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Cone-beam computed tomography based evaluation of rotational patterns of dentofacial structures in skeletal Class III deformity with mandibular asymmetry

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Objective: The purpose of this study was to assess rotational patterns of dentofacial structures according to different vertical skeletal patterns by cone-beam computed tomography (CBCT) and analyze their influence on menton deviation in skeletal Class III deformity with mandibular asymmetry. **Methods:** The control group consisted of 30 young adults (15 men, 15 women) without any severe skeletal deformity. The asymmetry group included 55 adults (28 men, 27 women) with skeletal Class III deformity and at least 3-mm menton deviation from the midsagittal plane; it was divided into the hyperdivergent and hypodivergent subgroups using a mandibular plane angle cutoff of 35°. Fourteen rotational variables of the dental arches and mandible were measured and compared among the groups. Correlations between menton deviation and the other variables were evaluated. **Results:** The asymmetry group showed significantly larger measurements of roll and yaw in the mandible than the control group. The hypodivergent subgroup showed significant differences in maxillary posterior measurements of yaw ($p < 0.01$) and maxillary anterior shift ($p < 0.05$) compared with the hyperdivergent subgroup. All the mandibular measurements had significant correlations with menton deviation ($p < 0.01$). Most measurements of roll were positively correlated with one another ($p < 0.01$). Measurements of yaw and roll in the posterior regions were also positively correlated ($p < 0.05$). **Conclusions:** Menton deviation in skeletal Class III deformity with mandibular asymmetry is influenced by rotation of mandibular posterior dentofacial structures. The rotational patterns vary slightly according to the vertical skeletal pattern.
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Key words: Cone-beam computed tomography, Facial asymmetry

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INTRODUCTION

Facial asymmetry is an imbalanced state between one side of the face and the other.[1,2] It is one of the essential factors affecting facial esthetics. Since pursuing facial beauty is a major trend in contemporary society, more patients who complain about facial asymmetry visit orthodontic clinics for treatment. In addition, some want to improve their facial appearance without knowing exactly which part is asymmetric and seek advice from the orthodontist. Therefore, orthodontists should be more discreet in diagnosing facial asymmetry.

Heretofore, posteroanterior (PA) cephalometry was the key to diagnosis of facial asymmetry. However, its reliability is limited because of overlapped anatomical structures, magnification errors, and image distortion.[3-5] Therefore, some posterior asymmetries may not be detectable.[6] Computed tomography (CT) greatly reduces such problems and enables more detailed understanding of dentofacial structures.[7-9] In addition, CT software are good tools for three-dimensional (3D) reconstruction and measurement. Several studies have used cone-beam CT (CBCT) to examine craniomaxillofacial relationships and facial asymmetry.

Given the 3D nature of the maxillofacial complex, facial asymmetry should be evaluated spatially. Ackerman et al.[10] proposed the use of not only translation in three planes (forward/backward, up/down, and right/left) but also rotation about three perpendicular axes (yaw, pitch, and roll) to describe the orientation of the head, jaws, and dentition for comprehensive evaluation of dentofacial traits. Accordingly, Kim[11] measured yaw and roll of the dental arches and mandible in Class III malocclusion with facial asymmetry.

Severt and Proffit[12] studied the relationship of clinically apparent asymmetry with dentofacial deformities and found different prevalences of facial asymmetry according to the vertical skeletal pattern. Baek et al.[13] reported that facial asymmetry in skeletal Class III deformity occurs due to greater growth and mesial inclination of the ramus and vertical maxillary excess on the contralateral side. Further, by 3D maxillofacial image analysis, Hwang et al.[14] suggested that six factors influence chin deviation: maxillary height, ramal length, frontal ramal inclination, lateral ramal inclination, mandibular body length, and mandibular body height. However, only a few studies of the relationship between rotation of dentofacial structures and mandibular asymmetry have been conducted, especially according to different vertical skeletal patterns. The purpose of this study was to assess rotational patterns of dentofacial structures according to different vertical skeletal patterns by CBCT and analyze their influence on menton deviation in skeletal Class III deformity with mandibular asymmetry.

MATERIALS AND METHODS

Subjects

Eighty-five Korean subjects participated in this study. The control group included 30 young adults (15 men and 15 women; mean age, 24.30 ± 4.14 years) with skeletal Class I features who were screened from 480 dental students of Wonkwang University (Iksan, Korea). The asymmetry group comprised 55 adults showing skeletal Class III deformity with mandibular asymmetry. They were sampled from 1,000 patients who underwent CBCT for routine diagnostic preparation in the orthodontic department of Wonkwang University Dental Hospital from March 2010 to February 2014. The inclusion criteria of the groups are described in Table 1.

