Original Article

Mandibular asymmetry types and differences in dental compensations of Class III patients analyzed with cone-beam computed tomography

Ho-Jin Kim[a]; Hyung-Kyu Noh[a]; Hyo-Sang Park[b]

ABSTRACT

Objectives: To assess differences in dental compensation of the incisors and first molars in skeletal Class III patients with roll-, yaw-, and translation-dominant mandibular asymmetries.

Materials and Methods: A total of 90 skeletal Class III adult patients (mean age, 22.00 ± 3.31 years; range, 18–37.9 years) with facial asymmetry were enrolled and divided into the roll-, yaw-, and translation-dominant type groups (n = 30 per group). The vertical, transverse, and anteroposterior distances and axial angles of the teeth were measured using cone-beam computed tomography images. The measurements were compared between the deviated and nondeviated sides using a paired *t*-test and among the three groups using one-way analysis of variance with a Tukey post hoc test.

Results: The roll-dominant groups showed the greatest values for the bilateral difference in the vertical position of the maxillary (2.42 ± 1.24 mm) and mandibular molars (2.23 ± 1.28 mm; $P < .001$). The transverse deviations of the maxillary (2.19 ± 1.51 mm) and mandibular incisors (−2.11 ± 1.39 mm) were greater in the yaw-dominant groups than those of other groups. Regarding tooth axial angle, the yaw-dominant group showed the greatest tipping of the mandibular incisor (−4.13 ± 3.30°; $P < .001$).

Conclusions: Dental compensation differed depending on the type of facial asymmetry. The roll-dominant type showed more vertical compensation of the posterior teeth, whereas the yaw-dominant type exhibited more tipping of the molars and incisors. By precisely assessing dental compensation in each asymmetry type, sufficient dental decompensation could be achieved. (*Angle Orthod*. 2023;93:695–705.)

KEY WORDS: Dental compensation; Mandibular asymmetry; Roll-, yaw-, and translation-dominant types

INTRODUCTION

Because of the increasing interest and demand in patients to correct facial asymmetry, orthodontic and surgical modalities are constantly being developed to improve treatment results. The accurate diagnosis in skeletal discrepancies and dental compensations of the patients can provide a guide for sufficient dental decompensation relative to the planes of each jaw, and this can help in achieving orthognathic surgery with accurate symmetric positioning of the jaws relative to cranial reference planes. Tooth position may play a crucial role as a guide in determining jaw position during surgery; thus, the accomplishment of proper tooth positioning by sufficient decompensation is one of the most important aspects leading to a successful outcome.

Regarding dental compensations in facial asymmetry, previous studies have highlighted the buccoversion of the maxillary molars and linguoversion of the mandibular molars on the deviated side (Dv), extrusion of the maxillary molar on the nondeviated side (NDv), and incisor tipping.[1–6] In addition, these dental changes can be accentuated or lessened depending on the positional variations of bones, particularly the mandible.[3,4] The mandible can be shifted to one side or rotated around horizontal and/or coronal planes, also known as roll or yaw rotation, and this can lead to different amounts and compositions of vertical, rotational, and transverse dental compensations of the maxillary and mandibular dentitions. Previous

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three-dimensional (3D) computed tomography studies have attempted to categorize the types of asymmetry.[7–9] However, detailed categorization methods were not provided or their classifications were based on only horizontal aspects of the mandible. With these methods, specific features of dental compensation of each type could not be characterized fully. Therefore, the categorization based on 3D rotation generally used in orthodontics, such as rolling or yawing, can be more effective in representing characteristics of mandibular asymmetries. A detailed understanding of dental compensations according to well-categorized asymmetry types may play a crucial role in the successful treatment of facial asymmetry.

Therefore, to clarify dental compensations based on different asymmetry types, this study investigated the distances (vertical, transverse, and anteroposterior) and angles of the incisors and first molars in skeletal Class III patients with roll-, yaw-, and translation-dominant type mandibular asymmetries. The null hypothesis was that there would be no significant difference in dental compensation among the three mandibular asymmetry types.

MATERIALS AND METHODS

This retrospective study was approved by the institutional review board of Kyungpook National University Dental Hospital (KNUDH 2022-08-01-00).

The necessary sample size was calculated based on a previous cone-beam computed tomography (CBCT) study[3] on skeletal and dental variables in patients with facial asymmetry using G*power (version 3.1.9.7; Heinrich Heine University of Düsseldorf, Düsseldorf, Germany). With a two-tailed significance level of .05, an effect size of 0.75, and a test power of 0.80, the estimated sample size was calculated to be at least 29 patients in each group; thus, to increase the power of this research, 30 patients were assigned to each group.

The inclusion criteria were patients with skeletal Class III relationship (Point A-nasion-point B angle [ANB] $< 0°$), no congenitally missing teeth except for the third molars, no dental prosthesis, no spacing, and tooth size–arch length discrepancy <3 mm. The exclusion criteria included patients with a history of prior orthodontic treatment, orthognathic surgery, or craniofacial syndrome or trauma.

This study comprised a total of 90 patients (63 men, 27 women; mean age, 22.00 $\pm$ 3.31 years; range, 18–37.9 years) with facial asymmetry ($>$4 mm menton [Me] deviations relative to the midsagittal plane [MSP]) who were diagnosed in the Department of Orthodontics at Kyungpook National University Dental Hospital, Daegu, Korea, between January 2010 and December 2021.

The sample was divided into three groups based on the extent of mandibular rolling (the angle between the mandibular horizontal plane [MHP] and Frankfort horizontal plane [FHP]) and yawing (the angle between the mandibular midsagittal plane [MnMSP] and MSP). The roll-dominant group included patients with moderate-to-high mandibular rolling ($\geq$5° between the MHP and FHP) and low mandibular yawing ($<$3° between the MnMSP and MSP); the yaw-dominant group included patients with moderate-to-high mandibular yawing ($\geq$5° between the MnMSP and MSP) and low mandibular rolling ($<$3° between the MHP and FHP); and, finally, the translation-dominant group included patients with low mandibular rolling and yawing ($<$3° between the MHP and FHP and $<$3° between the MnMSP and MSP) and $>$4 mm mental foramen (MF)–mid deviation relative to the MSP (Figure 1).

