*Original Article*

# Three-dimensional analysis of molar compensation in patients with facial asymmetry and mandibular prognathism

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**ABSTRACT**

**Objective:** To evaluate the characteristic transverse dental compensations in patients with facial asymmetry and mandibular prognathism and to compare features of dental compensations between two types of mandibular asymmetry using 3-dimensional (3D) cone-beam computed tomography (CBCT).

**Materials and Methods:** Seventy-eight adult patients with skeletal Class I (control group; n = 33; 19 men and 14 women) or skeletal Class III with facial asymmetry (experimental group; n = 45; 23 men and 22 women) were included. The experimental group was subdivided into two groups according to the type of mandibular asymmetry: translation type (T-type; n = 20) and roll type (R-type; n = 19). CBCT images were acquired before orthodontic treatment and 3D analyses were performed.

**Results:** The transverse dental distance was significantly different between the two groups only at the palatal root apex of the maxillary first molar ($P < .05$). In the experimental group, the first molar axes were compensated significantly on both arches except the maxillary nondeviated side. The vertical molar heights were different between the two groups only on the maxillary arch ($P < .001$). The R-type showed greater mandibular ramal length difference and menton deviation than the T-type ($P < .001$). In the R-type, transverse compensation of the maxillary first molars was more obvious than with the T-type, which resulted in canting in the maxillary occlusal plane.

**Conclusions:** Mandibular asymmetry with prognathism showed a characteristic transverse dental compensation pattern. The mandibular asymmetry type influenced the amount and direction of molar compensation on the maxillary arch. (*Angle Orthod.* 2016;86:421–430.)

**KEY WORDS:** Transverse compensation; Mandibular asymmetry; Mandibular prognathism; Translation type; Roll type; CBCT

## INTRODUCTION

Mandibular prognathism is highly prevalent in Asians and is usually accompanied by facial asymmetry.[1] When skeletal disharmony is present, the dentition migrates not only anteroposteriorly and vertically but also transversely to achieve occlusal function. For patients with facial asymmetry, accurate diagnosis and surgical treatment planning and adequate removal of transverse dental compensations in the maxillary and mandibular arches is a requisite for successful management of facial asymmetry.[2–4]

Traditionally, two-dimensional (2D) cephalometric radiographs, such as posteroanterior (PA) cephalograms and submentovertex radiographs, have been essential tools for evaluating facial asymmetry. In 2003, Kusayama et al.[5] showed a high correlation between skeletal asymmetry and dental compensation by analyzing PA radiographs and three-dimensional

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(3D) dental models. Shigefuji et al.[2] also reported greater molar axis changes in the deviated side than in the nondeviated side.

Previous studies revealed several characteristics of transverse dental compensations and their relationship with skeletal facial asymmetry but failed to quantify the severity of deviation due to the lack of a control group.[2] In addition, 2D modalities face limitations caused by image magnification, distortion, and superimposition of skeletal structures.[6–9] When using PA images, it is easy to overestimate or underestimate the severity of facial asymmetry. Gateno et al.[10] described significant distortion of the shape and size of the mandible in roll and yaw asymmetries.

Currently, diagnosis and treatment planning of facial asymmetry can be performed through quantitative measurement of 3D cone-beam computed tomography (CBCT) images.[3,11,12] Mandibular asymmetry should be described three-dimensionally using three angles: pitch, roll, and yaw. Pitch refers to the rotation of the object around the transverse axis, roll refers to the rotation of the object around the anteroposterior axis, and yaw refers to the rotation of the object around the vertical axis. However, there has been a lack of 3D classification of mandibular asymmetry as well as evaluations on transverse dental compensation in patients with asymmetry.

The purpose of this study was to evaluate the characteristic transverse dental compensations in patients with facial asymmetry and mandibular prognathism and to compare features of dental compensations between two types of mandibular asymmetry using 3D CBCT.

## MATERIALS AND METHODS

### Subjects

This retrospective study involved 78 adults with skeletal Class I or Class III asymmetry, who received orthodontic treatment from 2009 to 2014 in the Department of Orthodontics at Kyung Hee University Dental Hospital. The patients were divided into two groups: group 1 (control group; $n = 33$; 19 men and 14 women; mean age, 28.1 years) and group 2 (experimental group; $n = 45$; 23 men and 22 women; mean age, 21.2 years). The study protocol was approved by the institutional review board of Kyung Hee University Dental Hospital (KHD IRB 1404-3).

For the control group, the inclusion criteria were (1) absence of maxillary canting, (2) skeletal and dental Class I relation (ANB 2-4° and Class I molar relation), and (3) negligible facial asymmetry (menton deviation <3 mm). Only orthodontic treatment was planned for these patients. For the experimental group, the inclusion criteria were (1) skeletal and dental Class III relation (ANB <0° and Class III molar relationship) and (2) facial asymmetry (menton deviation > 4 mm) without maxillary canting. Orthognathic surgery was planned for these patients. Patients with (1) missing or abnormally shaped molars, (2) history of orthodontic treatment, and (3) diseases or congenital syndromes accompanied by skeletal disharmony were also excluded.