Fifty-five subjects of the asymmetry group were classified into two subgroups depending on the mandibular plane angle (SN-GoMe).[15] Mandibular plane angles were measured on lateral cephalometric images extracted from CBCT images and digitized with OnDemand3D software (Cybermed, Inc., Seoul, Korea). Subjects with mandibular plane angles larger than 35° were classified into the hyperdivergent subgroup (13 men and 15 women; mean age, 26.34 ± 3.14 years; mean SN-GoMe,

Table 1. Inclusion criteria

Control group	Asymmetry group
(1) Menton deviation less than 2 mm three-dimensionally from the midsagittal reference plane	(1) Menton deviation over 3 mm three-dimensionally from the midsagittal reference plane
(2) Skeletal Class I relationship (0° < ANB < 4°)	(2) Skeletal Class III relationship (ANB < 0°)
(3) Full permanent dentition with the exception of the third molar	(3) Full permanent dentition with the exception of the third molar
(4) No previous history of orthodontic treatment	(4) No previous history of orthodontic treatment
(5) No degenerative temporomandibular joint disease	(5) No degenerative temporomandibular joint disease
(6) No history of trauma or systemic disease	(6) No history of trauma or systemic disease
(7) No specific congenital deformities	(7) No specific congenital deformities

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Table 2. Definitions of landmarks

Landmark	Definition
N (nasion)	"V" notch between frontal and nasal bones
FZP (frontozygomatic point)	The intersection point of the frontozygomatic suture and the inner rim of the orbit in the frontal plane
Po (porion)	The most superior point of external auditory meatus
Or (orbitale)	The most inferior point of the lower margin of the bony orbit
Go (gonion)	The most lateral point of gonion area
Me (menton)	The most inferior point of symphyseal outline
#13, #23, #33, #43	Cusp tips of maxillary and mandibular canines
#16P, #26P	Mesiopalatal cusp tips of maxillary first molars
#16B, #26B	Mesiopalatal cusp tips of maxillary first molars
#17P, #27P	Mesiopalatal cusp tips of maxillary second molars
#36B, #46B	Mesiopalatal cusp tips of mandibular first molars
#37B, #47B	Mesiopalatal cusp tips of mandibular second molars
#11-#21 Mid	Middle point between maxillary central incisors
#31-#41 Mid	Middle point between mandibular central incisors
#13-#23 Mid	Middle point between maxillary canines
#16B-#26B Mid	Middle point between mesiobuccal cusp tips of maxillary first molars
#33-#43 Mid	Middle point between mandibular canines
#36B-#46B Mid	Middle point between mesiobuccal cusp tips of mandibular first molars
Lt. Go- Rt. Go Mid	Middle point between left and right gonions

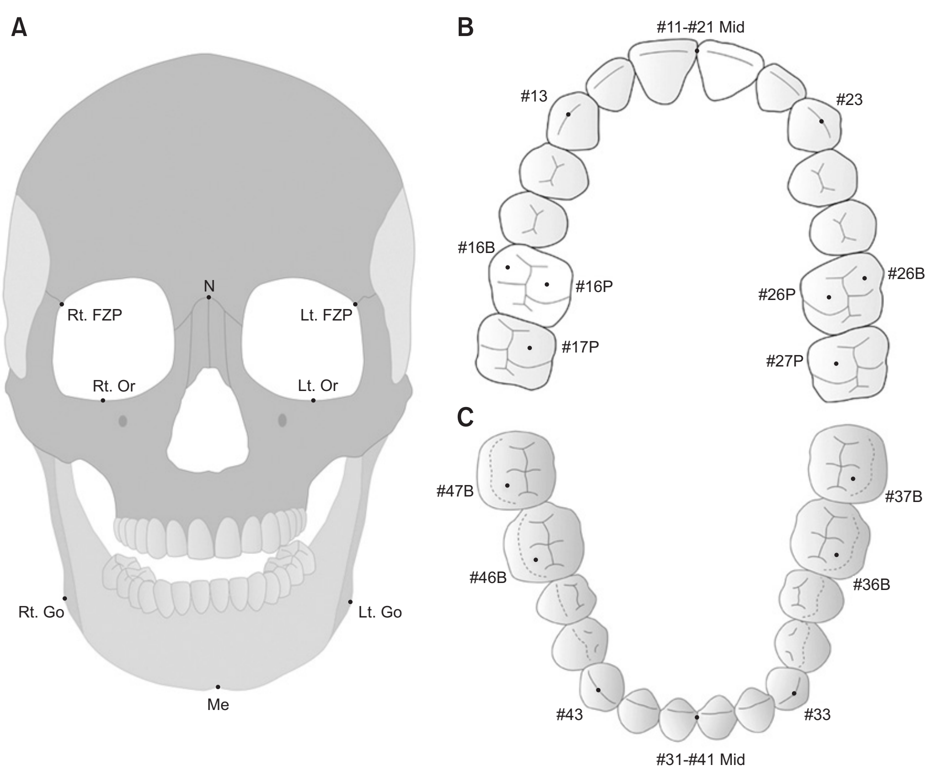

Figure 1. Landmarks used in this study. **A**, Facial skeleton. **B**, Maxillary dental arch. **C**, Mandibular dental arch. FZP, Or, and Go are bilateral landmarks. See Table 2 for definitions.

