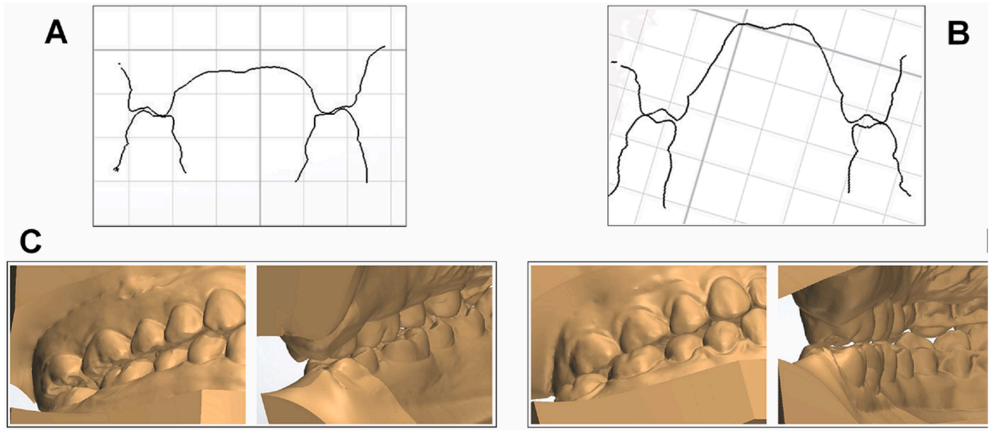

Figure 1 Assessment of posterior occlusion. Normal occlusion (A, C) and defective occlusion (B, D) are illustrated. A and B: Tracings of the coronal slices of CBCT scans passing through the mandibular molar furcation points. C and D: Buccal and lingual views of posterior occlusion, represented on the digital models.

perpendicular to the horizontal and vertical planes). Following reorientation, voxel-based superimposition of T0, T1, and T2 images was conducted using stable cranial structures from the anterior cranial base and forehead.[14]

Linear and angular measurements on CBCT images

Following superimposition, measurements were performed using Amira software. The coordinate origin was defined at Basion (0,0,0), with the axes set as follows: X-axis (left—-right, positive to the left), Y-axis (anteroposterior, positive posteriorly), and Z-axis (vertical, positive superiorly). Anatomical landmarks were digitized at each time point, and linear and angular measurements were calculated using Microsoft Excel.

Measurement items and definitions are provided in Table 1 and illustrated in Fig. 2. Cephalometric variables included SNA, SNB, ANB, SN-MP angle, Wits appraisal, and menton deviation. Transverse arch widths, including maxillary and mandibular widths, were defined as the distance between the root furcation points of the bilateral first molars in the maxillary and mandibular arches, respectively. Molar inclination was measured as the angle between the tooth's long axis (line connecting the central groove and root furcation) and a true vertical line (TVL) at midsagittal plane (Fig. 2A). Buccal inclination was recorded as positive; palatal or lingual inclination as negative. Molars on the same side as menton deviation were designated as the deviated (D) side, and those on the opposite side as the non-deviated (ND) side (Fig. 2B). For mandibular molar inclination, local superimposition of T1 onto T0 was performed using the mandibular inferior border and submental region to isolate dental changes from mandible repositioning during pre-surgical orthodontic treatment (Fig. 2C). Mandibular molar inclination changes from T0 to T1 were then measured relative to the mandibular reference line (MRL), defined by the bilateral mental foramina (Fig. 2D).

Reliability

Intra-observer reliability was evaluated using intraclass correlation coefficients (ICCs). CBCT measurements were repeated twice on 10 randomly selected subjects with a 2-week interval. All ICCs ranged from 0.935 to 0.999, indicating excellent measurement reliability.

Statistical analysis

Statistical analyses were performed using SPSS version 25 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to compare Groups 1 and 2 at each time point (T0, T1, T2). Data are expressed as median and interquartile range. Categorical variables were analyzed using the Chi-square test, while continuous variables were assessed using the Mann—Whitney U test. Logistic regression was performed to identify significant predictors of post-treatment occlusal outcomes, and receiver operating characteristic (ROC) analysis was applied to determine cutoff values for the significant variables. A P-value of <0.05 was considered statistically significant.

