

Relationship between transverse dental anomalies and skeletal asymmetry

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The recognition and elimination of dental compensation is essential in presurgical orthodontic treatment to achieve successful stabilization of the occlusion after surgery. However, the relationship between a transverse dental anomaly and skeletal asymmetry is not fully understood. To evaluate this relationship, frontal cephalometric and 3-dimensional dental model analyses were carried out on 44 adult Japanese Class III patients (mean age 21 years 11 months) who required surgical orthodontic treatment. The patients were divided into 2 groups: a facial asymmetry group in which the mandibular transverse deviation exceeded ± 1 SD from the norm, and a control group in which the mandibular transverse deviation was within ± 1 SD of the norm. Statistical comparison with a control group showed characteristic dental anomalies in the facial asymmetry group, including asymmetry of the curve of Spee, molar inclination, dental arch form, lateral overjet, and slanting of the occlusal plane. Stepwise linear regression analysis showed that transverse and vertical skeletal asymmetry variables including the mandible and the maxilla were effective parameters for characteristic dental anomaly variables, and a significant high correlation between dental anomalies and skeletal asymmetry was found. (*Am J Orthod Dentofacial Orthop* 2003;123:329-37)

Some patients who require surgical orthodontic treatment have severe skeletal asymmetry in the mandible and the maxilla^{1,2} together with a significant asymmetry in the path of condylar movement in function.^{3,4} Because of such skeletal and functional asymmetries, so-called dental compensations, such as dental asymmetry, slanting of the occlusal plane, and unilateral crossbite, are commonly observed.

Because the presurgical correction of dental compensation is a key factor for stabilizing occlusion after surgery, recognition of the dental compensation caused by a skeletal deformity is an essential diagnostic procedure.^{5,6} The purpose of this study was to examine characteristic transverse dental anomalies and to clarify their relationship with skeletal asymmetry in patients with facial asymmetry based on frontal cephalometric analysis and 3-dimensional (3D) dental model analysis.

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MATERIAL AND METHODS

The material taken at the first examination (mean age, 21 years 11 months) consisted of frontal cephalograms and gnathostatic models of 44 Japanese skeletal Class III patients with and without facial asymmetry, who required orthognathic surgery because of severe skeletal deformities. Patients with craniofacial anomalies, syndromes, and clefting, and edentulous persons were excluded; no patients had a history of orthodontic treatment. Patients with crowding or missing teeth were also excluded to avoid the effect of arch length discrepancy on the occlusal conditions such as dental midline and dental arch form.

Frontal cephalograms were traced on acetate paper for each patient. Sixteen dentoskeletal landmarks² were digitized (Fig 1). The line passing through Lo and Lo' was used for the transverse plane (x-axis), and a line perpendicular to this plane through CG represented the vertical plane² (y-axis). In this x-y coordinate system, the skeletal facial asymmetry was quantitatively examined, in both the transverse and the vertical dimensions. To evaluate transverse asymmetry, the ratio of the perpendicular distance from the y-axis to a paired landmark was used. To evaluate vertical asymmetry, the angle between the x-axis and a line connecting a paired landmark was used. Measured values were calculated on a personal computer.

The following measurements were used to evaluate transverse asymmetry: upper face: Lo/Lo'(ratio); mid-