39.78° ± 2.90°) and those with mandibular plane angles smaller than 35° were included in the hypodivergent subgroup (15 men and 12 women; mean age, 28.96 ± 5.27 years; mean SN-GoMe, 31.24° ± 2.78°). The institutional review board of Wonkwang University approved this study (WKDIRB201402-01).

Table 3. Definitions of reference planes

Reference plane	Definition
Midsagittal plane	A plane constructed with N which is perpendicular to the line connecting bilateral frontozygomatic point
FH (Frankfort horizontal) plane	A plane constructed with right FH line which is perpendicular to midsagittal plane
Frontal plane	A plane constructed with N which is perpendicular to the FH plane and midsagittal plane

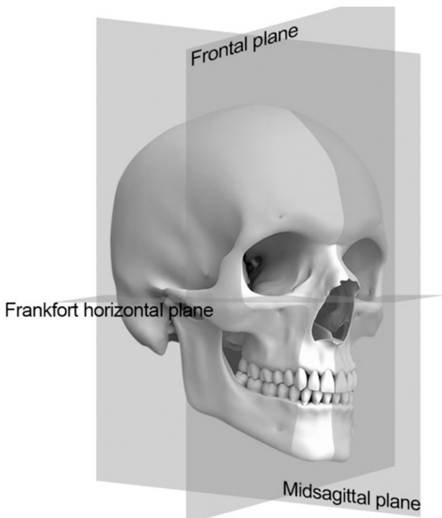

Figure 2. Reference planes used in this study. See Table 3 for definitions.

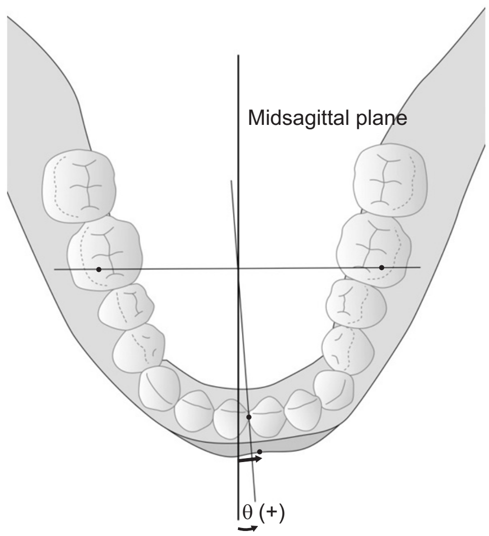

Figure 4. Positive sign of lower anterior yaw relative to the direction of menton deviation.

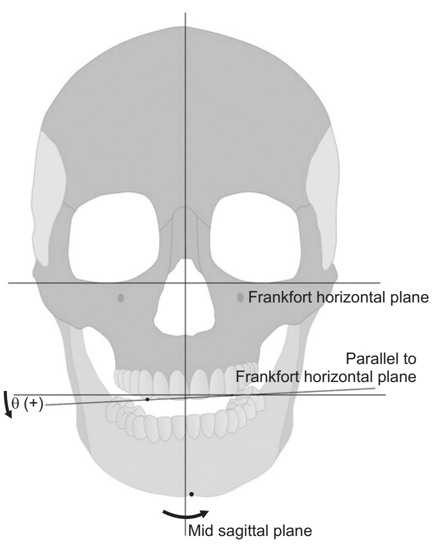

Figure 3. Positive upper canine roll relative to the direction of menton deviation.

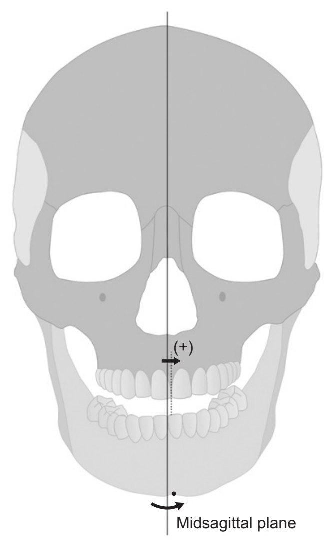

Figure 5. Positive upper anterior shift relative to the direction of menton deviation.

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CBCT imaging and 3D reconstruction

CBCT images were acquired with an Alphard VEGA scanner (Asahi Roentgen Ind. Co., Ltd., Kyoto, Japan). The following settings were used: field of view, 200 × 179 mm; 80 kV; 5.00 mA; exposure time, 17 s; voxel size, 0.39 mm; and slice thickness, 1.00 mm. The voxels were exported in digital imaging and communications in medicine (DICOM) format.