Results

Baseline characteristics

Of the 75 initially screened patients, 51 met the inclusion criteria (24 males, 27 females; mean age: 22.29 $\pm$ 4.71 years). Based on posterior occlusal status at T2, the patients were assigned to Group 1 (normal occlusion, n = 38) or Group 2 (defective occlusion, n = 13). Group 1 included the patients with normal occlusion on both side; while Group 2 included the patients with defective occlusion on one side or both sides.

The baseline characteristics of the two patient groups at T0 are summarized in Table 2. Group 2 exhibited significantly greater amount of maxillary arch crowding and longer overall treatment time compared to Group 1 ($P < 0.05$). Significant intergroup differences were also observed for cephalometric measurements at T0, including SN-MP, Wits appraisal, maxillary width, maxillary transverse discrepancy (MTD), and molar inclinations (U6 to TVL-ND, and L6 to TVL-ND) (Table 3). Compared to Group 1, Group 2 demonstrated more severe Class III skeletal discrepancy,

Table 1 Definitions of cephalometric variables.

Cephalometric variables	Definition
Skeletal measurements	
ANB (°)	Angle between NA line and NB line
SN−MP (°)	Angle between SN plane and mandibular plane
Wits appraisal (mm)	Distance between pointA and pointB projected onto functional occlusal plane
Mn deviation (mm)	Distance between point Menton and midsagittal plane
Maxillary width (mm)	Maxillary width, distance between the trifurcations of bilateral maxillary first molars
Mandibular width (mm)	Mandibular width, distance between the bifurcations of bilateral mandibular first molars
Maxillary transverse discrepancy (MTD)	Value of maxillary width minus mandibular width
Dental measurements[a]	
U6 to TVL−D, U6 to TVL−ND (°)	Angle between maxillary first molar axis and true vertical line (TVL) atD side and ND side
U6 to TVL-sum	Sum ofU6 to TVL−D and U6 to TVL −ND
L6 to TVL−D,L6 to TVL−ND (°)	Angle between mandibular first molar axis and TVL atD side and ND side
L6 to TVL-sum	Sum ofL6 to TVL−D andL6 to TVL −ND
L6 to MRL−D,L6 to MRL−ND (°)	Angle between mandibular first molar axis and mandibular reference line (MRL) atD side and ND side
L6 to MRL-sum	Sum ofL6 to MRL−D andL6 to MRL −ND

Abbreviations: U6, Maxillary first molar; L6, Mandibular first molar; TVL, true vertical line at midsagittal plane (frontal view); MRL, Line connecting bilateral mental foramina; D, deviated side; ND: non-deviated side.

[a] Positive values indicate buccal inclination and vice versa.

greater facial divergence, narrower maxillary arch, more maxillary transverse discrepancy and compensatory molar inclination. Group 2 presented significantly more buccal inclination of maxillary first molars on the non-deviated side compared to Group 1, as shown by the measurements U6 to TVL-ND. Moreover, the significant intergroup difference in L6 to TVL-ND indicated a more lingual inclination of mandibular first molar on the non-deviation side in Group 2 compared to Group 1.

Treatment outcome and treatment change

Table 4 presents the data at T1 and the changes from T0 to T1. At T1, significant intergroup differences persisted in several skeletal parameters, including SN-MP, Wits appraisal, maxillary width, and MTD. Although the changes in molar inclination did not reach statistical significance, Group 2 exhibited a greater degree of transverse dental decompensation from T0 to T1, i.e. in the pre-surgical orthodontic phase. Specifically, the buccal inclination of maxillary first molars on the non-deviated side (U6 to TVL-ND) decreased more in Group 2 than in Group 1 (−4.31° vs. −1.17°). The lingual inclination of mandibular first molars on the non-deviated side (L6 to TVL-ND) increased by 8.00° in Group 2 compared to 2.00° in Group 1. Furthermore, the total bilateral axial changes in mandibular molar inclination were 11.00° for Group 2 and 3.00° for Group 1. As to post-treatment (T2) comparison (Table 3), the significant intergroup differences remained for SN-MP, maxillary width, and MTD, with Group 2 exhibiting greater facial divergence, narrower maxillary arch, and persistent maxillary transverse discrepancy. No statistically significant differences in dental measurements were noted at T2, indicating the comparable molar inclinations between the two groups after treatment.