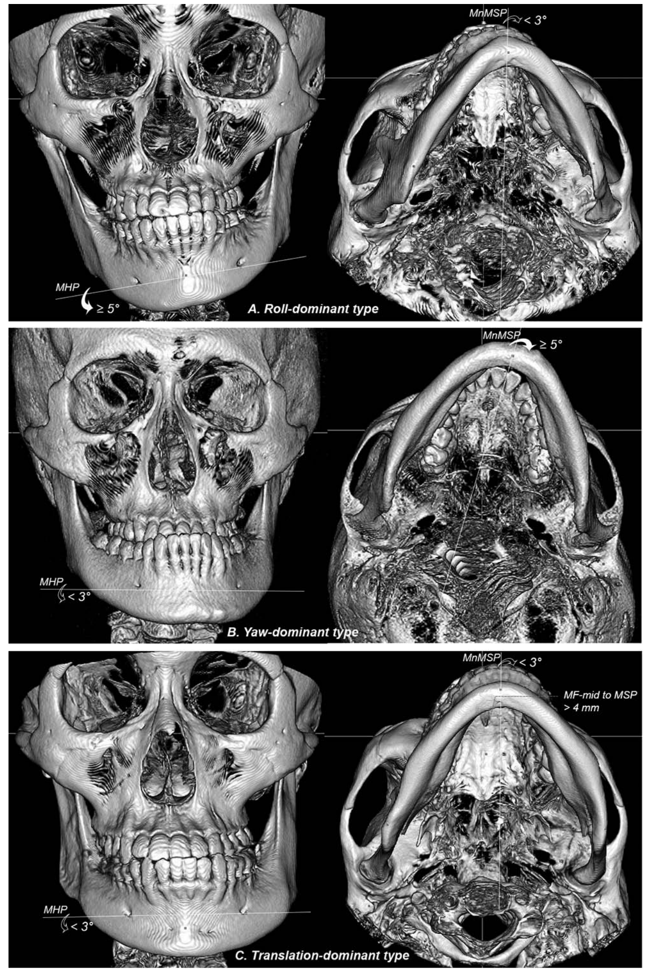

Figure 1. Mandibular asymmetry types investigated in this research. A, Roll-dominant type ($\geq$5° between the MHP and FHP; $<$3° between the MnMSP and MSP). B, Yaw-dominant type ($\geq$5° between the MnMSP and MSP; $<$3° between the MHP and FHP). C, Translation-dominant type ($<$3° between the MHP and FHP; $<$3° between the MnMSP and MSP; $>$4 mm between the MF-mid and MSP). FHP indicates Frankfort horizontal plane; MF-mid, midpoint of bilateral mental foramen; MHP, mandibular horizontal plane; MnMSP, mandibular midsagittal plane; and MSP, midsagittal plane.

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Table 1. Landmarks and Reference Planes[a]

Landmark	Definition
Or	The most inferior point of the lower orbital margin
Po	The most superior point of the external auditory meatus
Cg	The most superior point on the crista galli
Op	The midpoint of the posterior border of the foramen magnum
Go	The most inferior point of gonial angle on the lateral view
Cd	The most superior point of the condylar head
Me	The most inferior point on the symphyseal outline
MF	The most inferior point of the mental foramen
MF-mid	The midpoint between the MF of both sides
PM	The point where the curvature changes from concave to convex at the most anterior symphyseal border
UM	The central fossa of the maxillary first molar
UI-mid	The midpoint between the maxillary central incisor edge of both sides
LM	The central fossa of the mandibular first molar
LI-mid	The midpoint between the mandibular central incisor edges of both sides
Reference Plane	
Frankfort horizontal plane (FHP)	The plane passing by Po of both sides and right Or
Midsagittal plane (MSP)	The plane passing by Cg and Op, perpendicular to the FHP
Coronal plane	The plane passing by Cg, perpendicular to the FHP and MSP
Mandibular horizontal plane (MHP)	The plane passing by MF of both sides and PM
Mandibular midsagittal plane (MnMSP)	The plane passing by Me and MF-mid, perpendicular to the MHP
Mandibular coronal plane	The plane passing by Me, perpendicular to the MHP and MnMSP

[a] Cd indicates condylion; Cg, crista galli; Go, gonion; Me, menton; MF, mental foramen; Op, opisthion; Or, orbitale; PM, protuberance menti; and Po, porion.

The CBCT scans (120 kVp, 15 mA, 19-cm field of view, 0.377-mm voxel size, 9.6-second scan time) were acquired using a computed tomography scanner (CB MercuRay, Hitachi, Osaka, Japan). All measurements were assessed using Invivo 6 Anatomy imaging software (Anatomage, San Jose, Calif).

Definitions of landmarks and reference planes are described in Table 1 and Figure 2. The FHP and MSP were used as cranial reference planes in this study. For the mandible, the MHP and MnMSP were used to measure the angles of mandibular rolling or yawing and dental variables.

The skeletal variables were measured to compare the skeletal characteristics among the groups (Table 2, Figure 3). To investigate dental compensation, the distances (vertical, transverse, and anteroposterior) and angles of the central incisors and first molars of the jaws were measured relative to the reference planes (Table 2, Figures 4 and 5).

A single investigator (Dr Kim) performed all measurements, and 15 randomly selected patients were remeasured by the same investigator after 4 weeks. The intraclass correlation coefficient was 0.987 (mean; range, 0.976–0.998), and the Dahlberg errors

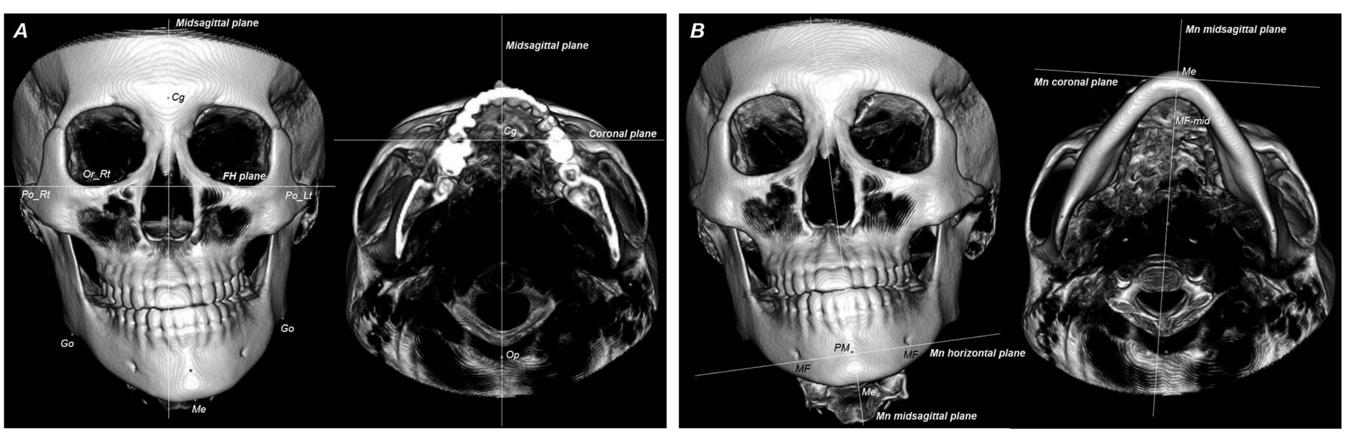

Figure 2. Landmarks and reference planes. A, Cranial reference planes. B, Mandibular reference planes. Cg indicates crista galli; FH, Frankfort horizontal; Go, gonion; Lt, left; Me, menton; MF, mental foramen; Mn, mandibular; Op, opisthion; Or, orbitale; PM, protuberance menti; Po, porion; and Rt, right.