The DICOM files were reconstructed to 3D images using OnDemand3D 1.0 software (Cybermed, Inc.) after the threshold was adjusted for visible pixels. To minimize measurement errors due to nonstandard head posture, the 3D images were reorientated according to two reference planes: nasofrontozygomatic and Frankfort horizontal planes. The nasofrontozygomatic plane was constructed with three points: nasion and bilateral frontozygomatic points. The origin (0, 0, 0) of the coordinate system was registered at nasion and three axes (x, y, and z) were constructed. The transverse axis (x-axis) was parallel to the frontozygomatic line. The anteroposterior axis (z-axis) was perpendicular to the frontozygomatic line and parallel to the right Frankfort horizontal line. The vertical axis (y-axis) was perpendicular to both the frontozygomatic and the right Frankfort horizontal lines.

Measurements

The amount of menton deviation and shift, roll, and yaw of the dental arches and mandible were measured according to a previous study[11] using the 3D Ceph module of OnDemand3D software. Landmarks for the measurements are described in Table 2 and Figure 1. The three reference planes are described in Table 3 and Figure 2. A positive or negative sign was added to each measurement depending on the direction of rotation relative to the direction of menton deviation (Figures

Table 4. Definitions of rotational variables

Measurement	Definition
Roll	
Upper canine roll (U3R)	An angle between FH plane and the projected line connecting #13 and #23 on the frontal plane (Figure 6A)
Upper first molar roll (U6R)	An angle between FH plane and the projected line connecting #16P and #26P on the frontal plane (Figure 6A)
Upper second molar roll (U7R)	An angle between FH plane and the projected line connecting #17P and #27P on the frontal plane (Figure 6A)
Lower canine roll (L3R)	An angle between FH plane and the projected line connecting #33 and #43 on the frontal plane (Figure 6B)
Lower first molar roll (L6R)	An angle between FH plane and the projected line connecting #36B and #46B on the frontal plane (Figure 6B)
Lower second molar roll (L7R)	An angle between FH plane and the projected line connecting #37B and #47B on the frontal plane (Figure 6B)
Mandibular roll (MnR)	An angle between FH plane and the projected line connecting Rt. Go and Lt. Go on the frontal plane (Figure 6B)
Yaw	
Upper anterior yaw (UAY)	An angle between midsagittal plane and the projected line connecting #13-#23 Mid and #11-#21 Mid on the FH plane (Figure 7A)
Upper posterior yaw (UPY)	An angle between midsagittal plane and the projected line connecting #16-#26 Mid and #11-#21 Mid on the FH plane (Figure 7A)
Lower anterior yaw (LAY)	An angle between midsagittal plane and the projected line connecting #33-#43 Mid and #31-#41 Mid on the FH plane (Figure 7B)
Lower posterior yaw (LPY)	An angle between midsagittal plane and the projected line connecting #36-#46 Mid and #31-#41 Mid on the FH plane (Figure 7B)
Mandibular yaw (MnY)	An angle between midsagittal plane and the projected line connecting Lt. Go- Rt. Go Mid and #11-#21 Mid on the FH plane (Figure 7C)
Shift	
Upper anterior shift (UAS)	Linear distance between #11-#21 Mid and the midsagittal plane (Figure 8)
Lower anterior shift (LAS)	Linear distance between #31-#41 Mid and the midsagittal plane (Figure 8)

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3−5).

Angular measurements

To measure roll (rotation around the z-axis), functional occlusal lines connecting canine cusp tips, mesiopalatal cusps of the maxillary molars, and mesiobuccal cusps of the mandibular molars were used (Table 4 and Figure 6). Yaw (rotation around the y-axis) was measured at canine cusp tips and mesiobuccal cusps of the molars (Table 4 and Figure 7).

Linear measurements

Menton deviation was measured as the distance between menton and the midsagittal plane. Shift was measured as the distance from the midpoint of the central incisors to the midsagittal plane (Table 4 and Figure 8).

Statistical analysis

All reorientations and measurements were repeated after a 2-week interval by the same investigator. As a paired *t*-test showed no significant difference between the assessments ($p > 0.05$) and the intra-examiner agreement was excellent (intraclass correlation coefficients = 0.828−0.930), the second assessment was used in this study. The measurements showed no significant gender difference in any group.