Logistic regression analysis

Univariate logistic regression identified 14 variables as significant predictors of post-treatment occlusal outcomes. These included maxillary crowding, U6 to TVL-ND, L6 to TVL-ND, SN-MP, Wits appraisal, maxillary width, and MTD at T0; SN-MP, Wits appraisal, maxillary width, and MTD at T1; as well as changes in molar inclinations from T0 to T1, ΔT1-T0_U6 to TVL-ND, ΔT1-T0_L6 to MRL-ND, andΔT1-T0_L6 to MRL-sum (Table 5). Based on clinical relevance and collinearity analysis, six variables were selected for multivariate logistic regression: maxillary arch crowding, SN-MP and Wits appraisal at T0, U6 and L6 to TVL-ND at T0, and MTD at T1. Ultimately, Wits appraisal at T0 and MTD at T1 emerged as significant independent predictors (Table 6). Controlling for MTD at T1, each 1-mm increase in Wits appraisal at T0 increased the likelihood of achieving normal posterior occlusion by 1.55 times. Conversely, controlling for Wits appraisal at T0, each 1-mm increase in MTD at T1 increased the odds by 2.07 times. The final multivariate model demonstrated high predictive accuracy (AUC = 0.95). The cutoff values for Wits appraisal at T0 and MTD at T1 were −13.69 mm and −3.47 mm, respectively, as determined by ROC analysis.

Discussion

We developed a multivariate logistic regression model incorporating the Wits appraisal at T0 and maxillary transverse discrepancy (MTD) at T1 to predict post-treatment posterior occlusion in Class III patients undergoing two-jaw orthognathic surgery combined with orthodontic treatment. The Wits appraisal, rather than the ANB angle, emerged as the most reliable variable for distinguishing Class III severity in this study. Unlike the ANB angle, the Wits appraisal is less affected by cranial base inclination and provides a more direct assessment of sagittal jaw relationship.[15,16] Our results showed that higher Wits appraisal at T0 and greater MTD at T1 were both associated with an increased likelihood of achieving normal posterior occlusion. Therefore, transverse maxillary deficiency must