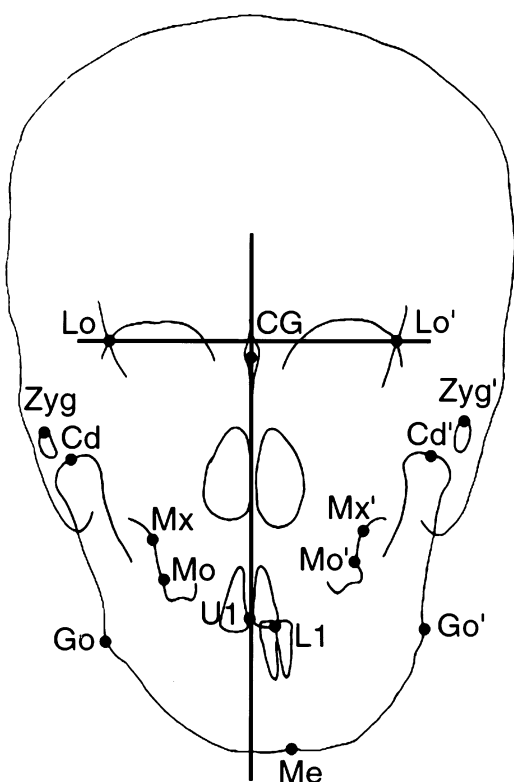


Fig 1. Landmarks in frontal cephalometric analysis. Lo/Lo': latero-orbitale, intersecting point between external orbital contour laterally and oblique line; CG: crista galli, neck of crista galli, most constricted point of projection of perpendicular lamina of ethmoid; Zyg/Zyg': zygoma, most lateral and superior point of shadow of zygomatic arch; Mx/Mx': maxilla, maximum concavity on contour of maxilla; Mo/Mo': molar, neck point on buccal surface of first permanent molar; U1: upper 1: contact point between maxillary central incisors; Cd/Cd': condylion, highest point of condylar head; Go/Go': gonion, most lateral inferior point at angle of mandible; L1: lower 1, contact point between mandibular central incisors; Me: menton, lowest point of contour of chin.

dle face: Zyg/Zyg' (ratio), Mx/Mx' (ratio), Mo/Mo' (ratio), U1 (mm); mandible: Cd/Cd' (ratio), Go/Go' (ratio), Me (mm), L1 (mm).

The following measurements were used to evaluate vertical asymmetry: middle face: Zyg-Zyg' ($^{\circ}$), Mx-Mx' ($^{\circ}$), Mo-Mo' ($^{\circ}$); mandible: Cd-Cd' ($^{\circ}$), Go-Go' ($^{\circ}$).

A 3D dental cast analyzing system^{7,8} was used for dental model analysis. The system comprised a measuring unit (3D-VMS-250R, UNISN, Inc, Osaka, Japan) that obtained 3D information from the dental model with laser scanning and an engineering worksta-

tion (COMPAQ, Houston, Tex) that generated the 3D graphic of the dental model. The following dental model measurements were established and computed with the 3D graphic of the dental model.

1. Occlusal plane angle (Fig 2, A). The occlusal plane defined by the midpoint of the center in the right and left incisor edge and the apices of the right and left second molar distobuccal cusps was established in the maxillary and mandibular dental arches. The occlusal plane angle was measured by using a line constructed by the occlusal plane and the perpendicular plane to the Frankfort horizontal plane (FH).
2. Curve of Spee (Fig 2, B). The vertical distance from the mandibular occlusal plane to the buccal cusp apex of each lateral tooth was measured, and the largest distance was used as a representative value for the curve of Spee.⁹
3. Dental arch form (Fig 2, C). Symmetry of the dental arch was evaluated by using the perpendicular distance from the apices of the canine and the second molar distobuccal cusps to the dental arch centerline. The dental arch centerline was drawn from the midpoint of the center in the right and left mandibular incisor edge, so as to intersect perpendicularly the line connected by the apices of the right and left second molar distobuccal cusps.
4. Lateral overjet and molar inclination (Fig 2, D). The graphic image representing contour data of the first molar and the alveolar ridge was formed by cutting the dental model with the perpendicular plane to FH plane, which included the apex of the first molar mesiobuccal cusp. This plane also crossed at right angles to the perpendicular plane to the FH plane, which included a line connecting the mesiodistal anatomical contact points of the first molar. On this cutting image, the amounts of lateral overjet and molar inclination were measured.^{10,11}

The method error was computed from all 44 sets of frontal cephalograms and dental models to examine measurement reliability. Each cephalogram was traced twice at an interval of 3 weeks. Similarly, dental model measurement was computed twice at an interval of 3 weeks. Analysis with a paired *t* test of the mean difference between duplicate measurements of the variables showed no significant systematic errors (Table I).

The subjects were divided into 2 groups for the comparative study: a facial asymmetry group (11 men and 14 women, total $n = 25$) in which the mandibular transverse deviation (Me) exceeded ± 1 SD (mean \pm SD: 2.2 ± 1.7 mm) from the Japanese norm² and a control group (8 men and 11 women, total $n = 19$) in which the mandibular transverse deviation (Me) was