As some variables were not normally distributed, according to the Shapiro-Wilk test, the Kruskal-Wallis test was used to compare differences among the groups. Then, the Mann-Whitney *U*-test was performed for *post-*

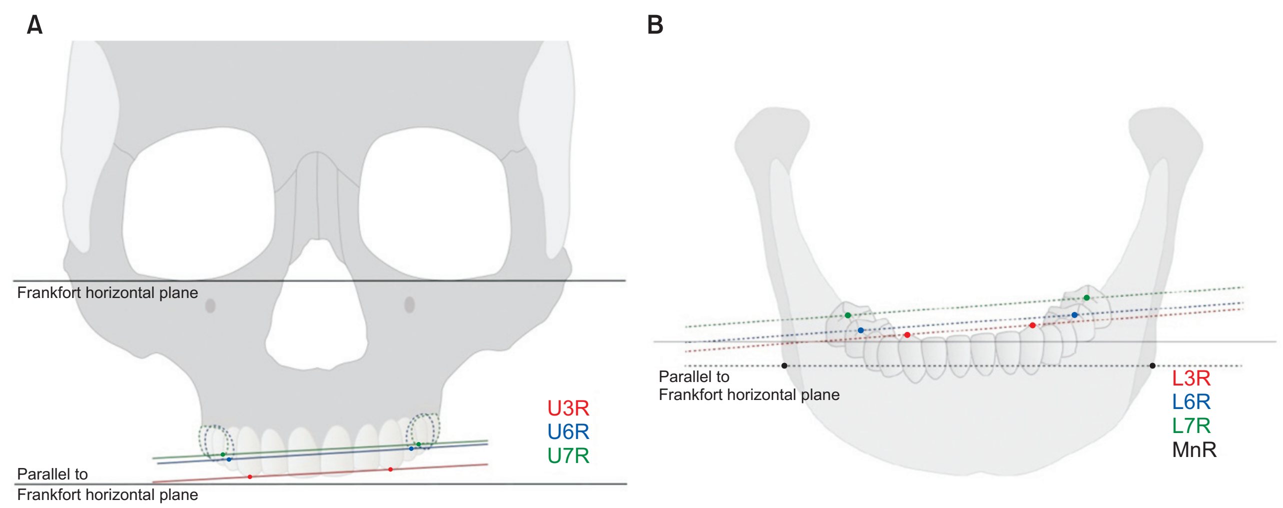

Figure 6. Measurements of roll in this study. A, Maxillary dental arch. B, Mandibular dental arch. See Table 4 for definitions.

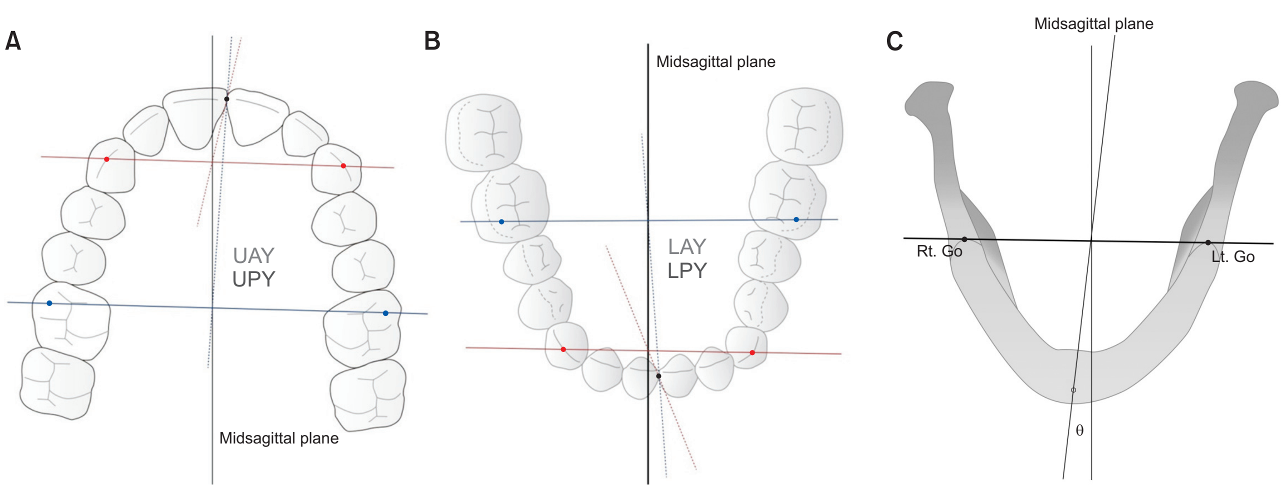

Figure 7. Measurements of yaw in this study. A, Maxillary dental arch. B, Mandibular dental arch. C, Mandible. LAY, Lower anterior yaw; LPY, Lower posterior yaw.