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Table 2. Skeletal and Dental Variables Measured in This Study[a]

Variables	Definition
Skeletal	
Menton deviation	The distance between Me and MSP
Body length	The distance between Me and Go
Ramus height	The distance between Go and Cd
Ramus inclination	The angle between the ramus axial line (Cd-Go) and MSP
Cd to MSP	The distance between the Cd and MSP
Go to MSP	The distance between the Go and MSP
MF-mid to MSP	The distance between the MF-mid and MSP
∠MHP to FHP	The angle between the MHP and FHP (projected on the coronal plane)
∠MnMSP to MSP	The angle between the MnMSP and MSP (projected on the FHP)
Dental	
Vertical distance	
UM to FHP	The distance between the UM and FHP
LM to MHP	The distance between the LM and MHP
Transverse distance	
UM to MSP	The distance between the UM and MSP
UI-mid to MSP	The distance between the UI-mid and MSP
LM to MSP	The distance between the LM and MSP
LI-mid to MSP	The distance between the LI-mid and MSP
LM to MnMSP	The distance between the LM and MnMSP
LI-mid to MnMSP	The distance between the LI-mid and MnMSP
Anteroposterior distance	
UM to coronal plane	The distance between the UM and coronal plane
LM to mandibular coronal plane	The distance between the LM and mandibular coronal plane
Angle	
∠UM_axis to FHP	The angle between the UM_axis (long axis of the maxillary first molar connecting the UM and midpoint of root furcation) and FHP (projected on the coronal plane)
∠UI_axis to MSP	The angle between the UI_axis (long axis of the maxillary incisors connecting the UI-mid and midpoint of root tips) and MSP (projected on the coronal plane)
∠LM_axis to MHP	The angle between the LM_axis (long axis of the mandibular first molar connecting the LM and midpoint of root furcation) and MHP (projected on the mandibular coronal plane)
∠LI_axis to MnMSP	The angle between the LI_axis (long axis of the mandibular incisors connecting the LI-mid and midpoint of root tips) and MnMSP (projected on the mandibular coronal plane)

[a] Cd indicates condylion; FHP, Frankfort horizontal plane; Go, gonion; LI-mid, midpoint of the bilateral mandibular central incisor edges; LM, mandibular first molar; Me, menton; MF-mid, midpoint of bilateral mental foramen; MHP, mandibular horizontal plane; MnMSP, mandibular midsagittal plane; MSP, midsagittal plane; UI-mid, midpoint of the bilateral maxillary central incisor edges; and UM, maxillary first molar.

were 0.49 mm (mean; range, 0.32–0.58) and 0.78° (mean; range, 0.76–0.81). Because of the confirmation of the normality of data using the Kolmogorov–Smirnov test, one-way analysis of variance with a Tukey post hoc test was used to compare each variable of the three groups. A linear-by-linear association was used to compare the sex distribution of the sample among the groups. A paired *t*-test was used for the

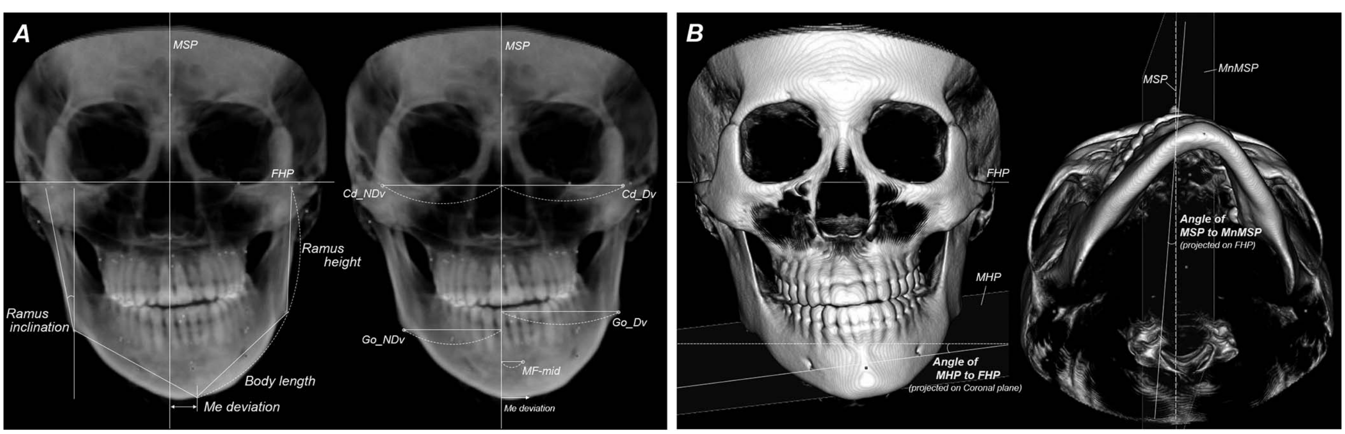

Figure 3. Skeletal measurements. A, Linear measurements and ramus inclination. B, Angular measurements between the reference planes. Cd indicates condylion; Dv, deviated side; FHP, Frankfort horizontal plane; Go, gonion; Me, menton; MF-mid, midpoint of bilateral mental foramen; MHP, mandibular horizontal plane; MnMSP, mandibular midsagittal plane; MSP, midsagittal plane; and NDv, nondeviated side.