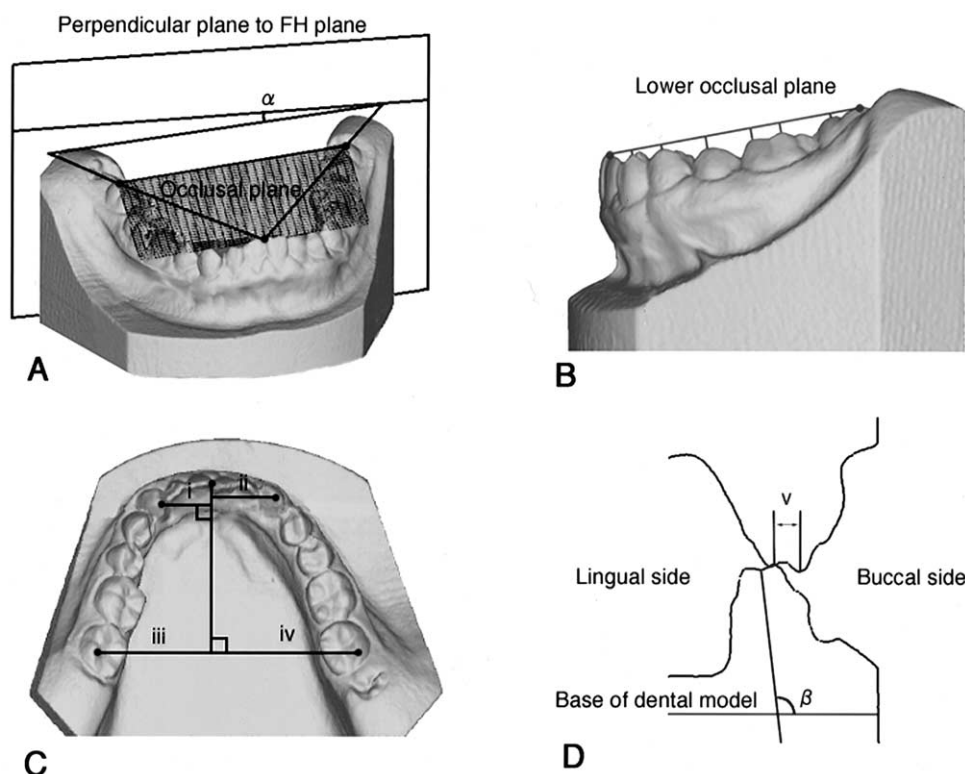


Fig 2. 3D dental model analysis. **A**, Occlusal plane angle (α); **B**, curve of Spee, greatest distance from lower occlusal plane to apex of each lateral tooth buccal cusp; **C**, dental arch form, symmetry of dental arch evaluated by using perpendicular distance at canine (*i*, *ii*) and second molar (*iii*, *iv*); **D**, lateral overjet (v) and molar inclination (β).

within ± 1 SD of the Japanese norm. Lateral cephalometric analysis demonstrated skeletal Class III malocclusion characterized by mandibular protrusion in both groups compared with the Japanese norm,¹² but no significant difference was found in lateral morphology between the 2 groups (Table II). Frontal cephalometric analysis, however, showed significant morphological differences between the 2 groups (Fig 3). When compared with the Japanese norm, the mean value of each cephalometric measurement in the control group was similar, but the facial asymmetry group showed marked facial asymmetry including maxillary and mandibular deviation in the transverse dimension.

Statistical values, including mean and SD, were computed for each dental model measurement on the mandibular shifted and nonshifted sides in each group. Subsequently, the asymmetry index was computed by subtracting the values on the mandibular shifted side from those of the nonshifted side for each dental model measurement, and the statistical values of this asymmetry index were also computed in each group. Statistical differences in each dental model measurement

between the 2 groups were examined with a paired *t* test.

Stepwise linear regression analysis was completed to obtain a significantly valid skeletal asymmetry for describing each dental anomaly using dental anomaly variables and skeletal asymmetry variables as response variables and explanatory variables (*F* value > 5.0). Then Pearson correlation coefficients were computed between a significant pair of dental anomaly variables and a pair of skeletal asymmetry variables to examine the quantitative relationship between the dental anomaly and the skeletal asymmetry.

The statistical analysis was performed with Stat-View 4.5 software (Abacus Concepts, SAS Institute, Cary, NC) on a personal computer system.

RESULTS

Characteristic dental anomalies in facial asymmetry (Table III)

The upper and lower occlusal plane angles in the facial asymmetry group (upper, $1.4^\circ \pm 1.6^\circ$; lower,

Table I. Method error: Differences between duplicate measurements of dental model and frontal cephalometric variables