Facial asymmetry and the consequent dental compensations were compared, particularly with respect to the subgroups of the experimental group. The experimental group was subdivided into two groups: translation type (T-type; $n = 20$) and roll type (R-type; $n = 19$). The T-type subgroup consisted of patients with similar left and right mandibular ramus, body length, and maxillary occlusal planes without canting. In the R-type subgroup, the body length was similar but the ramus differed significantly (>3 mm) and the maxillary occlusal planes were canted. The remaining six subjects in experimental group did not fulfill the criteria for inclusion in the subgroups. They showed compensated type; the side where the mandibular ramus was shorter and showed longer body length.

The reference value for the dental and skeletal transverse compensation analysis was established using the control group, when the participants of this group showed no skeletal discrepancy. Skeletal discrepancy and the consequent transverse dental compensations in the experimental group were assessed by comparisons with the reference values.

### Data Acquisition

The CBCT data were acquired before orthodontic treatment for diagnosis (PSR 9000N, Asahi Roentgen, Kyoto, Japan; 10 mA, 80 kV, and 30-second scan time, 0.1 $mm^3$ voxel size). The raw data were further processed using Invivo5 ver 5.3, (Anatomage, San Jose, Calif).

### Reorientation and Measurements

CBCT images were reoriented such that they were parallel to the FH plane (horizontal plane) and perpendicular to the frontozygomatic (FZ) suture line passing through nasion (midsagittal plane). The mandibular plane was defined by menton and gonion on either side (Figure 1).

Skeletal and dental measurements were performed. Skeletal measurements were evaluations of the transverse skeletal distance, maxillary height, maxillary canting, mandibular body length, mandibular ramal length, mandibular ramal angle, and menton deviation (Figure 2). Dental measurements were evaluations of the transverse dental distance, molar angulation, molar vertical height, dental midline deviation, maxillary

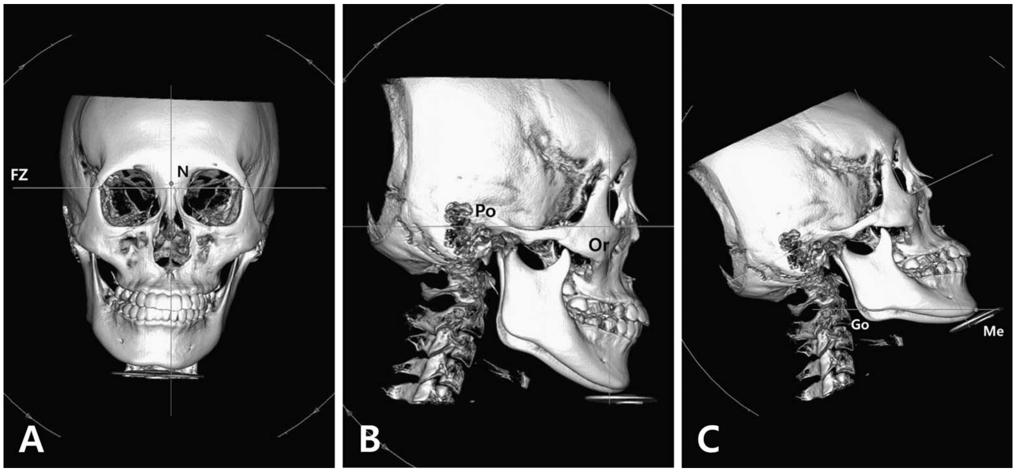


**Figure 1.** The coordinate system used in three-dimensional analysis. Cone-beam computed tomography images were reoriented as perpendicular to the frontozygomatic suture line passing through nasion (A) and parallel to FH plane (B). The mandibular plane was defined by menton (Me) and gonion (Go) on both sides (C). N indicates nasion; Po, porion; Or, orbitale.

alveolar height, and maxillary occlusal plane canting (Figure 3). The difference between the right and left sides was changed to an absolute value.

### Statistical Analysis

To determine the sample size, we used the Get Size ver 2.0.1 program (Seoul National University Dental Hospital, Seoul, Korea), which sets the statistical probability value at .05 and the statistical power (1-$\beta$) at 0.8 with a typical two-tailed statistical analysis. A significant difference can be acquired when each group is composed of more than 15 patients. To evaluate intraobserver reliability, the same operator measured the images twice at an interval of 2 weeks. The initial assessment and reassessment data were analyzed using intraclass correlation coefficients (ICCs). The independent *t*-test was performed to detect significant differences between the control and experimental groups and between the subgroups.

## RESULTS

The average ICCs for intraobserver reliability were greater than 0.900. Therefore, the average value of each variable was used.

### Comparison Between the Control and Experimental Groups

*Skeletal measurements.* There was no significant difference in maxillary height, maxillary canting, and transverse skeletal distance measurements between