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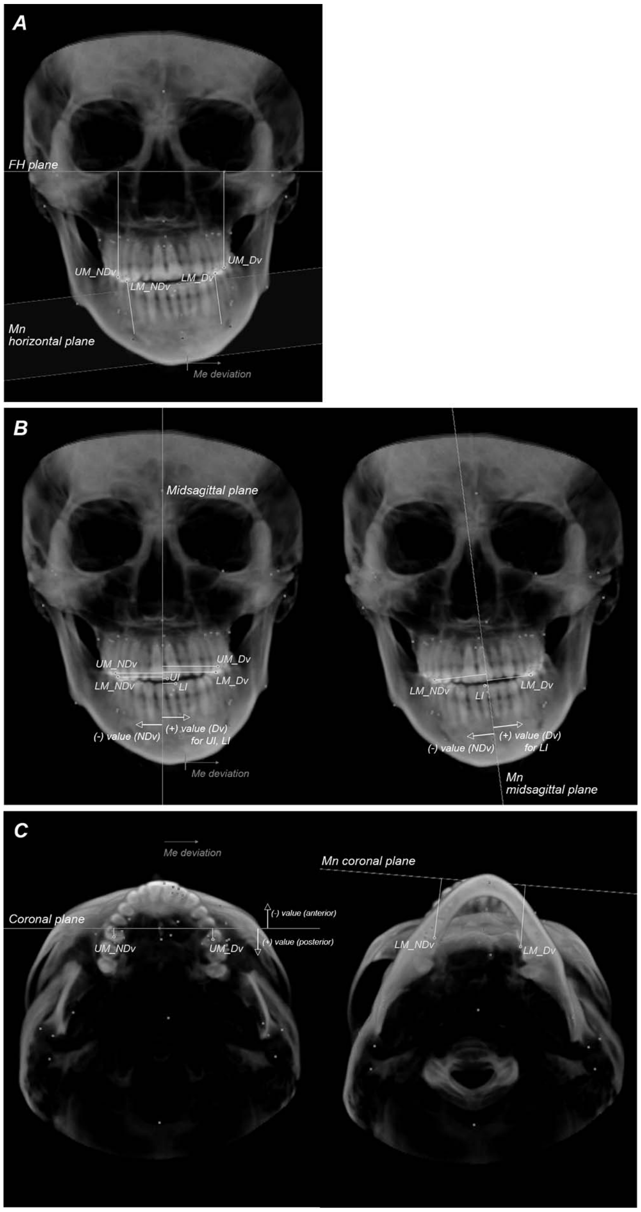

Figure 4. Dental linear measurements. A, Vertical distance. B, Transverse distance. C, Anteroposterior distance. Dv indicates deviated side; FH, Frankfort horizontal; LI, midpoint of the bilateral mandibular central incisor edges; LM, mandibular first molar; Me, menton; Mn, mandibular; NDv, nondeviated side; UI, midpoint of the bilateral maxillary central incisor edges; and UM, maxillary first molar.

comparison of the variables at the Dv and NDv. All statistical analyses were performed using SPSS statistical software (version 22; IBM, Chicago, Ill), and the significance level was set at $P < .05$.

RESULTS

The samples showed no significant difference in sex distribution, age, or cephalometric measurements among the three groups (Table 3).

Regarding 3D skeletal measurements (Table 4), the amount of Me deviation was significantly greater in the roll- and yaw-dominant groups (roll, 9.40 $\pm$ 2.94 mm; yaw, 8.65 $\pm$ 3.25 mm) compared with the translation-dominant group (6.24 $\pm$ 1.70 mm; $P < .01$). The roll-dominant group showed significantly greater values of the bilateral difference (ΔNDv$-$Dv) in ramus height (8.45 $\pm$ 3.73 mm) and angle between the MHP to FHP (6.45 $\pm$ 1.50°) than the other groups ($P < .001$). The yaw-dominant group exhibited significantly greater values of the ΔNDv$-$Dv in body length (5.40 $\pm$ 2.77 mm; $P < .001$) and angle between the MnMSP to MSP (7.63 $\pm$ 1.95°; $P < .001$) than the other groups. For the comparisons of bilateral measurements, all samples showed significant differences between the sides, excluding in the distance between the condylion and MSP.

Regarding the dental linear measurements (Table 5 and Figure 6), the roll-dominant groups showed significantly higher ΔNDv$-$Dv in the vertical distance of the maxillary (UM, 2.42 $\pm$ 1.24 mm) and mandibular first molars (LM, 2.23 $\pm$ 1.28 mm) than the yaw- and translation-dominant groups ($P < .001$). In a comparison of these measurements between the sides, the roll-dominant groups showed a significant difference in both jaws ($P < .001$); however, the other groups presented significance for the UM only ($P < .01$), not for the LM. Regarding the transverse dental distance relative to the MSP, the deviations of the midpoint of both maxillary (UI, 2.19 $\pm$ 1.51 mm) and mandibular incisor edges (LI, 6.62 $\pm$ 2.68 mm) were greater in the yaw-dominant groups than those of the other groups. The transverse distances of the UM and LM relative to the MSP were significantly longer at the Dv than those at the NDv in all samples ($P < .001$); however, the ΔNDv$-$Dv in the distance was not significantly different among the groups. Regarding the distance from the MnMSP, the yaw-dominant group showed the greatest amount of LI deviation toward the NDv ($-$2.11 $\pm$ 1.39 mm) among the three groups ($P < .001$). In addition, the LM distance at the Dv was significantly shorter than that at the NDv in all patients ($P < .01$); however, no significant difference in the ΔNDv$-$Dv of the LM distance was observed among the groups. For the anteroposterior distance relative to the coronal or mandibular coronal plane, no significant difference was found among the groups and between the sides, except for the LM distance from the mandibular coronal plane of the yaw-dominant group ($P < .001$). This indicated that the yaw-dominant group exhibited mesial and distal crown tipping of the mandibular molars at the Dv and NDv, respectively; however, not for the other groups.