<i>Variable</i>	<i>Difference mean \pm SD</i>	<i>Statistical significance</i>
Dental model variables		
Occlusal plane		
Upper	0.2 \pm 0.3	NS
Lower	0.2 \pm 0.4	NS
Spee curve		
Shifted side	0.2 \pm 0.3	NS
Nonshifted side	0.2 \pm 0.3	NS
Dental arch form at maxillary canine		
Shifted side	0.4 \pm 0.7	NS
Nonshifted side	0.3 \pm 0.6	NS
Dental arch form at maxillary second molar		
Shifted side	0.4 \pm 0.6	NS
Nonshifted side	0.4 \pm 0.6	NS
Dental arch form at mandibular canine		
Shifted side	0.3 \pm 0.7	NS
Nonshifted side	0.3 \pm 0.5	NS
Dental arch form at mandibular second molar		
Shifted side	0.4 \pm 0.8	NS
Nonshifted side	0.3 \pm 0.7	NS
Lateral overjet		
Shifted side	0.2 \pm 0.2	NS
Nonshifted side	0.1 \pm 0.2	NS
Maxillary molar inclination		
Shifted side	0.5 \pm 0.8	NS
Nonshifted side	0.6 \pm 1.0	NS
Mandibular molar inclination		
Shifted side	0.6 \pm 1.1	NS
Nonshifted side	0.6 \pm 1.0	NS
Frontal cephalometric variables		
Transverse dimension		
Lo/Lo'	0.01 \pm 0.03	NS
Zyg/Zyg'	0.01 \pm 0.02	NS
Mx/Mx'	0.01 \pm 0.03	NS
Mo/Mo'	0.02 \pm 0.03	NS
Cd/Cd'	0.01 \pm 0.02	NS
Go/Go'	0.01 \pm 0.02	NS
U1	0.10 \pm 0.41	NS
L1	0.12 \pm 0.46	NS
Me	0.25 \pm 0.74	NS
Vertical dimension		
Zyg-Zyg'	0.17 \pm 0.20	NS
Mx-Mx'	0.11 \pm 1.17	NS
Mo-Mo'	0.11 \pm 0.41	NS
Cd-Cd'	0.27 \pm 0.41	NS
Go-Go'	0.12 \pm 0.26	NS

NS, not significant.

1.7° \pm 2.0°) were significantly larger than in the control group (upper, 0.6° \pm 0.5°; lower 0.7° \pm 0.6°).

The curve of Spee on the mandibular shifted side in the facial asymmetry group (1.7 \pm 0.9 mm) was larger than in the control group (1.6 \pm 0.9 mm), but no significant difference was found between the 2 groups. The curve of Spee on the mandibular nonshifted side in

the facial asymmetry group (0.8 \pm 0.9 mm) was significantly smaller than in the control group (1.4 \pm 0.8 mm). The mean value of the asymmetry index in the facial asymmetry group (0.9 \pm 0.6 mm) was significantly larger than in the control group (0.2 \pm 0.1 mm).

No significant asymmetry of the maxillary dental arch was found at the canines or the second molars

Table II. Lateral cephalometric analysis

	Asymmetry group	Control group	Asymmetry group vs Control group	Japanese norm	
	Mean \pm SD	Mean \pm SD	Statistical significance	Men	Women
SNA	81.8 \pm 2.7	82.1 \pm 2.8	NS	81.8 \pm 3.1	82.3 \pm 3.45
SNB	84.0 \pm 3.4	85.4 \pm 3.5	NS	78.6 \pm 3.1	78.9 \pm 3.45
A-B difference	-2.2 \pm 2.5	-3.4 \pm 2.6	NS	3.3 \pm 2.7	3.4 \pm 1.8
Overjet	-2.5 \pm 2.6	-2.7 \pm 1.3	NS	NA	NA
Overbite	2.4 \pm 1.9	2.3 \pm 1.4	NS	NA	NA

NS, not significant; NA, not available.

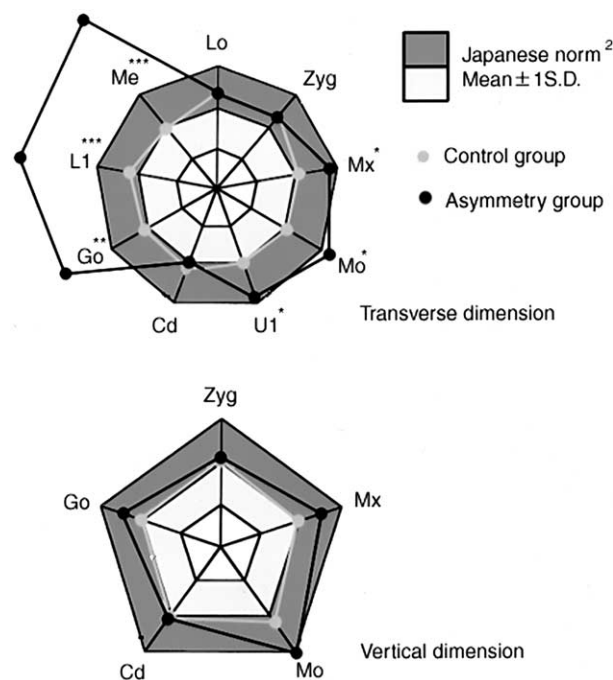


Fig 3. Frontal cephalometric analysis. * $P < .05$; ** $P < .01$; *** $P < .0001$; NS, not significant.