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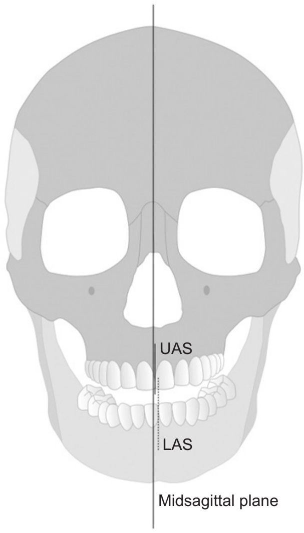

Figure 8. Measurements of shift in this study. See Table 4 for definitions.

hoc multiple comparison with Bonferroni correction. Spearman rank correlation and multiple regression analyses were performed to determine the relationships between the rotational variables and menton deviation. All statistical tests were set at 95% confidence level ($p < 0.05$) and performed using SPSS Statistics software, version 17.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Comparison of the control and asymmetry groups

Table 5 shows the results of the intergroup comparisons. Lower anterior shift ($p < 0.01$), lower first molar roll ($p < 0.01$), lower second molar roll ($p < 0.01$), upper posterior yaw ($p < 0.05$), lower posterior yaw ($p < 0.01$), and mandibular yaw ($p < 0.01$) were significantly larger in the hyperdivergent subgroup than in the control group. Further, upper anterior shift ($p < 0.01$), lower anterior shift ($p < 0.01$), upper second molar roll ($p < 0.01$), lower canine roll ($p < 0.01$), lower first molar roll ($p < 0.01$), lower second molar roll ($p < 0.01$), lower

Table 5. Differences among control group and asymmetry groups

Variable	Control group (n=30)	Hyperdivergent subgroup (n=28)	Hypodivergent subgroup (n=27)	*p*-value	Multiple comparision
Mandibular plane angle (°)	32.86 ± 4.25	39.78 ± 2.90	31.24 ± 2.78	0.000†	G1 < G2, G3 < G2
Menton deviation (mm)	1.09 ± 0.99	5.94 ± 2.23	5.72 ± 2.05	0.000†	G1 < G2, G1 < G3
Roll (°)					
U3R	0.37 ± 1.09	−0.07 ± 2.26	1.20 ± 3.00	0.83	NS
U6R	0.60 ± 1.56	0.34 ± 1.61	1.28 ± 2.50	0.21	NS
U7R	0.70 ± 1.85	1.44 ± 1.95	2.04 ± 1.51	0.024*	G1 < G3
L3R	0.58 ± 1.76	1.63 ± 2.83	2.68 ± 3.08	0.012*	G1 < G3
L6R	0.70 ± 1.37	2.07 ± 2.00	2.32 ± 2.33	0.001†	G1 < G2, G1 < G3
L7R	0.38 ± 1.55	2.01 ± 1.87	2.10 ± 1.95	0.001†	G1 < G2, G1 < G3
MnR	0.14 ± 1.60	1.12 ± 1.70	1.04 ± 2.67	0.13	NS
Yaw (°)					
UAY	−0.81 ± 3.10	−2.92 ± 9.16	−1.88 ± 6.29	0.90	NS
UPY	−0.33 ± 1.41	−1.32 ± 2.95	0.28 ± 2.25	0.009†	G1 < G2, G2 < G3
LAY	0.80 ± 5.36	4.89 ± 10.54	3.08 ± 14.09	0.17	NS
LPY	−0.17 ± 1.48	3.70 ± 3.06	3.78 ± 3.86	0.000†	G1 < G2, G1 < G3
MnY	0.03 ± 1.38	3.41 ± 2.06	2.35 ± 2.14	0.000†	G1 < G2, G1 < G3
Shift (mm)					
UAS	0.41 ± 1.26	0.98 ± 1.64	1.82 ± 1.31	0.001†	G1 < G3
LAS	0.69 ± 1.08	4.45 ± 2.24	3.93 ± 2.60	0.001†	G1 < G2, G1 < G3

Group 1, Control group; group 2, hyperdivergent asymmetry group; group 3, hypodivergent asymmetry group; SD, standard deviation; NS, not significant.
See Table 4 for definition of each landmark or measurement.
Kruskal-Wallis test and Mann-Whitney *U*-test as a *post-hoc* multiple comparion (Bonferroni correction) were used for statistical anlaysis.*$p < 0.05$; †$p < 0.01$.

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Table 6. Inter-variables correlationship coefficients