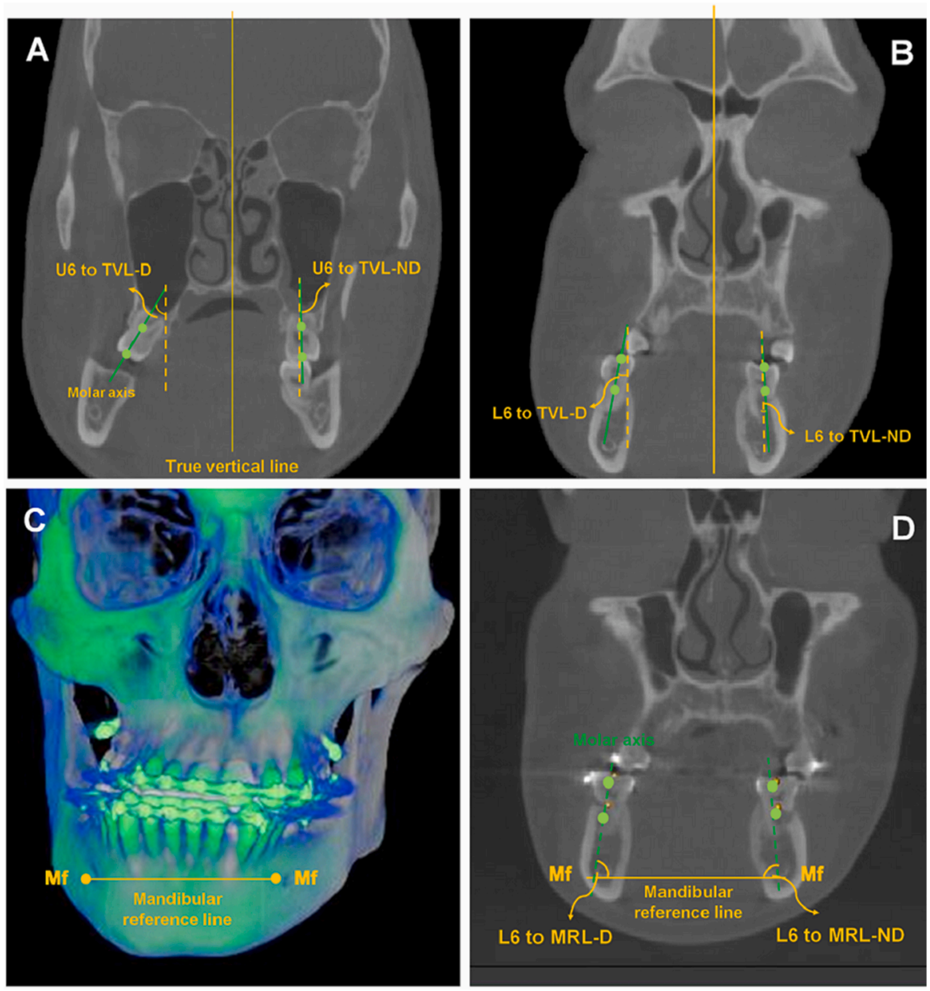

Figure 2 Measurements of maxillary and mandibular molar inclinations. (A) Angles between the long axes of the maxillary molars and the true vertical line (TVL) at midsagittal plane (frontal view). (B) Angles between the long axes of the mandibular molars and the TVL. (C) Volumetric superimposition of the mandibles at pre-treatment (T0) and pre-surgery (T1). (D) Angles between the long axes of the mandibular molars and the MRL were measured to assess changes in mandibular molar inclination from T0 to T1. Abbreviations: D, deviation side; ND: non-deviation side; MRL, mandibular reference line connecting the bilateral mental foramina (Mf).

be thoroughly addressed, particularly in patients with severe sagittal discrepancy. Based on our statistical analysis, a Wits appraisal at T0 < -13.69 mm and a MTD at T1 < -3.47 mm were significantly associated with an increased risk of post-treatment defective occlusion. These thresholds may help identify patients at higher risk for unfavorable outcomes and highlight the importance of comprehensive skeletal evaluation prior to treatment planning.

Class III malocclusion is commonly associated with maxillary crowding, incisor proclination, and buccal tipping of the posterior teeth.[3,7,17] In these patients, deficient transverse maxillary development is closely related to dental crowding and often requires maxillary expansion.[17,18] Furthermore, vertical facial patterns can exert a significant influence on transverse jaw development.[19] In this study on Class III patients who completed surgical-orthodontic treatment, those with defective posterior occlusion (Group 2) exhibited greater facial divergence, narrower maxillary arch, more pronounced maxillary transverse discrepancy, and lower Wits appraisal compared to those with normal occlusion (Group 1). Pre-treatment intergroup differences in SN-MP, Wits, maxillary width, and MTD underscore the heterogeneity in skeletal morphology and Class III severity among patients.

In untreated individuals with normal occlusion, the maxillary first molars have been reported to exhibit a buccal inclination of $5.3° \pm 6.2°$, whereas the mandibular first molars show a lingual inclination of $-14.4° \pm 5.2°$. Both inclinations are correlated with transverse arch dimensions.[20] Previous studies have demonstrated that transverse dental compensation is closely associated with the underlying skeletal pattern.[21–23] When planning surgical correction of skeletal transverse discrepancies in Class III patients, careful consideration should be given to the inclination of the maxillary first molars.[24] In the present study, Group 2 exhibited greater changes in molar inclination on the non-deviation side during pre-surgical orthodontic treatment, indicating a more pronounced decompensation response. However, post-treatment molar

Table 2 Baseline characteristics of patients in the two groups.

