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Correlations of Mandibular Condyle Morphology with Occlusion and Maxillofacial Morphology in Patients with Malocclusion

Tadahiro ARAKAWA[1], Kenji SUEISHI[2], Satoru SHIMIZU[3] and Hideki OGIUCHI[1]

[1]Department of Oral and Maxillofacial Surgery (Director: Prof. Hideki OGIUCHI),
Tokyo Women's Medical University, School of Medicine
[2]Division of Orthodontics, Department of Clinical Oral Health Science (Director: Prof. Takashi KAKIZAWA),
Tokyo Dental College
[3]Department of Hygiene and Public Health II (Director: Prof. Naoto YAMAGUCHI),
Tokyo Women's Medical University, School of Medicine

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This study was conducted in order to investigate correlations between mandibular condyle morphology with occlusion and maxillofacial morphology. A total of 281 female were subjected to the study, and tomograms of their temporomandibular joints (TMJ), lateral cephalograms and intraoral models were studied. Mandibular condyle morphology was classified into 4 types, and molar occlusions were classified into 3 types based on Angle's classification. In addition, maxillofacial morphology was assessed by measuring 10 items. Based on these data, correlations between mandibular condyle morphology and occlusion, and correlations between mandibular condyle morphology and maxillofacial morphology were investigated, and the following conclusions were reached.

1. Type 1 mandibular condyle morphology was observed most frequently throughout all occlusions, especially in the Angle class III. Type 2 was seen less frequently in the Angle class III, and type 3 was seen more frequently in the Angle class III than in the Angle class II. Type 4 was not observed very often throughout the occlusions.

2. In the Angle class I, type 2 and 3 mandibular condyle morphology presented maxillofacial morphology featuring small incisor overbites. In addition, a slight antero-superior rotation of the mandible was observed in type 4. In the Angle class II, type 2 and 3 presented posterior or postero-inferior rotations of the mandible. In the Angle class III, positive incisor overlap was seen only with type 2.

3. According to AIC analysis, the measurement item which was associated the most with mandibular condyle morphology was ramus inclination, suggesting that the most significant correlation was between the mandibular ramus inclination and the mandibular condyle morphology. Moreover, the horizontal relationship of mandible was assumed to be relatively more associated with mandibular condyle morphology than with vertical relationship.

Key words: mandibular condyle morphology, occlusion, maxillofacial morphology

Introduction

There have been many studies reported regarding mandibular condyle morphology[1)~3)]. However, only a few reports are available for studies regarding correlations between mandibular condyle morphology with occlusion and maxillofacial morphology. Schellhas et al[4)] and Ozawa et al[5)] reported the possibility of morphological change of maxillofacial feature along with morphological change in mandibular condyle, and Imai et al[6)] reported that malocclusions such as open bite in incisor region, molar crossbite or maxillary protrusion induced by

postero-inferior rotation or lateral deviation of mandible due to morphological change or absorption of mandibular condyle would result in facial feature including withdrawal of mentum or facial asymmetry. In addition, it has also been reported that malocclusion is related in some way to the development of TMJ disorder including morphological change in mandibular condyle[7)~11)]. Hence, it is assumed that there are close relationships between abnormal mandibular condyle morphology and malocclusion, and between abnormal mandibular condyle morphology and abnormal maxillofacial morphology. However, it is not clear if abnormal mandibular condyle morphology induced malocclusion and abnormal maxillofacial morphology or vice versa, or if this was the consequence of interactions between two conditions. In any event, it seems that mandibular condyle morphology and occlusion or mandibular condyle morphology and maxillofacial morphology are affecting one another in morphological development, resulting in the presentation of particular features. The correlations between occlusion and maxillofacial morphology have been already clarified in many reports[12)13)]. Therefore, in this study, investigations were performed in order to assume the correlations between occlusion and mandibular condyle morphology, and those between mandibular condyle morphology and maxillofacial morphology.

Subjects and Methods

1. Subjects and materials

Among all malocclusion patients from whom necessary materials were obtained for orthodontic diagnosis, only female patients were subjected to the study so that there was no need to consider morphological differences associated with the sex of subjects.

Two hundred and eighty one female patients aged from 17 years and 0 month to 39 years and 11 months (mean: 24 years and 1 month), excluding those who had TMJ disorders or systemic inflammatory diseases such as rheumatoid arthritis or congenital morphological anomalies such as cleft lips and/or cleft palates or those missing multiple teeth, were included in the study. The patients younger than 17 years of age who seem to present significant growth-related changes in maxillofacial features, as well as those aged 40 years or older who are considered to have more prominent regressive changes in TMJ morphology were not subjected to the study. Among all the diagnostic materials obtained, tomograms of TMJ, lateral cephalograms and intraoral models were used as study materials.

2. Study methods

1) Classification of mandibular condyle morphology

Based on the classifications suggested by Ueda[14)] and Shiina et al[15)], mandibular condyle morphology were classified into 4 types by observing regions with morphological changes in tomograms of TMJ (Fig. 1 and 2). The assessments were performed on each side of 562 mandibular condyles.

Type 1: Mandibular condyle morphology is nearly round.

Type 2: Anterior region of mandibular condyle is flattened.

Type 3: Upper region of mandibular condyle is flattened.

Type 4: Posterior region of mandibular condyle is flattened.

2) Analysis of cephalograms

Tracing pictures were prepared for all cephalograms by the same technician, and assessments of mandibular condyle morphology were performed by measuring the angles and distances of 10 items, including 7 items for skeletal systems and 3 items for dental and alveolar systems (Fig. 3).

1. SNA (angle that S-N and N-A make): Assess the position of maxilla in term of anterior/posterior relationship.

2. SNB (angle that S-N and N-B make): Assess the position of mandible in term of anterior/posterior relationship.

3. ANB (difference between SNA and SNB): Assess the position of mandible with regard to maxilla in term of anterior/posterior relationship.