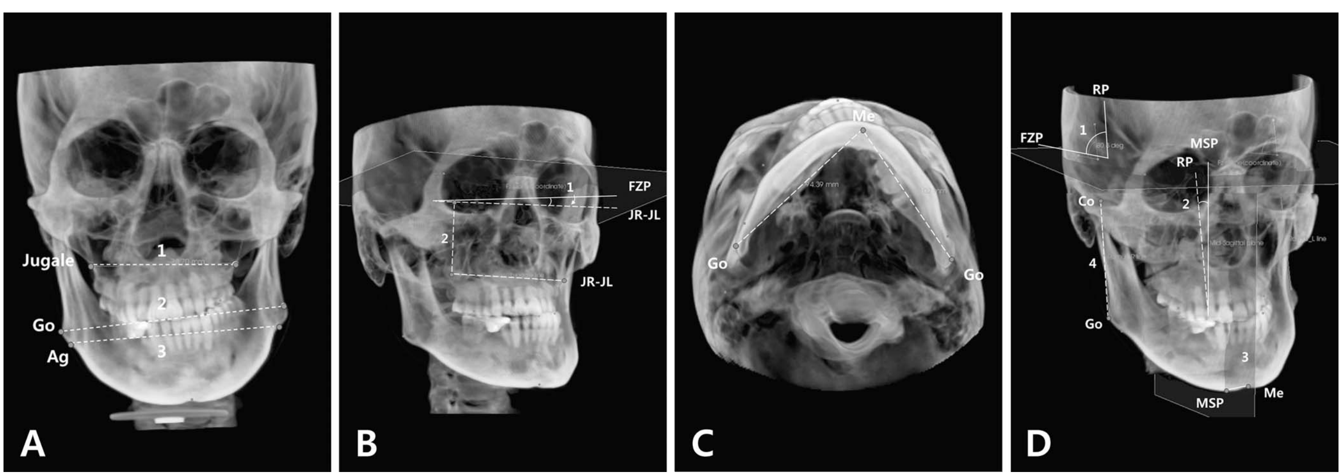


**Figure 2.** Definition of skeletal measurements. (A) Transverse skeletal measurements. 1 indicates Bi-jugal distance; 2, Bi-Gonion (Go) distance; 3, Bi-Antegonion (Ag) distance. (B) 1 indicates maxillary canting (angle between bi-jugal and FZP); 2, maxillary height (distance from Jugal to FZP). (C) Mandibular body length (distance from Me to Go). (D) Mandibular ramal angle. 1 indicates between ramus and FZP; 2, between ramus and midsagittal plane (MSP); 3, menton deviation (distance from Me to MSP); 4, ramus length (distance from Ccndylion to gonion). JR/JL, jugal on the right/left; FZP, frontozygomatic plane; RP, ramal plane.