between the 2 groups, but a significant asymmetry of the mandibular dental arch was found at the canines and the second molars between the 2 groups. The mean values of the distance from the mandibular canine and the second molar to the dental arch centerline on the mandibular shifted side in the facial asymmetry group (canine, 18.3 \pm 4.3 mm; second molar, 36.5 \pm 8.1 mm) were smaller than in the control group (canine, 18.9 \pm 1.1 mm; second molar, 37.7 \pm 2.5 mm). The mean values on the mandibular nonshifted side in the facial asymmetry group (canine, 20.3 \pm 4.3 mm; second molar, 40.4 \pm 8.7 mm) were larger than in the control group (canine, 19.1 \pm 0.7 mm; second molar, 38.0 \pm

2.1 mm). No significant differences were found in the distance on either the mandibular shifted side or nonshifted side between the 2 groups, but the mean values of the asymmetry index at both the mandibular canine and the second molar in the facial asymmetry group (canine, -2.0 \pm 3.1 mm; second molar, -3.8 \pm 6.0 mm) were significantly smaller than in the control group (canine, -0.2 \pm 0.3 mm; second molar, -0.3 \pm 1.3 mm).

Lateral overjet on the mandibular shifted side in the facial asymmetry group (-1.3 \pm 1.6 mm) was significantly smaller than in the control group (0.4 \pm 1.8 mm), and that on the mandibular nonshifted side in the facial asymmetry group (2.0 \pm 1.2 mm) was significantly larger than in the control group (0.5 \pm 1.4 mm). The mean value of the asymmetry index in the facial asymmetry group (-3.3 \pm 1.7 mm) was significantly smaller than in the control group (-0.1 \pm 0.5 mm).

The maxillary molar inclination on the mandibular shifted side in the facial asymmetry group (82.4° \pm 5.3°) was significantly smaller than in the control group (86.5° \pm 2.3°). The maxillary molar inclination on the mandibular nonshifted side in the facial asymmetry group (88.5° \pm .5°) was significantly larger than in the control group (86.7° \pm 2.2°). The mean value of the asymmetry index in the facial asymmetry group (-6.0° \pm 5.5°) was significantly smaller than in the control group (-0.9° \pm 1.9°).

In contrast, the mandibular molar inclination on the mandibular shifted side in the facial asymmetry group (100.6° \pm 7.9°) was significantly larger than in the control group (95.8° \pm 2.5°), and that on the mandibular nonshifted side in the facial asymmetry group (92.4° \pm 3.6°) was significantly smaller than in the control group (94.8° \pm 2.5°). The mean value of the asymmetry index in the facial asymmetry group (8.2° \pm 8.9°) was significantly smaller than in the control group (1.0° \pm 1.5°).

Table III. Characteristic dental anomalies

<i>Dental model measurements</i>	<i>Asymmetry group</i>	<i>Control group</i>	<i>Asymmetry group vs control group</i>
	<i>Mean ± SD</i>	<i>Mean ± SD</i>	<i>Statistical significance</i>
Occlusal plane (°)			
Upper	1.4 ± 1.6	0.6 ± 0.5	*
Lower	1.7 ± 2.0	0.7 ± 0.6	**
Spee curve (mm)			
Shifted side	1.7 ± 0.9	1.6 ± 0.9	NS
Nonshifted side	0.8 ± 0.9	1.4 ± 0.8	**
Asymmetry index	0.9 ± 0.6	0.2 ± 0.1	***
Dental arch form at maxillary canine (mm)			
Shifted side	25.5 ± 5.1	24.2 ± 1.8	NS
Nonshifted side	24.6 ± 5.3	24.0 ± 1.3	NS
Asymmetry index	0.9 ± 1.51	0.3 ± 0.8	NS
Dental arch form at maxillary second molar (mm)			
Shifted side	42.7 ± 9.4	41.6 ± 1.2	NS
Nonshifted side	40.5 ± 9.1	41.8 ± 1.6	NS
Asymmetry index	2.2 ± 4.4	-0.2 ± 1.1	NS
Dental arch form at mandibular canine (mm)			
Shifted side	18.3 ± 4.3	18.9 ± 1.1	NS
Nonshifted side	20.3 ± 4.3	19.1 ± 0.7	NS
Asymmetry index	-2.0 ± 3.1	-0.2 ± 0.3	*
Dental arch form at mandibular second molar (mm)			
Shifted side	36.5 ± 8.1	37.7 ± 2.5	NS
Nonshifted side	40.4 ± 8.7	38.0 ± 2.1	NS
Asymmetry index	-3.8 ± 6.0	-0.3 ± 1.3	*
Lateral overjet (mm)			
Shifted side	-1.3 ± 1.6	0.4 ± 1.8	**
Nonshifted side	2.0 ± 1.2	0.5 ± 1.4	**
Asymmetry index	-3.3 ± 1.7	-0.1 ± 0.5	***
Maxillary molar inclination (°)			
Shifted side	82.4 ± 5.3	86.5 ± 2.3	*
Nonshifted side	88.5 ± 3.5	86.7 ± 2.2	*
Asymmetry index	-6.0 ± 5.5	-0.9 ± 1.9	**
Mandibular molar inclination (°)			
Shifted side	100.6 ± 7.9	95.8 ± 2.5	*
Nonshifted side	92.4 ± 3.6	94.8 ± 2.5	*
Asymmetry index	8.2 ± 8.9	1.0 ± 1.5	***