Variable[a]	Group 1 (Normal occlusion) n = 38	Group 2 (Defective occlusion) n = 13	*P*-value[c]
Gender (male/female)	20/18	4/9	NS
Facial asymmetry (Y/N)[b]	24/14	6/7	NS
Molar crossbite (Y/N)	21/17	10/3	NS
Extraction (Y/N)	16/22	4/9	NS
Le Fort I (3-/1-piece)	14/24	4/9	NS
Age (years)	23.00 ± 5.09	22.84 ± 5.15	NS
Maxillary arch crowding (mm)	2.66 ± 3.66	8.46 ± 5.71	0.000
Preoperative orthodontics (months)	12.45 ± 5.16	15.46 ± 7.44	NS
Postoperative orthodontics (months)	13.16 ± 5.53	16.00 ± 7.03	NS
Total treatment time (months)	26.18 ± 6.75	31.69 ± 8.97	0.041

Abbreviations: Y, Yes; N, No; NS, non-significant.
[a] Data are expressed as the number of patients or mean ± standard deviation.
[b] Menton deviation ≥2 mm.
[c] Mann–Whitney U test; *P*-values that reached statistical significance (<0.05) are shown.

inclinations were comparable between the two groups, suggesting that transverse dental decompensation was effective and played a crucial role in correcting jaw deviation in Class III facial asymmetry.

In this study, some patients underwent maxillary premolar extractions to relieve crowding or facilitate dental decompensation, followed by either a one-piece or three-piece Le Fort I osteotomy. In Group 1, those who underwent maxillary premolar extraction ultimately achieved a stable Class II molar relationship. The post-treatment MTD was −1.0 mm in Group 1 patients with a Class I molar relationship and −3.25 mm in those with a Class II molar relationship (data shown in the Supplemental Table). These findings underscore the clinical importance of evaluating both transverse discrepancies and molar classification during treatment planning. An MTD of −3.25 mm may represent a threshold for considering transverse correction in non-segmental Le Fort I surgery among patients requiring maxillary premolar extraction.

Temporary anchorage devices applied for posterior teeth distalization can effectively create space for crowding relief and pre-surgical orthodontic decompensation, while preserving or augmenting maxillary arch width.[25–27] Evidence indicates that miniscrew-assisted rapid palatal expansion is a clinically acceptable approach in young adults, and it may therefore be employed as an adjunct in the management of maxillary transverse deficiency prior to orthognathic surgery in patients with skeletal Class III malocclusion.[28–30] In the present study, Group 1 demonstrated significantly less maxillary arch crowding compared with Group 2, a finding consistent with the greater maxillary widths observed in the former. Nevertheless, no significant intergroup differences were identified in the frequency of maxillary premolar extraction or the use of a segmental approach during maxillary surgery. Notably, the three-piece Le Fort I osteotomy offers a reliable approach for comprehensive three-dimensional repositioning of the maxilla, including the correction of transverse discrepancies.[31] However, in our study, the segmentation of Le Fort I osteotomy did not significantly affect occlusal

Table 3 Comparison of measurements between the two groups at pre-treatment (T0) and post-treatment (T2).

Cephalometric variable	T0 Group 1 (n = 38)	T0 Group 2 (n = 13)	T0 *P*-value[a]	T2 Group 1 (n = 38)	T2 Group 2 (n = 13)	T2 *P*-value[a]
	Median (interquartile range)			Median (interquartile range)		
SNA	84.00 (5.00)	84.00 (2.00)	NS	85.00 (4.00)	86.00 (6.00)	NS
SNB	87.00 (5.00)	89.00 (5.00)	NS	83.50 (5.00)	83.00 (4.00)	NS
ANB	−3.00 (4.00)	−5.00 (3.00)	NS	2.00 (3.00)	3.00 (1.00)	NS
SN-MP	32.00 (9.00)	37.00 (9.00)	0.015	36.50 (6.00)	41.00 (4.00)	0.017
Wits appraisal	−10.35 (5.99)	−16.38 (3.54)	0.000	−4.94 (3.71)	−5.76 (1.53)	NS
Menton deviation	1.72 (6.17)	2.00 (1.79)	NS	0.49 (3.14)	1.11 (2.90)	NS
Maxillary width	46.95 (3.28)	43.32 (2.16)	0.000	46.53 (2.79)	44.70 (2.71)	0.018
Mandibular width	48.68 (2.87)	49.94 (3.46)	NS	48.75 (2.29)	48.99 (2.14)	NS
MTD	−1.90 (3.56)	−6.17 (2.71)	0.001	−2.04 (3.12)	−4.05 (2.86)	0.013
U6 to TVL–ND	5.01 (10.35)	12.08 (9.47)	0.015	4.07 (5.22)	3.71 (5.28)	NS
U6 to TVL–D	13.58 (11.74)	12.97 (13.74)	NS	3.72 (3.97)	1.72 (5.01)	NS
U6 to TVL-sum	21.22 (17.41)	24.88 (21.50)	NS	7.21 (9.55)	6.39 (13.92)	NS
L6 to TVL–ND	−14.70 (10.02)	−20.83 (16.23)	0.041	−11.08 (5.67)	−9.94 (9.69)	NS
L6 to TVL–D	−17.68 (10.28)	−16.27 (10.65)	NS	−12.67 (5.72)	−7.76 (9.28)	NS
L6 to TVL-sum	−34.00 (16.56)	−38.71 (21.31)	NS	−22.54 (8.27)	−19.21 (7.35)	NS