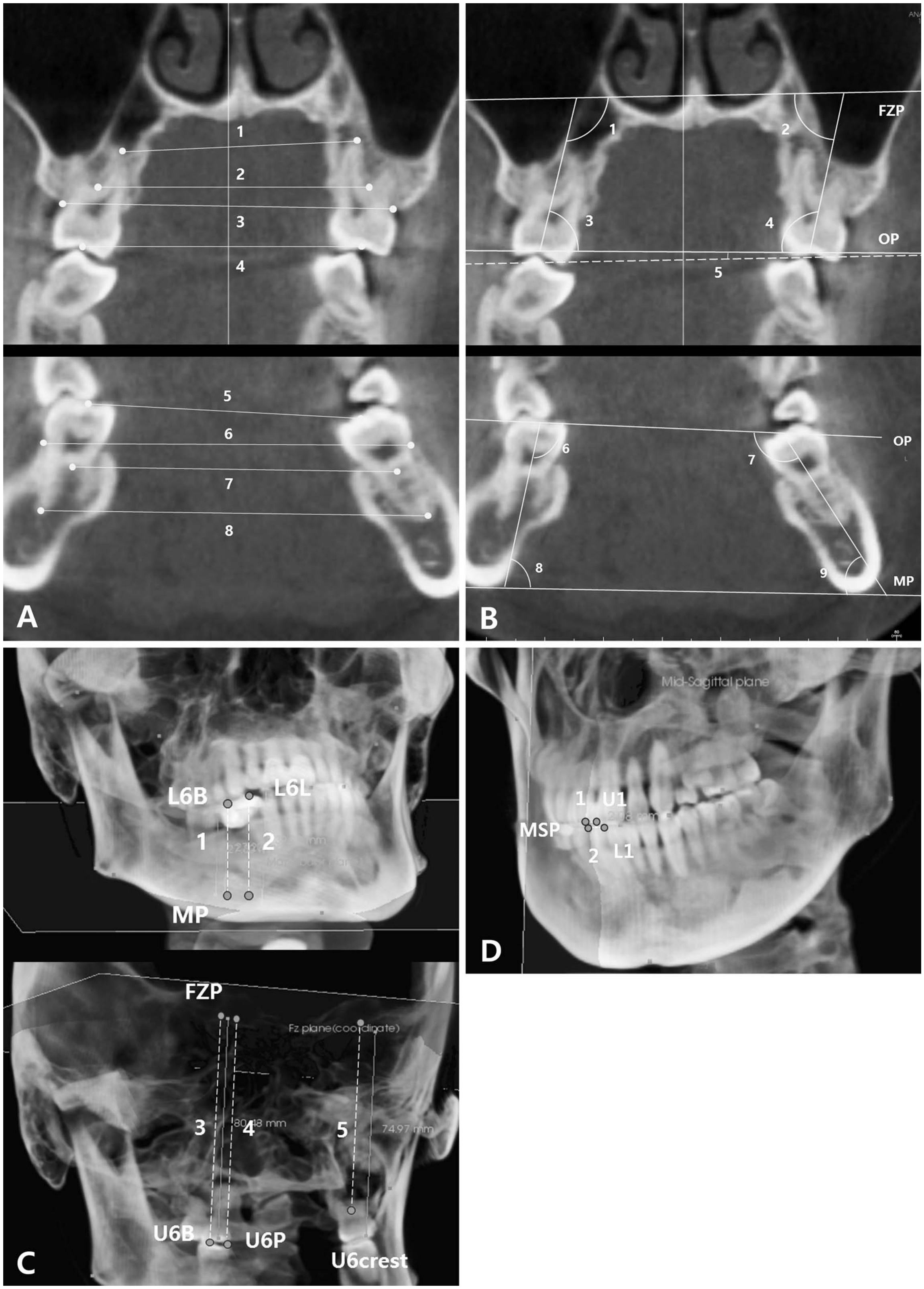


**Figure 3.** Definition of dental measurements. (A) Transverse dental distance. 1 indicates the palatal root apex of the maxillary first molar (U6); 2, the furcation of U6; 3, the cementoenamel junction (CEJ) of U6; 4, the central groove of U6; 5, the central groove of the mandibular first molar (L6); 6, the CEJ of L6; 7, the furcation of L6; 8, the buccal root apex of L6. (B) Molar angulation. 1 and 2 indicate U6 to frontozygomatic plane (FZP) angle; 3 and 4, U6 to occlusal plane (OP) angle; 5, maxillary occlusal plane canting (angle between OP and FZP); 6 and 7, L6 to OP angle; 8 and 9, L6 to mandibular plane (MP) angle. (C) Vertical height of molars. 1 indicates distance from buccal cusp of L6 (L6B) to MP; 2, lingual cusp

**Table 1.** Comparison of Skeletal Measurements Between the Control and Experimental Groups[a]

| Skeletal Variables | Skeletal Class I (Group 1) Mean | SD | Skeletal Class III With Facial Asymmetry (Group 2) Mean | SD | *P* Value |
|---|---|---|---|---|---|
| Transverse skeletal distance | | | | | |
| Bi-jugale distance (mm) | 65.28 | 3.88 | 64.26 | 5.65 | .3733 |
| Bi-gonion distance (mm) | 98.59 | 6.87 | 97.46 | 6.68 | .4694 |
| Bi-ntegonion distance (mm) | 91.13 | 5.12 | 90.11 | 5.75 | .4198 |
| Maxilla (difference between deviated and nondeviated side) | | | | | |
| Maxillary height (mm) | 1.24 | 0.96 | 1.74 | 1.65 | .0931 |
| Maxillary canting (°) | 1.08 | 0.84 | 1.48 | 1.42 | .1325 |
| Mandible (difference between deviated and nondeviated side) | | | | | |
| Mandible ramal length (mm) | 2.24 | 1.74 | 5.05 | 4.19 | .0005*** |
| Mandible body length (mm) | 1.62 | 0.98 | 3.25 | 2.29 | .0002*** |
| Mandible ramus angle (°) | | | | | |
| Ramus to MSP angle | 2.14 | 1.18 | 2.67 | 1.92 | .1618 |
| Ramus to FZ plane angle | 2.02 | 1.48 | 3.59 | 2.03 | .0003*** |
| Menton deviation (mm) | 1.63 | 0.98 | 7.69 | 3.13 | .0000*** |

[a] Independent *t*-test was performed for comparison of the mean differences between the two groups. SD indicates standard deviation; FZ plane, frontozygomatic plane; MSP, midsagittal plane

* $P < .05$; ** $P < .01$; *** $P < .001$.

groups. Mandibular asymmetry was confirmed in the experimental group, which showed significant difference in the mandibular ramal length, body length, and ramal angle between the deviated and nondeviated sides (all $P < .001$; Table I). Menton deviation was 1.63 mm in the control group and 7.69 mm in the experimental group ($P < .001$).

*Dental measurements.* With regard to the transverse dental distance, a significant difference between the two groups was observed only at the maxillary first molar's palatal root apex (Table 2; $P < .05$). In the experimental group, characteristic transverse molar compensation was observed (Figure 4). Maxillary molar compensation (buccal tipping) related to the FZ plane was apparent on the deviated side (control group 93.9° vs experimental group 101.4°; $P < .001$), whereas no significant change on the nondeviated side (control group 92.5° vs experimental group 93.5°). On the other hand, mandibular molars showed significant axes changes on both the deviated and nondeviated side. The axes differences between the deviated and nondeviated sides in the experimental group were 6.11° and 7.89° for the maxillary first molar to the occlusal plane and FZ plane, respectively, and 8.52° and 8.40° for the mandibular first molar to the occlusal plane and mandibular plane, respectively (all $P < .001$, except the maxillary first molars to occlusal plane angle, $P < .05$).

Significant vertical heights differences of the molars between the deviated and nondeviated sides were observed only in the maxilla ($P < .001$). Differences of 1.61 mm and 1.94 mm were present with respect to the distance from the palatal cusp of the maxillary first molar to the FZ plane and from the buccal cusp to the FZ plane, respectively. Maxillary occlusal plane canting was greater in the experimental group ($P < .001$).

## Comparison Between Translation Type and Roll Type in the Experimental Group

*Skeletal measurements.* When compared to the T-type, the R-type showed significantly higher differences in mandibular ramal length and menton deviation (Table 3; $P < .001$). The mandibular ramal length difference between the deviated and nondeviated sides was 4.03 mm in the R-type and 1.19 mm in the T-type. Menton deviation difference was 10.39 mm in the R-type and 6.65 mm in the T-type. There was no significant difference in transverse skeletal distance, maxillary height and canting, mandibular body length, and mandibular ramal angle.