* $P < .05$; ** $P < .01$; *** $P < .0001$; NS, not significant.**Relationship between dental anomalies and skeletal asymmetry (Table IV)**

Stepwise linear regression analysis selected mandibular vertical asymmetry (Go-Go') as a valid parameter for the upper and lower occlusal plane angle. Significant correlations were found between mandibular vertical asymmetry and occlusal plane angle (upper, $r = 0.57$; lower, $r = 0.56$).

Mandibular transverse asymmetry (Me) coupled with maxillary vertical asymmetry (Mx-Mx') was found to be a valid parameter for the curve of Spee on the mandibular nonshifted side and the asymmetry index of the curve of Spee. The curve of Spee on the mandibular nonshifted side showed significant correlations with mandibular transverse deviation ($r = -0.48$)

and maxillary vertical asymmetry ($r = -0.39$). Similarly, the asymmetry index of the curve of Spee showed significant correlations with mandibular transverse asymmetry ($r = 0.60$) and maxillary vertical asymmetry ($r = 0.36$).

Mandibular transverse asymmetry (Me) was found to be a valid parameter for lateral overjet on both the mandibular shifted and nonshifted sides and the asymmetry index of lateral overjet. A significant correlation was found between mandibular transverse asymmetry and lateral overjet on the mandibular shifted side ($r = -0.47$) and nonshifted side ($r = 0.48$). Similarly, the asymmetry index of lateral overjet showed a significant correlation with mandibular transverse asymmetry ($r = -0.73$).

Table IV. Stepwise linear regression analysis and significant correlation coefficients between dental model measurements and cephalometric measurements

Response variable (dental model measurement)	Explanatory variable (cephalometric measurement)	F value	Correlation coefficients
Occlusal plane			
Upper	Go-Go'	20.2	0.57***
Lower	Go-Go'	18.7	0.56**
Curve of Spee			
Nonshifted side	Me	12.5	-0.48**
	Mx-Mx'	7.5	-0.39*
Asymmetry index	Me	23.1	0.60***
	Mx-Mx'	6.2	0.36*
Lateral overjet			
Shifted side	Me	11.6	-0.47**
Nonshifted side	Me	12.5	0.48**
Asymmetry index	Me	47.2	-0.73***
Maxillary molar inclination			
Shifted side	Me	20.3	-0.58***
Nonshifted side	Me	6.8	0.38*
Asymmetry index	Me	44.2	-0.78***
Mandibular molar inclination			
Shifted side	Me	8.7	0.42**
Nonshifted side	Me	19.5	-0.57**
Asymmetry index	Me	23.9	0.63***

* $P < .05$; ** $P < .01$; *** $P < .0001$.

Mandibular transverse asymmetry (Me) was found to be a valid parameter for maxillary molar inclination on both the mandibular shifted and nonshifted sides and the asymmetry index of maxillary molar inclination. A significant correlation was found between mandibular transverse asymmetry and maxillary molar inclination on the mandibular shifted side ($r = -0.58$) and nonshifted side ($r = 0.38$). Similarly, the asymmetry index of the maxillary molar inclination showed a significant correlation with mandibular transverse asymmetry ($r = -0.78$).

Mandibular transverse asymmetry (Me) was found to be a valid parameter for mandibular molar inclination on both the mandibular shifted and nonshifted sides and the asymmetry index of mandibular molar inclination. A significant correlation was found between mandibular transverse asymmetry and mandibular molar inclination on the mandibular shifted side ($r = 0.42$) and the mandibular nonshifted side ($r = -0.57$). Similarly, the asymmetry index of maxillary molar inclination showed a significant correlation with mandibular transverse asymmetry ($r = 0.63$).