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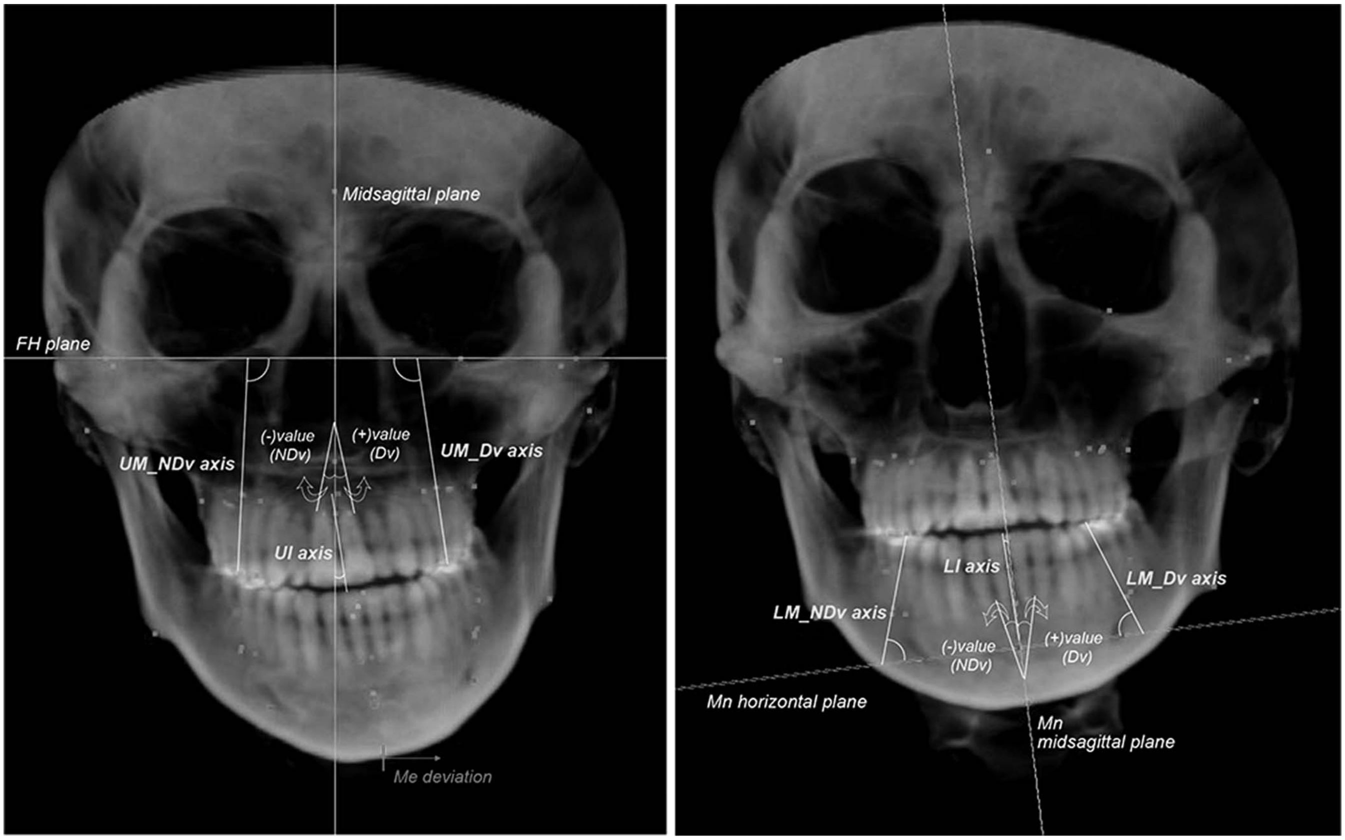

Figure 5. Dental angular measurements. Dv indicates deviated side; FH, Frankfort horizontal; LI, midpoint of the bilateral mandibular central incisor edges; LM, mandibular first molar; Me, menton; Mn, mandibular; NDv, nondeviated side; UI, midpoint of the bilateral maxillary central incisor edges; and UM, maxillary first molar.

Regarding tooth inclinations, tipping of the maxillary incisor was significantly greater in the roll-dominant group (3.22 ± 2.82°) than that of the translation-dominant group (1.07 ± 2.06°; $P = .01$). The maxillary first molar inclination at the Dv was significantly greater than that at the NDv in all groups ($P < .001$); however, there was no significant difference in the ΔNDv−Dv of the molar inclination among the groups. Based on the MnMSP and MHP, the yaw-dominant group yielded the greatest tipping of the mandibular incisor (−4.13 ± 3.30°) compared with the other groups ($P < .001$); the inclination of the mandibular first molar demonstrated a significantly lower value at the Dv than at the NDv ($P < .05$), indicating molar lingual tipping at the Dv. In addition, the roll-dominant group showed the lowest value of ΔNDv−Dv in the mandibular molar inclination (2.28 ± 4.84°) among all groups ($P < .001$; yaw, 9.05 ± 5.94°; translation, 6.83 ± 4.86°).

Table 3. Demographic Characteristics and Cephalometric Measurements of the Sample[a]

	Roll	Yaw	Translation	*P* Value
Demographic characteristics				
Sex				.401
Male (n)	20	23	20	
Female (n)	10	7	10	
Age (y)	21.70 ± 2.72	21.70 ± 2.94	22.50 ± 4.12	
Cephalometric measurements				
SNA (°)	81.18 ± 2.82	81.92 ± 2.32	81.80 ± 3.53	
SNB (°)	83.53 ± 2.85	84.95 ± 3.01	85.14 ± 3.92	
ANB (°)	−2.35 ± 1.91	−3.02 ± 2.57	−3.35 ± 2.39	
FMA (°)	27.11 ± 4.75	26.34 ± 5.87	24.45 ± 6.19	

[a] Values are mean ± standard deviation. Values in the same row with no superscript are not statistically significant and with different superscript letters are significantly different at $P < .05$ according to a one-way analysis of variance with a Tukey post hoc test. Linear-by-linear association was performed to compare the sex distribution between the groups. No significant difference was observed between the three groups. SNA, sella-nasion-point A angle; SNB, sella-nasion-point B angle; ANB, point A-nasion-point B angle; FMA, Frankfort-mandibular plane angle.

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Table 4. Differences in Three-Dimensional Skeletal Measurements Between the Dv and NDv and Among the Three Mandibular Asymmetry Groups[a]

	Roll		Yaw		Translation	
	Mean ± SD	*P* Value (Between the Sides)	Mean ± SD	*P* Value (Between the Sides)	Mean ± SD	*P* Value (Between the Sides)
Me deviation (mm)	9.40 ± 2.94[A]	–	8.65 ± 3.25[A]	–	6.24 ± 1.70[B]	–
Body length (mm)						
Dv	80.94 ± 6.01	< .001***	80.74 ± 4.32	< .001***	82.63 ± 4.52	< .001***
NDv	82.20 ± 6.19[A]		86.14 ± 4.24[B]		84.44 ± 5.29[AB]	
ΔNDv−Dv	1.26 ± 1.51[A]	–	5.40 ± 2.77[B]	–	1.81 ± 2.01[A]	–
Ramus height (mm)						
Dv	65.10 ± 6.18[A]	< .001***	68.86 ± 6.17[AB]	.018*	69.63 ± 7.01[B]	< .001***
NDv	73.56 ± 6.11		70.10 ± 5.04		71.75 ± 5.67	
ΔNDv−Dv	8.45 ± 3.73[A]	–	1.25 ± 2.71[B]	–	2.13 ± 2.61[B]	–
Ramus inclination (°)						
Dv	1.45 ± 2.89	< .001***	2.96 ± 2.46	.002**	2.83 ± 2.73	< .001***
NDv	7.10 ± 2.97		5.42 ± 3.69		6.45 ± 2.38	
ΔNDv−Dv	5.65 ± 3.41[A]	–	2.46 ± 4.02[B]	–	3.62 ± 3.26[AB]	–
MF mid to MSP (mm)	7.27 ± 2.59[A]	–	7.02 ± 2.97[AB]	–	5.58 ± 1.70[B]	–
Cd to MSP (mm)						
Dv	52.41 ± 3.23	.550	52.77 ± 3.02	.202	53.19 ± 3.55	.428
NDv	52.68 ± 3.66		53.60 ± 2.69		52.85 ± 2.76	
ΔNDv−Dv	0.28 ± 2.52	–	0.83 ± 3.48	–	−0.34 ± 2.32	–
Go to MSP (mm)						
Dv	51.30 ± 4.57	< .001***	49.58 ± 3.18	.002**	51.26 ± 4.03	< .001***
NDv	43.61 ± 4.24[A]		47.10 ± 4.08[B]		44.88 ± 3.18[AB]	
ΔNDv−Dv	−7.69 ± 4.34[A]	–	−2.48 ± 4.08[B]	–	−6.39 ± 3.59[A]	–
MHP to FHP (°)	6.45 ± 1.50[A]	–	0.09 ± 1.71[B]	–	0.91 ± 1.27[B]	–
MnMSP to MSP (°)	1.39 ± 1.46[A]	–	7.63 ± 1.95[B]	–	2.05 ± 0.76[A]	–