*Dental measurements.* The R-type showed greater molar compensation with respect to the maxillary first molar axes than the T-type. The angular difference between the deviated and nondeviated sides of the maxillary first molar to the FZ plane was 11.05° in the R-type and 5.05° in the T-type (Table 4; $P < .001$). On

←
of L6 (L6L) to MP; 3, buccal cusp of U6 (U6B) to FZP; 4, palatal cusp of U6 (U6P) to FZP; 5, U6 crest to FZP. (D) Dental midline deviation to midsagital plane (MSP). 1 indicates upper; 2, lower. U1, maxillary central incisor; L1, mandibular central incisor.

**Table 2.** Comparison of Dental Measurements Between the Control and Experimental Groups[a]

| Dental Variables | | Skeletal Class I (Group 1) Mean | Skeletal Class I (Group 1) SD | Skeletal Class III With Facial Asymmetry (Group 2) Mean | Skeletal Class III With Facial Asymmetry (Group 2) SD | *P* Value |
|---|---|---|---|---|---|---|
| Transverse dental distance at (between Lt and Rt, mm) | | | | | | |
| Mx 6 palatal root apex | | 37.26 | 2.63 | 35.56 | 3.57 | .0235* |
| Mx 6 furcation | | 47.18 | 2.78 | 45.97 | 2.94 | .0695 |
| Mx 6 CEJ | | 58.08 | 2.96 | 57.00 | 3.00 | .1209 |
| Mx 6 central groove | | 48.38 | 2.64 | 49.09 | 3.10 | .2886 |
| Mn 6 central groove | | 43.32 | 2.72 | 48.87 | 3.10 | .4140 |
| Mn 6 CEJ | | 56.39 | 2.82 | 57.30 | 2.90 | .1730 |
| Mn 6 furcation | | 48.30 | 2.15 | 49.13 | 2.56 | .1350 |
| Mn 6 buccal root apex | | 57.12 | 3.07 | 58.20 | 3.36 | .1631 |
| Dental compensation by angular measurements | | | | | | |
| Mx 6 to FZ plane | deviated | 93.92 | 4.42 | 101.40 | 5.23 | .000*** |
| | nondeviated | 92.51 | 4.56 | 93.51 | 6.00 | .424 |
| | diff | 3.98 | 3.59 | 7.89 | 5.96 | .0006*** |
| Mx OP | deviated | 86.54 | 4.56 | 81.02 | 5.67 | .000*** |
| | nondeviated | 88.02 | 4.34 | 84.19 | 6.20 | .002** |
| | diff | 4.11 | 3.01 | 6.11 | 5.30 | .0384* |
| Mn OP | deviated | 104.58 | 4.81 | 111.50 | 6.13 | .000*** |
| | nondeviated | 105.37 | 4.82 | 102.98 | 4.65 | .032* |
| | diff | 4.35 | 2.46 | 8.52 | 6.00 | .0003*** |
| Mn 6 to MP | deviated | 76.01 | 4.57 | 68.89 | 5.67 | .0000*** |
| | nondeviated | 74.45 | 4.61 | 77.29 | 5.20 | .015* |
| | diff | 3.77 | 2.21 | 8.40 | 5.69 | .0000*** |
| Vertical height of molars (difference between deviated and nondeviated side, mm) | | | | | | |
| Mx 6 palatal to FZ plane | | 0.63 | 0.50 | 1.61 | 1.16 | .0000*** |
| Mx 6 buccal to FZ plane | | 1.06 | 0.89 | 1.94 | 1.41 | .0003*** |
| Mn 6 buccal to MP | | 0.95 | 0.82 | 1.19 | 1.01 | .2583 |
| Mn 6 lingual to MP | | 0.83 | 0.64 | 1.23 | 1.19 | .0813 |
| Dental midline (mm) | | | | | | |
| U1 to midsagittal plane | | 0.97 | 0.92 | 1.69 | 1.23 | .0038** |
| L1 to midsagittal plane | | 1.20 | 1.06 | 4.72 | 2.57 | .0000*** |
| Maxillary alveolar height (difference between deviated and nondeviated side, mm) | | | | | | |
| Mx 6 crest to FZ plane (mm) | | 1.07 | 0.97 | 1.75 | 1.45 | .0151* |
| Mx OP canting | | | | | | |
| Mx OP to FZ plane angle (°) | | 0.78 | 0.95 | 2.14 | 1.53 | .0000*** |

[a] Independent *t*-test was performed for comparison of the mean differences between the two groups. SD, indicates standard deviation; Lt, left; Rt, right; Mx 6, maxillary first molar; CEJ, cementoenamel junction; Mn 6, mandibular first molar; diff, difference; FZ plane, frontozygomatic plane; Mx OP, maxillary occlusal plane; Mn OP, mandibular occlusal plane; MP, mandibular plane; U1,upper incisor; L1, lower incisor; Mx, maxillary.
* $P < .05$; ** $P < .01$; *** $P < .001$.

the other hand, there was no significant difference in the mandibular molar axes between groups.