Abbreviations: T0, pre-treatment; T2, post-treatment; MTD, Maxillary transverse discrepancy; U6, Maxillary first molar; L6, Mandibular first molar; TVL, true vertical line at midsagittal plane (frontal view); D, deviated side; ND: non-deviated side; NS, non-significant.
[a] Mann–Whitney U test; *P*-values that reached statistical significance (<0.05) are shown.

Table 4 Comparison of the two groups at pre-surgery (T1) and in the changes from T0 to T1 (ΔT1—T0).

Cephalometric variable	T1			ΔT1-T0		
	Group 1 (n = 38)	Group 2 (n = 13)	*P*-value[a]	Group 1 (n = 38)	Group 2 (n = 13)	*P*-value[a]
	Median (interquartile range)			Median (interquartile range)		
SNA	84.00 (5.00)	84.00 (2.00)	NS	0.00 (0.00)	0.00 (0.00)	NS
SNB	87.00 (5.00)	88.00 (4.00)	NS	0.00 (2.00)	0.00 (1.00)	NS
ANB	−2.00 (4.00)	−3.00 (3.00)	NS	0.00 (2.00)	1.00 (1.00)	NS
SN-MP	33.00 (10.00)	38.00 (7.00)	0.012	0.00 (1.00)	0.00 (1.00)	NS
Wits appraisal	−10.67 (6.71)	−16.61 (3.93)	0.000	−0.05 (2.08)	−0.17 (2.00)	NS
Menton deviation	1.69 (5.90)	1.62 (1.93)	NS	−0.21 (1.20)	−0.06 (1.18)	NS
Maxillary width	47.43 (3.53)	43.98 (1.14)	0.001	0.22 (1.38)	0.02 (2.71)	NS
Mandibular width	48.88 (2.56)	50.05 (2.59)	NS	−0.09 (1.50)	0.19 (1.10)	NS
MTD	−1.48 (3.18)	−5.44 (2.25)	0.001	0.43 (2.01)	0.24 (1.66)	NS
U6 to TVL—ND	5.81 (9.10)	8.73 (6.49)	NS	−1.17 (7.06)	−4.31 (4.95)	0.019
U6 to TVL—D	6.74 (8.35)	10.38 (10.65)	NS	−3.03 (7.55)	−5.33 (7.10)	NS
U6 to TVL-sum	13.03 (13.65)	20.62 (12.65)	NS	−3.36 (7.80)	−10.24 (13.36)	NS
L6 to TVL—ND	−11.77 (10.61)	−10.98 (5.36)	NS	2.00 (8.00)[b]	8.00 (14.00)[b]	0.001
L6 to TVL—D	−13.32 (9.86)	−13.06 (12.17)	NS	3.00 (7.00)[b]	3.00 (10.00)[b]	NS
L6 to TVL-sum	−24.72 (17.56)	−24.93 (9.44)	NS	3.00 (17.00)	11.00 (24.00)	0.037

Abbreviations: T1, pre-surgery; ΔT1-T0, change from T0 to T1; MTD, Maxillary transverse discrepancy; U6, Maxillary first molar; L6, Mandibular first molar; TVL, true vertical line at midsagittal plane (frontal view); D, Deviated side; ND: Non-deviated side; NS, non-significant.
[a] Mann—Whitney U test; *P*-values that reached statistical significance (<0.05) are shown.
[b] Measurements obtained relative to mandibular reference line (MRL).