[a] Cd indicates condylion; Dv, deviated side; FHP, Frankfort horizontal plane; Go, gonion; Me, menton; MF-mid, midpoint of bilateral mental foramen; MHP, mandibular horizontal plane; MnMSP, mandibular midsagittal plane; MSP, midsagittal plane; NDv, nondeviated side; and SD, standard deviation. Values in the same row with no superscript are not statistically significant and with different superscript letters are significantly different at $P < .05$ according to a one-way analysis of variance with a Tukey post hoc test. Paired *t*-test was performed to compare the Dv and NDv.

* Significant difference at $P < .05$ between the Dv and NDv.

** Significant difference at $P < .01$ between the Dv and NDv.

*** Significant difference at $P < .001$ between the Dv and NDv.

DISCUSSION

This study investigated the amount of mandibular rolling and yawing to distinguish among the asymmetry types. The body length and ramus height or inclination used in previous studies[4,7] may not fully reflect the mandibular rolling or yawing because the position of the glenoid fossa may affect the mandibular asymmetry.[10–13] For this reason, in this study, the angles between the mandibular and cranial reference planes were used to accurately classify the mandibular asymmetry types. In addition, when establishing these mandibular planes, the mental foramen was used as the reference landmark in this study because of its reliability and stability.[3,14–18]

The roll-dominant group exhibited vertical dental compensation with the extruded posterior teeth at the NDv in both jaws (Figure 6A). Considering the angular dental compensation in the mandible in contrast to the maxilla, the tipping of the teeth toward the NDv was lesser in the roll-dominant group than in the other groups. Thus, it can be inferred that, by the mandibular rolling itself, the mandibular teeth tipped spontaneously toward the NDv; thus, the compensatory tipping of the teeth might be less. Accordingly, the transverse occlusal cant and maxillary tooth tipping should be a focus (Figure 7A). Particularly, in the maxilla, the canted-down molar should be intruded and tipped buccally using elastomeric thread from the buccal microimplant, and/or the canted-up molar should be extruded and tipped palatally using an auxiliary extrusion spring supported by the buccal microimplant or buccal intermaxillary elastics to the lingual button of the ipsilateral mandibular molar.[19] Notably, to achieve successful improvement in patients with roll-type asymmetry, the vertical dental discrepancies between the sides should be completely removed. If not, this may result in a remaining mandibular roll and unsatisfactory surgical outcomes.

The yaw rotation generally represents a large horizontal deviation in the anterior part of the mandible.

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Table 5. Differences in Three-Dimensional Dental Measurements Between the Dv and NDv and Among the Three Mandibular Asymmetry Groups[a]

	Roll		Yaw		Translation	
	Mean ± SD	*P* Value (Between the Sides)	Mean ± SD	*P* Value (Between the Sides)	Mean ± SD	*P* Value (Between the Sides)
Vertical distance						
UM to FHP						
Dv	49.57 ± 3.88	<.001***	50.36 ± 3.58	.001**	49.44 ± 4.30	.002**
NDv	51.99 ± 3.86		51.16 ± 3.83		50.19 ± 4.35	
ΔNDv−Dv	2.42 ± 1.24^{A}	–	0.80 ± 1.17^{B}	–	0.75 ± 1.23^{B}	–
LM to MHP						
Dv	24.85 ± 2.69	<.001***	25.37 ± 2.76	.060	25.37 ± 3.78	.397
NDv	27.08 ± 2.78^{A}		24.86 ± 2.91^{B}		25.13 ± 3.38^{B}	
ΔNDv−Dv	2.23 ± 1.28^{A}	–	−0.51 ± 1.42^{B}	–	−0.24 ± 1.53^{B}	–
Transverse distance						
UI to MSP	1.68 ± 1.52^{AB}	–	2.19 ± 1.51^{A}	–	1.06 ± 1.52^{B}	–
UM to MSP						
Dv	25.75 ± 2.52^{A}	<.001***	27.20 ± 2.32^{B}	<.001***	26.56 ± 2.17^{AB}	<.001***
NDv	22.46 ± 2.28		23.31 ± 2.30		22.50 ± 2.28	
ΔNDv−Dv	−3.28 ± 3.07	–	−3.89 ± 2.86	–	−4.06 ± 2.74	–
LI to MSP	4.59 ± 2.07^{A}	–	6.62 ± 2.68^{B}	–	4.71 ± 1.90^{A}	–
LM to MSP						
Dv	25.13 ± 2.57	<.001***	26.04 ± 2.70	<.001***	25.94 ± 2.54	<.001***
NDv	18.94 ± 2.10		18.59 ± 2.58		19.12 ± 2.12	
ΔNDv−Dv	−6.19 ± 3.76	–	−7.45 ± 4.10	–	−6.82 ± 3.49	–
LI to MnMSP	−0.40 ± 1.29^{A}	–	−2.11 ± 1.39^{B}	–	−0.95 ± 1.05^{A}	–
LM to MnMSP						
Dv	21.27 ± 2.08	.001**	21.04 ± 1.77	<.001***	21.27 ± 1.83	<.001***
NDv	22.86 ± 1.68		23.77 ± 2.04		23.80 ± 1.89	
ΔNDv−Dv	1.59 ± 2.46	–	2.73 ± 1.74	–	2.53 ± 2.01	–
Anteroposterior distance						
UM to coronal plane						
Dv	6.35 ± 4.04	.364	5.91 ± 3.77	.477	6.32 ± 3.82	.139
NDv	6.67 ± 4.19		5.65 ± 3.83		6.85 ± 3.87	
ΔNDv−Dv	0.31 ± 1.87	–	−0.25 ± 1.91	–	0.53 ± 1.90	–
LM to coronal plane						
Dv	5.05 ± 3.35^{A}	.165	4.16 ± 2.72^{A}	.372	3.10 ± 2.74^{B}	.076
NDv	4.53 ± 3.59		4.88 ± 4.34		3.60 ± 2.79	
ΔNDv−Dv	−0.51 ± 1.98	–	0.72 ± 4.34	–	0.49 ± 1.46	–
LM to Mn coronal plane						
Dv	23.60 ± 5.57	.430	25.03 ± 5.57	< .001***	26.01 ± 6.40	.109
NDv	23.30 ± 6.41		26.78 ± 5.37		26.46 ± 5.95	
ΔNDv−Dv	−0.30 ± 2.05^{A}	–	1.75 ± 1.88^{B}	–	0.45 ± 1.49^{A}	–
Angle						
UI_axis to MSP	3.22 ± 2.82^{A}	–	2.47 ± 3.33^{AB}	–	1.07 ± 2.06^{B}	–
UM_axis to FHP						
Dv	98.79 ± 3.75	<.001***	100.97 ± 4.18	<.001***	100.17 ± 5.17	<.001***
NDv	89.04 ± 5.13^{A}		93.64 ± 5.61^{B}		91.13 ± 5.98^{AB}	
ΔNDv−Dv	−9.75 ± 5.88	–	−7.33 ± 5.85	–	−9.04 ± 5.64	–
LI_axis to MnMSP	−0.19 ± 2.74^{A}	–	−4.13 ± 3.30^{B}	–	−1.96 ± 2.58^{A}	–
LM_axis to MHP						
Dv	71.72 ± 4.90^{A}	.015*	67.77 ± 4.17^{B}	<.001***	69.19 ± 5.31^{AB}	<.001***
NDv	74.00 ± 4.78		76.82 ± 5.32		76.02 ± 5.83	
ΔNDv−Dv	2.28 ± 4.84^{A}	–	9.05 ± 5.94^{B}	–	6.83 ± 4.86^{B}	–