The R-type showed significantly higher differences with regard to the vertical height of the maxillary molar on the palatal and buccal sides, which led to the maxillary occlusion plane canting compared with the T-type (all $P < .05$; Table 4). Vertical height difference of the mandibular molars between groups was observed only in the lingual cusp area ($P < .05$). Maxillary dental midline deviation in the R-type (2.11 mm) was greater than in the T-type (1.33 mm).

## DISCUSSION

The CBCT is widely applied in orthodontics because it can produce undistorted 3D morphologic images, which make it possible to identify craniofacial structures more naturally.[13] However, the 2D evaluation method is still being applied to evaluate 3D images, and CBCT-generated cephalograms have been introduced.[14] Many studies comparing CBCT-generated lateral cephalograms with original 2D cephalograms reported the former to be highly accurate and reliabile.[15,16] On the other hands, few studies on CBCT-generated PA cephalograms have been reported. Kim et al.[17] observed that the virtual frontal cephalograms differed significantly from conventional cephalograms depending on the conversion technique.

In this study, landmarks were directly measured on 3D CBCT images instead of using CBCT-generated virtual cephalograms. Unconverted CBCT data have

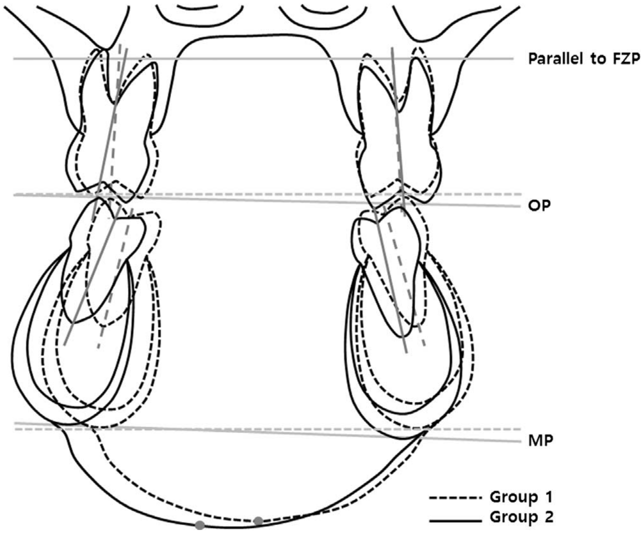


**Figure 4.** Illustration of the molar compensation in patients with mandibular asymmetry and prognathism (group 2) compared with control subjects (group 1). Maxillary molar compensation was apparent on the deviated side only, whereas mandibular molars showed significant axes changes on the deviated and nondeviated side.

more precise information about 3D morphology. Hwang et al.[11] reported a step-by-step procedure for 3D analysis based on six contributing factors for chin deviation. Although the assessment methodology for 3D landmarks is still developing, and there is a lack of established normative data, direct 3D measurement will likely emerge as an alternative diagnostic tool in the future.

This study was the first to include transverse analysis using CBCT for patients with skeletal Class III asymmetry. To the best of our knowledge, few average values of 3D transverse analysis are available. Therefore, it was hard to directly compare our results with those of the previous study.[10] Using frontal cephalograms and 3D dental model analyses,[2,5] the asymmetry index, that is, the difference between the left and right sides of the maxillary first molar to the occlusal plane angle, and those of the mandibular first molar to the occlusal plane angle, was reported to be 6.0 ± 5.5° and 8.2 ± 8.9°, respectively; these values were accordance with our results.