DISCUSSION

Using 11 facial asymmetry patients. Shigefuji et al¹¹ reported a significant difference in buccolingual

tooth inclination of the maxillary and mandibular molars between the mandibular shifted and nonshifted sides. They also reported a significantly high correlation between tooth inclination of the maxillary molar on the mandibular nonshifted side and the amount of mandibular transverse deviation. Using 24 facial asymmetry patients, Suda et al¹³ reported a significantly high correlation between buccolingual tooth inclination of the mandibular molar on the mandibular shifted side and the amount of mandibular transverse deviation. They also reported a significantly high correlation between the upward slanted occlusal plane angle and the amount of mandibular transverse deviation. These previous studies demonstrated some characteristic transverse dental anomalies and their relationship with skeletal facial asymmetry but failed to characterize these dental anomalies because there was no control group.

In the present study, however, the subjects were divided into 2 groups according to the amount of facial asymmetry. Significant morphological differences were found in the frontal cephalometric analysis but not in the lateral cephalometric analysis. Accordingly, statistical comparisons between the 2 groups clearly disclosed the following more detailed transverse dental anomalies characterized by the patients with facial asymmetry.

1. The upper and lower occlusal plane in the patients with facial asymmetry slanted significantly upward to the mandibular shifted side.
2. The curve of Spee on the mandibular nonshifted side in patients with facial asymmetry was significantly smaller, and a significant difference was found in the curve of Spee between the mandibular shifted and nonshifted sides.
3. Lateral overjet in patients with facial asymmetry was significantly smaller on the mandibular shifted side and significantly larger on the mandibular nonshifted side. A significant difference was also found in lateral overjet between the mandibular shifted and nonshifted sides, which could be a main cause of unilateral crossbite characteristically found in patients with facial asymmetry.
4. In patients with facial asymmetry, significant labial tipping of the maxillary molar inclination coupled with lingual tipping of the mandibular molar inclination was found on the mandibular shifted side. In contrast, significant lingual tipping of the maxillary molar inclination coupled with labial tipping of the mandibular molar inclination was found on the mandibular nonshifted side. Significant differences were also found in the tooth inclination of the

maxillary and mandibular molars between the mandibular shifted and nonshifted sides.

5. No significant asymmetry of the maxillary dental arch was found at the canine and second molar in patients with asymmetry, but a significant asymmetry of the mandibular dental arch because of the lateral deviation of the canine and second molar was found in patients with facial asymmetry.

To evaluate relationships between dental anomalies and skeletal asymmetry, a simple correlation analysis between dental anomalies and mandibular transverse asymmetry alone was performed in previous studies.^{11,13} However, it was reported that the patients with facial asymmetry had variable skeletal asymmetry not only in the transverse dimension but also in the vertical dimension,^{4,5} and that multiple correlations existed among skeletal asymmetry variables. Therefore, in the present study, stepwise linear regression analysis was first performed to clarify valid skeletal asymmetry variables for describing characteristic dental anomalies. The Pearson correlation coefficients were subsequently computed between a significant pair of dental anomaly variables and skeletal asymmetry variables to examine the quantitative relationship between dental anomalies and skeletal asymmetry.

Stepwise linear regression analysis showed significant valid skeletal asymmetry variables for explaining dental anomaly variables except asymmetry of the maxillary and mandibular dental arch forms. Transverse and vertical skeletal asymmetry variables including the mandible and maxilla were found to be effective parameters for characteristic dental anomaly variables, but selected skeletal asymmetry variables were different in each dental anomaly variable. Stepwise linear regression analysis selected only transverse mandibular asymmetry as a valid parameter for buccolingual tooth inclination of the maxillary and mandibular molars in addition to lateral overjet. Significantly high correlation coefficients between these dental and skeletal variables suggested that the greater the mandible's transverse deviation, the greater the difference in molar inclination between the mandibular shifted and nonshifted sides. According to the mandibular transverse deviation, labial tipping of the maxillary molar and lingual tipping of the mandibular molar on the mandibular shifted side increased, while lingual tipping of the maxillary molar and labial tipping of the mandibular molar on the mandibular nonshifted side increased. Similarly, it was suggested that the greater the mandible deviated transversely, the greater the difference in lateral overjet between the mandibular shifted and nonshifted sides because of the decreased lateral overjet on the shifted

side coupled with the increased lateral overjet on the nonshifted side. In contrast, stepwise linear regression analysis selected only vertical mandibular asymmetry as a valid parameter for the cant of the upper and lower occlusal planes. Significantly high correlation coefficients between occlusal plane angle and mandibular vertical asymmetry suggested that the greater the mandible deviated vertically, the greater the upper and lower occlusal planes slanted upward to the mandibular shifted side. Transverse mandibular asymmetry and vertical maxillary asymmetry were found to be effective parameters for the differences in the curve of Spee between the mandibular shifted and nonshifted sides. Significant correlation coefficients suggested that the greater the mandible deviated transversely and the greater the maxilla deviated vertically, the greater the differences in the curve of Spee between the mandibular shifted and nonshifted sides because of the decreased curve of Spee on the mandibular nonshifted side. These results clearly demonstrate that transverse and vertical skeletal asymmetry including the maxilla and the mandible have a significant correlation with transverse dental anomalies, suggesting characteristic dental compensation in patients with facial asymmetry.