[a] Dv indicates deviated side; FHP, Frankfort horizontal plane; LI, midpoint of the bilateral mandibular central incisor edges; LM, mandibular first molar; MHP, mandibular horizontal plane; MnMSP, mandibular midsagittal plane; MSP, midsagittal plane; NDv, non-deviated side; SD, standard deviation; UI, midpoint of the bilateral maxillary central incisor edges; and UM, maxillary first molar. Values in the same row with no superscript are not statistically significant and with different superscript letters are significantly different at $P < .05$ according to a one-way analysis of variance with a Tukey post hoc test. Paired *t*-test was performed to compare the Dv and NDv.

* Significant difference at $P < .05$ between the Dv and NDv.

** Significant difference at $P < .01$ between the Dv and NDv.

*** Significant difference at $P < .001$ between the Dv and NDv.

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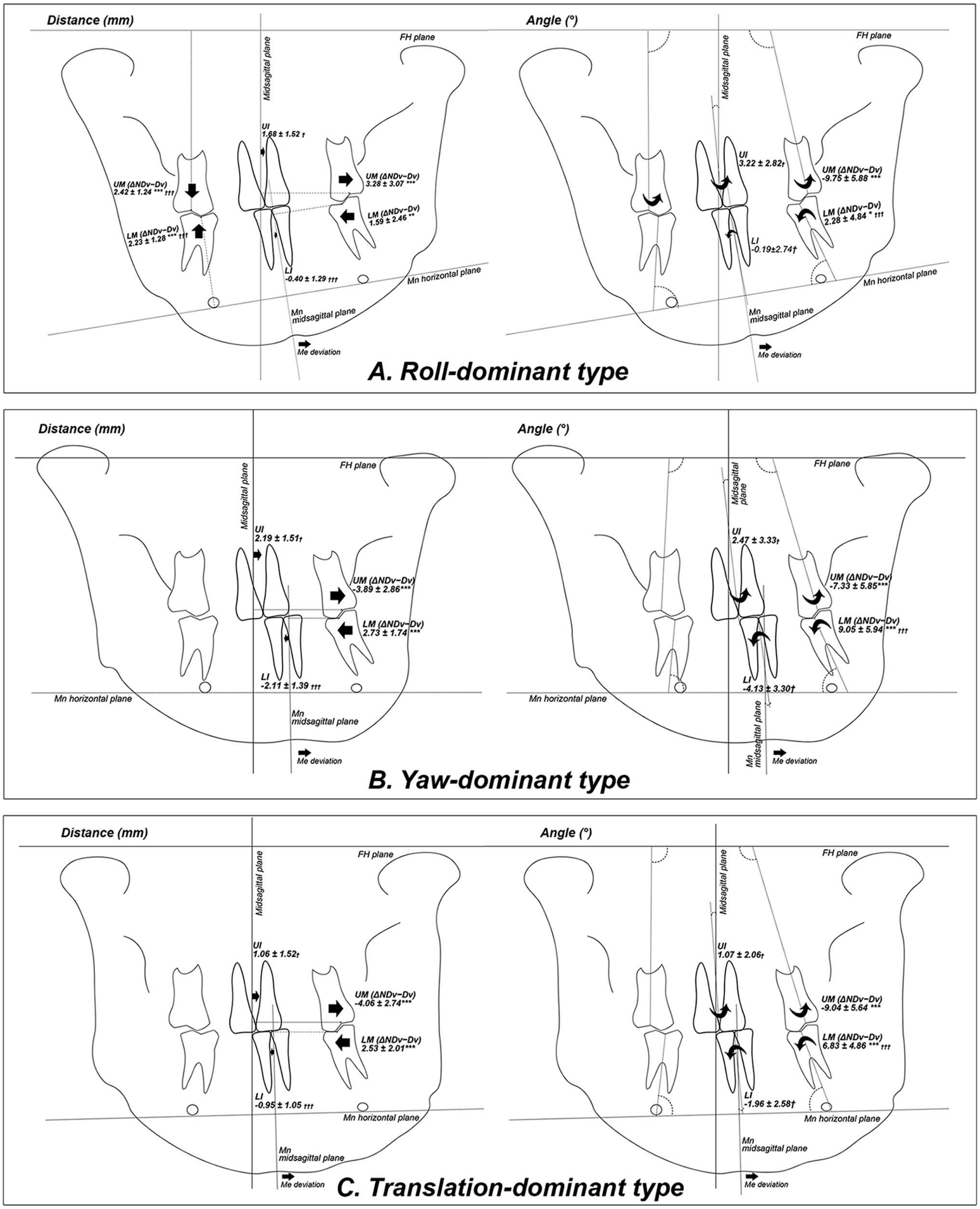

Figure 6. Schematic diagrams of dental compensation in each asymmetry type (*left*, vertical and transverse distance; *right*, angle [significant difference between the sides, $^{*}P < .05$, $^{**}P < .01$, $^{***}P < .001$; significant difference among the groups, $^{\dagger}P < .05$, $^{\dagger\dagger}P < .01$, $^{\dagger\dagger\dagger}P < .001$]). A, Roll-dominant type. B, Yaw-dominant type. C, Translation-dominant type. Dv indicates deviated side; FH, Frankfort horizontal; LI, midpoint of the bilateral mandibular central incisor edges; LM, mandibular first molar; Me, menton; Mn, mandibular; NDv, nondeviated side; UI, midpoint of the bilateral maxillary central incisor edges; and UM, maxillary first molar.