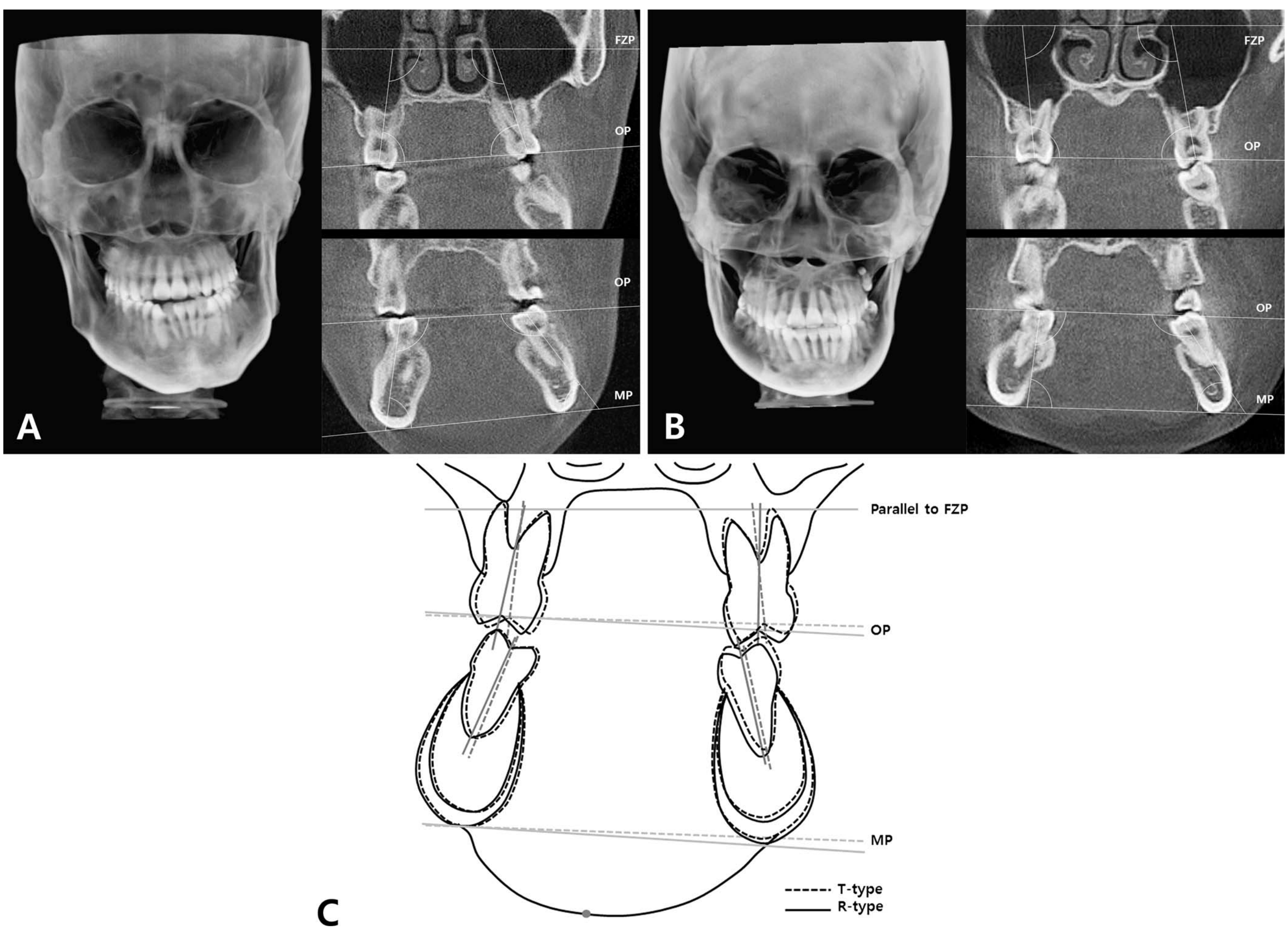


**Figure 5.** Examples of roll type (A) and translation type (B), and comparison diagram of transverse molar compensation (C). The roll type showed greater transverse compensation and vertical height difference on the maxillary molar region compared with the translation type.

**Table 3.** Comparison of Skeletal Measurements Between the Roll Type and Translation Type[a]

| Skeletal Variables | Roll Type | | Translation Type | | *P* Value |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Transverse skeletal distance | | | | | |
| Bi-jugale distance (mm) | 64.32 | 6.94 | 62.90 | 3.21 | .4253 |
| Bi-gonion distance (mm) | 97.68 | 6.28 | 97.17 | 7.59 | .8198 |
| Bi-antegonion distance (mm) | 89.99 | 6.18 | 90.07 | 5.35 | .9642 |
| Maxilla (difference between deviated and nondeviated side) | | | | | |
| Maxillary height (mm) | 1.66 | 1.50 | 1.54 | 1.13 | .7649 |
| Maxillary canting (°) | 1.51 | 1.61 | 1.38 | 0.98 | .7711 |
| Mandible (difference between deviated and nondeviated side) | | | | | |
| Mandible ramal length (mm) | 4.03 | 8.55 | 1.19 | 2.65 | .0000*** |
| Mandible body length (mm) | 0.28 | 4.19 | 1.11 | 2.92 | .2059 |
| Mandible ramus angle (°) | | | | | |
| Ramus to MSP angle | 2.73 | 2.11 | 2.49 | 1.83 | .7145 |
| Ramus to FZ plane angle | 3.73 | 2.35 | 3.51 | 1.97 | .7509 |
| Menton deviation (mm) | 10.39 | 3.52 | 6.65 | 2.70 | .0006*** |

[a] Independent *t*-test was performed for comparison of the mean differences between the two groups. SD indicates standard deviation; MSP, midsagittal plane; FZ plane, frontozygomatic plane.
* $P < .05$; ** $P < .01$; *** $P < .001$.

In order to assess jaw width and first molar inclination, Miner et al.[18] obtained normative data of CBCT analysis based on their control group. They reported that the maxillary molar axial angle was approximately 98°, and the mandibular axial angle was 104°. With respect to our control group, the axial angles of the mandibular molar were similar, although the maxillary molar axis angle was smaller. They also reported that the unilateral crossbite group had more upright teeth on the non-crossbite side. Their sample did not contain patients with skeletal asymmetry, however, and the origin of the crossbite was primarily dental, not skeletal. Therefore, it was hard to directly compare their findings with our result of transverse dental compensations in the molar axis of patients with skeletal asymmetry.

To evaluate mandibular asymmetry, identification of the etiologic mandibular structures is extremely important. In our study, mandibular asymmetry was classified into the T-type and R-type. The T-type involves horizontal displacement of the mandible combined with chin deviation. It shows neither vertically elongated ramus nor cant of occlusal plane. Gonion of both sides lies at the same level. On the other hand, the R-type is characterized by different height of the ramus and condylar neck between the deviated and nondeviated side as well as occlusal plane canting. The vertical position of gonion on both sides is at different levels, and the mandibular lower border on the deviated side is bowed downward at a lower level.[19,20] The R-type showed (1) greater transverse compensation with regard to the maxillary first molar axes and vertical height of molars, (2) greater maxillary midline deviation, and (3) more canted maxillary occlusal plane than the T-type, Figure 5. In the R-type, vertical compensation is closely related to transverse compensation pattern. When the angular change of the molar axis is planned for transverse decompensation, any combined effect on the vertical height should be considered.