CONCLUSIONS

The records of 44 Japanese adult skeletal Class III patients who required orthognathic surgery were examined to assess the relationship between transverse dental anomalies and skeletal asymmetry. The patients were divided into control and facial asymmetry groups according to the mandibular transverse deviation. Statistical comparisons with the control group disclosed the following characteristic transverse dental anomalies in the facial asymmetry group:

1. Upper and lower occlusal planes slanted significantly upward to the mandibular shifted side.
2. A significant difference was found in the curve of Spee between the mandibular shifted and nonshifted sides because of a significantly small curve of Spee on the mandibular nonshifted side.
3. A significant difference was found in the lateral overjet between the mandibular shifted and nonshifted sides because of a significantly small lateral overjet on the mandibular shifted side.
4. Significant labial tipping of the maxillary molar inclination coupled with lingual tipping of the mandibular molar inclination was found on the mandibular shifted side. In contrast, significant lingual tipping of the maxillary molar inclination coupled with labial tipping of mandibular molar inclination was found on the mandibular nonshifted side.

5. A significant asymmetry of the mandibular dental arch due to the lateral deviation of the canine and the second molar was found in patients with facial asymmetry.

Stepwise linear regression analysis was performed to examine relationships between transverse dental anomalies and skeletal asymmetry. The results showed that transverse and vertical skeletal asymmetry variables including the mandible and the maxilla were effective parameters for characteristic dental anomaly variables, and a significantly high correlation between transverse dental anomalies and skeletal asymmetry was found.

REFERENCES

1. Aoshima O. Investigation of the facial asymmetry of cases with crossbites needing surgical orthodontic treatment using postero-anterior roentgenographic cephalometrics. *J Jpn Orthod Soc* 1990;49:256-62.
2. Kato Y, Tengan T, Shimizu R, Uji M, Motohashi N, Kuroda T. Frontal cephalometric analysis. *Jpn J Jaw Deform* 1994;4:87-95.
3. Fukui T, Satoh Y, Yamada K, Morita S, Hanada K. Relationships between mandibular lateral deviation and bilateral condylar paths on mandibular movement. *J Jpn Orthod Soc* 1992;51:203-9.
4. Kato Y, Motohashi N, Nakagawa F, Kawamoto T, Ono T, Kuroda T, et al. Relation between frontal morphology of the facial skeleton and the condylar path in facial asymmetry patients. *Jpn J Jaw Deform* 2000;10:264-72.
5. Woods MG, Swift JQ, Markowitz NR. Clinical implications of advances in orthognathic surgery. *J Clin Orthod* 1989;23:420-9.
6. Hanada K. Surgical orthodontics in the mandibular prognathism. *J Jpn Orthod Soc* 1992;51:1-24.
7. Kuroda T, Motohashi N, Tominaga R, Iwata K. Three-dimensional dental cast analyzing system using laser scanning. *Am J Orthod Dentofacial Orthop* 1996;110:365-9.
8. Motohashi N, Kuroda T. A 3D computer-aided design system applied to diagnosis and treatment planning in orthodontics and orthognathic surgery. *Eur J Orthod* 1999;21:263-74.
9. Iwasawa T, Namura S. The curve of Spee and occlusal plane in the persons with normal occlusion. *J Jpn Orthod Soc* 1964;23:13-20.
10. Okada R, Motohashi N, Kuroda T. Molar occlusal changes in the frontal dimension following surgical orthodontic treatment for patient with skeletal mandibular protrusion. *Jpn J Jaw Deform* 1996;6:129-36.
11. Shigefuji R, Motohashi N, Kuroda T. Longitudinal changes of molar dental compensation following orthognathic surgery in facial asymmetry patients. *Jpn J Deform* 2001;11:11-20.
12. Iizuka T, Ishikawa F. Normal standards for various cephalometric analysis in Japanese adults. *J Jpn Orthod Soc* 1957;16:4-12.
13. Suda K, Daimoto M, Muramatsu H, Ichikawa K. Relationship between skeletal and denture patterns in facial asymmetric cases—analysis using P-A cephalograms and cast models. *J Tokyo Orthod Soc* 2001;11:15-25.

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