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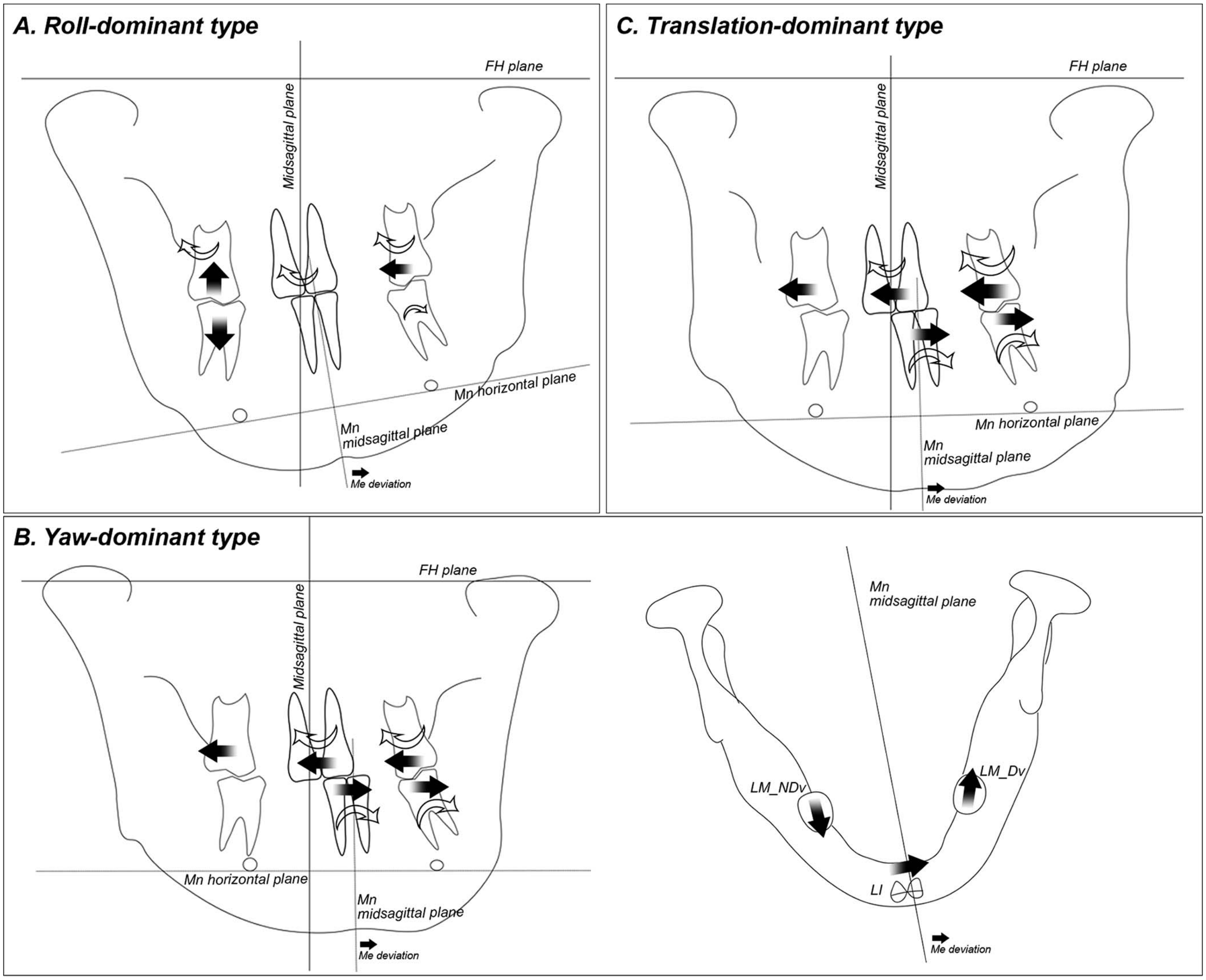

Figure 7. Schematic diagrams of dental decompensation required in each asymmetry type. A, Roll-dominant type. B, Yaw-dominant type. C, Translation-dominant type. Dv indicates deviated side; FH, Frankfort horizontal; LI, midpoint of the bilateral mandibular central incisor edges; LM, mandibular first molar; Me, menton; Mn, mandibular; and NDv, nondeviated side.

Hence, compensatory tipping of the incisors might be more predominant in the yaw-dominant group than in the other groups (Figure 6B). The maxillary molars on the Dv showed buccal tipping, whereas the mandibular molars showed lingual tipping. Anteroposteriorly, the mandibular molars tipped mesially at the Dv and distally at the NDv. For dental decompensation in patients with yaw-dominant mandibular asymmetry, buccolingual tipping of the posterior teeth should be corrected including anterior tooth angulation and anteroposterior tipping of the mandibular posterior teeth; however, vertical tooth movement is rarely required (Figure 7B). Hence, the use of Class II intermaxillary elastics on the NDv may be effective in performing appropriate tooth movement anteroposteriorly.

The translation-dominant group had the lowest Me deviation among the three types. Regarding dental compensation, differences were observed in the transverse distance and angle between the sides; however, there were no differences in the vertical distance in the mandible and sagittal difference in both jaws (Figure 6C). Therefore, transverse dental correction is required, including lateral movement and tipping correction. Notably, their extent may be greater in the maxilla than in the mandible (Figure 7C). This dental decompensation should be sufficient to surgically move the posterior side of the mandible toward the NDv.

Collectively, the differential tooth movement based on the mandibular asymmetry types can provide strong assurance of accomplishing better facial symmetry in

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patients. In addition, after proper dental decompensation and precise jaw surgery based on the reference planes, the supplementary osteotomies for compensatory bone modeling, such as the mandibular inferior border and gonion, can be taken into account to maximize improvement of the face.[20,21]

Although this study provided valuable findings on dental compensation in patients with different asymmetry types, it did not include atypical asymmetry. Hence, dental compensation of the atypical asymmetry type should be evaluated in future research.

CONCLUSIONS

- The null hypothesis of this study was rejected, and the asymmetry types showed different and unique features of dental compensations.
- The roll-dominant group showed transverse occlusal canting of both jaws and buccal tipping to the Dv in the maxilla; the yaw-dominant group presented buccolingual tipping of the molars in both jaws and a large midline discrepancy in the mandible; the translation-dominant group demonstrated greater transverse tipping in the maxilla than in the mandible at the Dv.
- A complete understanding of the differences in dental compensation according to asymmetry types may enable clinicians to achieve satisfactory treatment outcomes in patients with facial asymmetry.

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