Transverse discrepancy should be corrected from the early stage of presurgical treatment. Adequate dental decompensation suited to the basal bone is important for achieving a stable occlusal relationship and critical for ensuring stability after surgery. In our study, average dental compensation values were established for patients with Class III facial asymmetry; thus, it would help to set up the strategic decompensation method during the early stage of presurgical orthodontic treatment. The limitation of our study is that mandibular asymmetry was classified into two groups only. Other subtypes of mandibular and maxillary asymmetry and their combinations should be evaluated.[3]

## CONCLUSIONS

- Transverse compensation in patients with facial asymmetry and mandibular prognathism showed characteristic changes in the axes and the vertical height of the molars on both arches.
- The R-type had greater transverse compensation and vertical height difference on the maxillary molars compared with the T-type. This finding could serve as a future guideline for performing transverse decompensation during preoperative orthodontics.

**Table 4.** Comparison of Dental Measurements Between the Roll Type and Translation Type[a]

| Dental Variables | | Roll Type Mean | Roll Type SD | Translation Type Mean | Translation Type SD | *P* Value |
|---|---|---|---|---|---|---|
| Transverse dental distance at (between Lt and Rt, mm) | | | | | | |
| Mx 6 palatal root apex | | 35.81 | 3.67 | 34.99 | 3.22 | .4620 |
| Mx 6 furcation | | 45.62 | 3.32 | 45.85 | 2.72 | .8175 |
| Mx 6 CEJ | | 56.79 | 3.18 | 56.70 | 2.91 | .9228 |
| Mx 6 central groove | | 48.67 | 3.29 | 48.88 | 2.89 | .8280 |
| Mn 6 central groove | | 43.71 | 3.34 | 43.78 | 2.98 | .9509 |
| Mn 6 CEJ | | 56.98 | 3.09 | 57.40 | 3.06 | .6744 |
| Mn 6 furcation | | 48.94 | 2.81 | 49.17 | 2.54 | .7919 |
| Mn 6 buccal root apex | | 58.12 | 3.28 | 58.47 | 3.60 | .7538 |
| Dental compensation by angular measurements | | | | | | |
| Mx 6 to FZ plane | deviated | 102.70 | 6.33 | 100.13 | 4.36 | .147 |
| | nondeviated | 91.64 | 6.89 | 95.08 | 4.06 | .064 |
| | diff | 11.05 | 5.84 | 5.05 | 3.62 | .0006*** |
| Mx OP | deviated | 79.19 | 6.42 | 80.47 | 4.32 | .469 |
| | nondeviated | 86.74 | 6.14 | 84.55 | 3.74 | .184 |
| | diff | 7.55 | 4.89 | 4.09 | 3.46 | .0145* |
| Mn OP | deviated | 113.14 | 6.35 | 111.06 | 5.68 | .286 |
| | nondeviated | 102.38 | 5.19 | 103.88 | 3.62 | .301 |
| | diff | 10.75 | 6.75 | 7.61 | 5.16 | .1097 |
| Mn 6 to MP | deviated | 67.32 | 5.96 | 68.95 | 4.36 | .333 |
| | nondeviated | 77.37 | 5.17 | 76.72 | 5.28 | .699 |
| | diff | 10.06 | 5.90 | 7.77 | 5.84 | .2316 |
| Vertical height of molars (difference between deviated and nondeviated side, mm) | | | | | | |
| Mx 6 palatal to FZ plane | | 2.05 | 1.18 | 1.22 | 0.96 | .0198* |
| Mx 6 buccal to FZ plane | | 2.53 | 1.45 | 1.48 | 1.18 | .0174* |
| Mn 6 buccal to MP | | 1.04 | 0.81 | 1.18 | 0.88 | .6142 |
| Mn 6 lingual to MP | | 1.59 | 1.53 | 0.78 | 0.62 | .0408* |
| Dental midline (mm) | | | | | | |
| U1 to midsagital plane | | 2.11 | 1.32 | 1.33 | 0.94 | .0405* |
| L1 to midsagital plane | | 5.17 | 2.96 | 4.65 | 2.23 | .5380 |
| Maxillary alveolar height (difference between deviated and nondeviated side) | | | | | | |
| Mx 6 crest to FZ plane (mm) | | 2.06 | 1.57 | 1.63 | 1.40 | .3676 |
| Mx OP canting | | | | | | |
| Mx OP to FZ plane angle (°) | | 2.66 | 1.87 | 1.64 | 1.16 | .0468* |

[a] Independent *t*-test was performed for comparison of the mean differences between the two groups. SD indicates standard deviation; Lt, left; Rt, right; Mx 6, maxillary first molar; CEJ, cementoenamel junction; Mn 6, mandibular first molar; FZ plane, frontozygomatic plane; diff, difference; Mx OP, maxillary occlusal plane; Mn OP, mandibular occlusal plane; MP, mandibular plane; U1, upper incisor; L1, lower incisor.

* $P < .05$, ** $P < .01$, *** $P < .001$.


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