Table 5 Significant variables identified in univariate logistic regression analysis.

Variable	OR (95 % CI)	*P*-value[a]
Maxillary arch crowding	0.77 (0.65—0.91)	0.002
U6 to TVL—ND atT0	0.88 (0.79—0.98)	0.016
L6 to TVL—ND at T0	1.08 (1.01—1.15)	0.036
SN-MP at T0	0.87 (0.77—0.99)	0.029
Wits appraisal at T0	1.32 (1.09—1.59)	0.003
Maxillary width at T0	1.61 (1.19—2.19)	0.002
MTD at T0	1.50 (1.16—1.94)	0.002
SN-MP at T1	0.87 (0.77—0.98)	0.020
Wits value at T1	1.32 (1.09—1.60)	0.003
Maxillary width at T1	1.65 (1.18—2.31)	0.003
MTD at T1	2.63 (1.19—2.20)	0.002
ΔT1-T0_U6 to TVL—ND	1.18 (1.03—1.35)	0.019
ΔT1-T0_L6 to MRL—ND	0.88 (0.79—0.97)	0.008
ΔT1-T0_L6 to MRL-sum	0.95 (0.90—0.99)	0.027

Abbreviations: OR, odds ratio; CI, confidence interval; MTD, Maxillary transverse discrepancy; T1, pre-surgery; ΔT1-T0, change from T0 to T1; MTD, Maxillary transverse discrepancy; U6, Maxillary first molar; L6, Mandibular first molar; TVL, true vertical line at midsagittal plane (frontal view); MRL, mandibular reference line; D, Deviated side; ND: Non-deviated side.
[a] *P*-values that reached statistical significance (<0.05) are shown.

outcomes. The procedure may have been undertaken for purposes other than transverse expansion, such as differential impaction of the posterior segments or pitch rotation of the anterior segment.

Table 6 Statistical significance of variables in the multivariate logistic regression model.

Variable	OR (95 % CI)	*P*-value[a]
Maxillary arch crowding	0.790 (0.62—1.01)	NS
SN-MP at T0	0.89 (0.70—1.13)	NS
Wits appraisal at T0	1.55 (1.14—2.18)	0.011
U6 to TVL—ND atT0	1.06 (0. 95-1.19)	NS
L6 to TVL—ND at T0	1.03 (0.86—1.24)	NS
MTD at T1	2.07 (1.02—4.24)	0.045

Abbreviations: OR, odds ratio; CI, confidence interval; MTD, Maxillary transverse discrepancy; T0, pre-treatment; T1, pre-surgery; MTD, Maxillary transverse discrepancy; U6, Maxillary first molar; L6, Mandibular first molar; TVL, true vertical line at midsagittal plane (frontal view); NS, non-significant.
[a] *P*-values that reached statistical significance (<0.05) are shown.

Dental crowding and proclination of the incisors were common features in the maxillary arch of Class III patients with maxillary transverse deficiency. For pre-surgical orthodontic decompensation, bilateral maxillary premolar extraction may be a useful strategy to relieve crowding, establish proper incisor inclination, and improve the buccolingual inclination of posterior teeth.[7] However, premolar extraction may also reduce arch width and exacerbate maxillary transverse discrepancy. In this study, the Wits appraisal at T0 and MTD at T1 were identified as significant predictors of post-treatment occlusion through multivariate logistic regression analysis. These findings should be interpreted with caution, as the limited sample size may restrict generalizability. Future studies with larger sample sizes and longer follow-up periods are needed to validate these predictors.

In conclusion, pre-treatment Wits appraisal and pre-surgical maxillary transverse discrepancy are significant predictors of post-treatment occlusion in Class III patients undergoing surgical-orthodontic treatment. Careful consideration of these factors during treatment planning may enhance the likelihood of achieving favorable occlusal outcomes.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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Appendix A. Supplementary data

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