Variable	MD	U3R	U6R	U7R	L3R	L6R	L7R	MnR	UAY	UPY	LAY	LPY	MnY	UAS	LAS
MD	-	0.136	0.124	0.323†	0.364†	0.458†	0.483†	0.195	0.031	0.006	0.355†	0.571†	0.674†	0.448†	0.820†
U3R	0.136	-	0.490†	0.443†	0.328†	0.445†	0.388†	0.333†	0.166	0.249*	−0.049	−0.016	0.010	0.176	−0.060
U6R	0.124	0.490†	-	0.624†	0.583†	0.491†	0.560†	0.299†	0.206	0.229*	−0.112	−0.100	0.062	0.127	−0.184
U7R	0.323†	0.443†	0.624†	-	0.561†	0.552†	0.586†	0.387†	0.172	0.248*	0.085	0.214*	0.181	0.245*	0.101
L3R	0.364†	0.328†	0.583†	0.561†	-	0.537†	0.518†	0.185	0.169	0.223*	0.117	0.139	0.133	0.286†	0.089
L6R	0.458†	0.445†	0.491†	0.552†	0.537†	-	0.765†	0.343†	0.148	0.074	0.099	0.255*	0.282†	0.150	0.218*
L7R	0.483†	0.388†	0.560†	0.586†	0.518†	0.765†	-	0.272*	0.197	0.175	0.080	0.254*	0.413†	0.136	0.189
MnR	0.195	0.333†	0.299†	0.387†	0.185	0.343†	0.272*	-	−0.076	−0.099	0.042	0.078	0.186	−0.103	0.001
UAY	0.031	0.166	0.206	0.172	0.169	0.148	0.197	−0.076	-	0.501†	0.269*	−0.023	−0.084	0.419†	0.092
UPY	0.006	0.249*	0.229*	0.248*	0.223*	0.074	0.175	−0.099	0.501†	-	0.096	0.049	0.003	0.397†	−0.057
LAY	0.355†	−0.049	−0.112	0.085	0.117	0.099	0.080	0.042	0.269*	0.096	-	0.382†	0.276*	0.195	0.422†
LPY	0.571†	−0.016	−0.100	0.214*	0.139	0.255*	0.254*	0.078	−0.023	0.049	0.382†	-	0.664†	0.219*	0.631†
MnY	0.674†	0.010	0.062	0.181	0.133	0.282†	0.413†	0.186	−0.084	0.003	0.276*	0.664†	-	0.093	0.601†
UAS	0.448†	0.176	0.127	0.245*	0.286†	0.150	0.136	−0.103	0.419†	0.397†	0.195	0.219*	0.093	-	0.489†
LAS	0.820†	−0.060	−0.184	0.101	0.089	0.218*	0.189	0.001	0.092	−0.057	0.422†	0.631†	0.601†	0.489†	-

See Table 4 for definition of each landmark or measurement.
Spearman's rank correlation analysis was used for statistical anlaysis. $^*p < 0.05$, $^†p < 0.01$.

Table 7. Multiple regression analysis to assess the relative contributions of variables to menton deviation

Variable	B	β	*p*-value
LAS	0.826	0.752	0.000‡
L7R	0.309	0.206	0.001†
MnY	0.361	0.291	0.000‡
L3R	0.226	0.211	0.000‡
LPY	−0.206	−0.245	0.001‡

Adjusted R^2, 0.825.
B, Non-standardized regression coefficient; β, standardized regression coefficient.
See Table 4 for definition of each landmark or measurement.
$^†p < 0.01$; $^‡p < 0.001$.

posterior yaw ($p < 0.01$), and mandibular yaw ($p < 0.01$) were significantly larger in the hypodivergent subgroup than in the control group. Only upper posterior yaw ($p < 0.01$) was significantly larger in the hypodivergent subgroup than in the hyperdivergent subgroup.

Relationships between rotational variables

The results of Spearman rank correlation analysis are listed in Table 6. Lower anterior shift (r = 0.820; $p < 0.01$), mandibular yaw (r = 0.674; $p < 0.01$), lower posterior yaw (r = 0.571; $p < 0.01$), lower second molar roll (r = 0.483; $p < 0.01$), lower first molar roll (r = 0.458; $p < 0.01$), upper anterior shift (r = 0.448; $p < 0.01$), lower canine roll (r = 0.364; $p < 0.01$), lower anterior yaw (r = 0.355; $p < 0.01$), and upper second molar roll (r = 0.323; $p < 0.01$) showed positive correlations with menton deviation.

The measurements of roll except lower canine roll and mandibular roll were significantly ($p < 0.01$) and positively correlated with one another (Table 6). Upper anterior yaw showed significant positive correlations with upper posterior yaw (r = 0.501; $p < 0.01$) and lower anterior yaw (r = 0.269; $p < 0.05$). Lower anterior yaw showed significant positive correlations with lower posterior yaw (r = 0.382; $p < 0.01$) and mandibular yaw (r = 0.276; $p < 0.05$). Further, lower posterior yaw showed a significant positive correlation with mandibular yaw (r = 0.664; $p < 0.01$). Upper anterior shift was positively correlated with lower anterior shift (r = 0.489; $p < 0.01$).

Upper and lower anterior yaw showed no significant correlation with any measurement of roll. However, upper posterior yaw was positively correlated with upper canine roll (r = 0.249; $p < 0.05$), upper first molar roll (r = 0.229; $p < 0.05$), upper second molar roll (r = 0.248; $p < 0.05$), and lower canine roll (r = 0.223; $p <$

0.05). Lower posterior yaw was significantly correlated with upper second molar roll ($r = 0.214$; $p < 0.05$), lower first molar roll ($r = 0.255$; $p < 0.05$), and lower second molar roll ($r = 0.254$; $p < 0.05$) (Table 6).

Multiple regression analysis showed that menton deviation was influenced by lower anterior shift, lower second molar roll, mandibular yaw, lower canine roll, and lower posterior yaw (Table 7).

DISCUSSION

Greater patient awareness of facial asymmetry, especially chin deformity, warrants greater attention in diagnosis of mandibular asymmetry.[16] Mandibular asymmetry can be evaluated by the amount of menton deviation from the midsagittal plane. However, in some cases, deviation or rotation of the maxilla can cause mandibular asymmetry as the temporomandibular joints adapt by remodeling or growth. Maeda et al.[17] detected solely mandibular asymmetry in 80% of their patients, while both the maxilla and the mandible were involved in 20% of the cases. Another report described similar results: 74% of the cases involved mandibular asymmetry and 36% had both maxillary and mandibular asymmetry.[12] In this study, rotation of mandibular structures affected menton deviation more than that of maxillary structures.

Midline discrepancy of the dental arches also influences the patient's cognition of facial asymmetry. It reflects not only mandibular asymmetric growth but also deformation of the upper and middle thirds of the face. Furthermore, dental features such as space deficiency, spacing, missing teeth, supernumerary teeth, and premature contact sometimes increase the tendency for facial asymmetry by altering arch form and direction of skeletal growth. Therefore, this study examined the effect of rotation of the dental arches on facial asymmetry.

According to Haraguchi et al.,[18] any landmark deviating by more than 2 mm from the facial midline is asymmetric. Severt and Proffit[12] found an increased percentage of chin deviation of at least 2 mm from the midline in Class III deformity. Further, Chebib and Chamma[19] suggested that deviation of more than 3 mm is abnormal. In this study, mandibular asymmetry was considered present when menton deviation was more than 3 mm from the midsagittal plane: the asymmetry group showed a greater amount of menton deviation than the control group.

Radiographic techniques such as PA cephalometry and panoramic radiography can be used to assess facial asymmetry but produce only two-dimensional images and are prone to errors.[20,21] Although CBCT is relatively reliable with regard to head orientation,[22] natural head position is not always ensured because head tilting is common in patients with facial asymmetry.[23] Therefore, reorientation based on the midsagittal plane is necessary to assess facial asymmetry. Various landmarks have been proposed to develop the midsagittal plane. As the position of the anterior nasal spine changes if there is facial asymmetry including the maxilla, mandibular asymmetry can be overestimated or underestimated in relation to the maxilla.[23] Thus, the anterior nasal spine was not used as a landmark in this study. The frontozygomatic suture shows good potential as a reference for assessing facial asymmetry,[5,24,25] so the nasion and bilateral frontozygomatic points were used to construct the midsagittal plane in this study.[26] Importantly, Kim et al.[27] found that cranial base volume is correlated with mandibular asymmetry in patients with facial asymmetry and mandibular prognathism, influencing the construction of reference planes with landmarks at the cranial base.

A few studies have focused on canting of anatomical structures (eye, lip, occlusal plane, otobasion, gonion), similar to roll in this study. Using frontal cephalograms, frontal photos, 3D CT images, Hwang et al.[28] found that preoperative lip-line cant shows positive correlations with menton deviation and mandibular anterior occlusal plane cant. Lee et al.[29] demonstrated that lip cant and chin deviation affect the assessment of facial asymmetry. These results are consistent with those of the present study, in which most measurements of roll were strongly correlated with menton deviation.

Kim[11] examined rotational patterns of the dental arches and mandible in Class III deformity with facial asymmetry. In this study, roll and yaw of dentofacial structures in skeletal Class III deformity with mandibular asymmetry were measured according to different vertical skeletal patterns, as modified in establishing reference planes. Upper posterior yaw varied slightly between the vertical skeletal patterns. Interestingly, differences in the mandibular plane angle did not explain menton deviation.

Only roll and yaw of the posterior parts of the mandible showed significant differences between the control and the asymmetry groups and positive correlations with menton deviation. The result implies that rotation of mandibular posterior dentofacial structures affects menton deviation, and therefore, mandibular asymmetry.

Further study with a larger sample size would enable more detailed evaluation of rotational patterns of dentofacial structures. Moreover, the relationship between the anteroposterior skeletal pattern and rotation of dentofacial structures should be assessed for in-depth study of facial asymmetry.

CONCLUSION

Menton deviation in skeletal Class III deformity with mandibular asymmetry is associated with rotation of mandibular posterior dentofacial structures. The rotational patterns vary slightly according to the vertical skeletal pattern.

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