4. Ramus inclination (angle that Po-Or and ramus plane make): Assess inclination of the posterior margin of mandibular ramus.

5. Occlusal inclination (angle that Po-Or and oc-

clusal plane make): Assess inclination of occlusion.

6. Facial axis (angle that Ba-N and Pt-Gn make): Assess the position of mandible in term of superior/inferior and anterior/posterior relationships.

7. Mandibular plane angle (angle that Po-Or and mandibular plane make): Assess inclination of the lower margin of mandible.

8. Lower facial height (angle that ANS-Xi and Xi-Pm make): Assess position of maxilla and mandible in term of superior/inferior relationship.

9. Overjet (horizontal distance between edge of upper incisor and lower incisor): Assess position of maxillary and mandibular incisors in term of anterior/posterior relationship.

10. Overbite (vertical distance between edge of upper incisor and lower incisor): Assess position of maxillary incisor in term of superior/inferior relationship.

3) Molar occlusion

Based on classification for malocclusion suggested by Angle[16], medio-distal occlusion of maxillary and mandibular first molars was classified into the following 3 types (Fig. 4). The assessments were performed on each side of 562 occlusions.

Angle class I: Medio-distal occlusion of maxillary and mandibular first molar is normal.

Angle class II: Mandibular first molar is more distally located by at least half a cusp width with regard to the maxillary first molar compared to a normal occlusion.

Angle class III: Mandibular first molar is more medially located by at least half a cusp width with regard to the maxillary first molar compared to a normal occlusion.

4) Statistical analysis

(1) Tests for significant differences

In order to investigate the differences in maxillofacial morphology in association with mandibular condyle morphology and with molar occlusion, the mean value and the standard deviation of each measurement item obtained from cephalometric analysis were calculated. If a difference was observed between groups after confirming a normal distribution and equal variance, multiple comparisons were performed using Scheffe's test. The significant differences in the incidences of the each mandibular condyle morphology were assessed by performing tests regarding differences in ratios. In this investigation, tests were performed on each side of 562 mandibular condyles. In statistical proc-

Fig. 1 Classification of mandibular condyle morphology
(left) Type 1: Nearly round.
(mid-left) Type 2: Anterior region flattened.
(mid-right) Type 3: Upper region flattened.
(right) Type 4: Posterior region flattened.

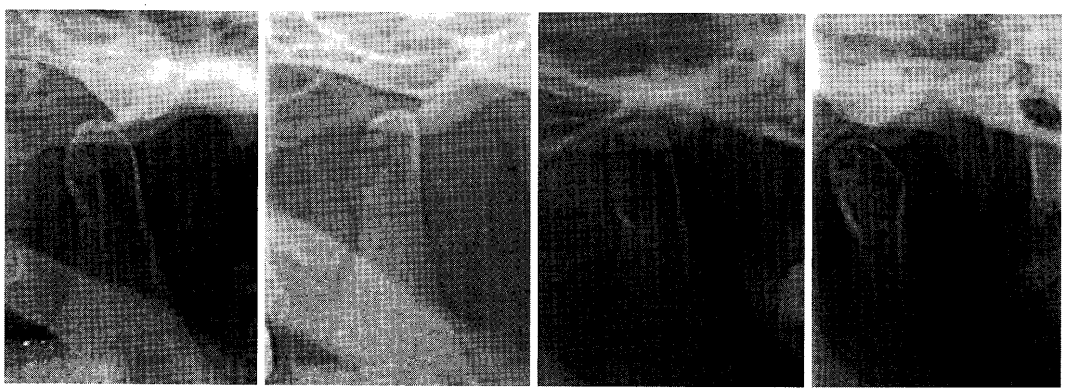

Fig. 2 Classification of mandibular condyle morphology (X-ray)
(left) Type 1: Nearly round.
(mid-left) Type 2: Anterior region flattened.
(mid-right) Type 3: Upper region flattened.
(right) Type 4: Posterior region flattened.

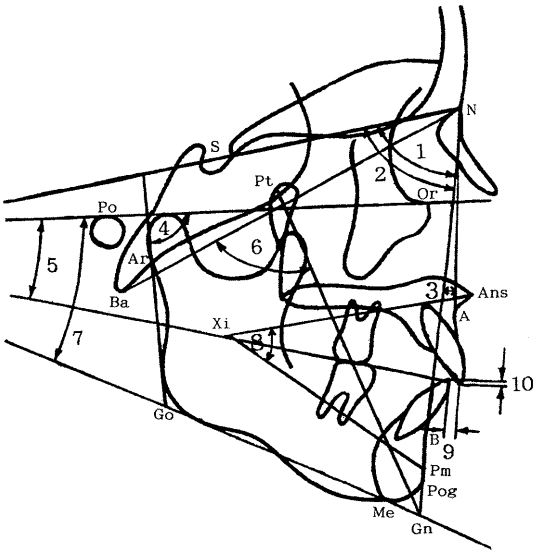

Fig. 3 Analysis of cephalograms
1. SNA, 2. SNB, 3. ANB, 4. Ramus inclination, 5. Occlusal plane angle, 6. Facial axis, 7. Mandibular plane angle, 8. Lower facial height, 9. Overjet, 10. Overbite.
N: Nasion, Or: Orbiale, Ans: Anterior nasal spine, A: Point A, B: Point B, Pm: Protuberance menti, Pog: Pogonion, Gn: Gnathion, Me: Menton, S: Sella turcica, Pt: Pterygoido point, Po : Porion, Ar: Articulare, Ba: Basion, Xi: point Xi, Go: Gonion

essing, Stat View J 4.0 (Abacus Concept, USA), a statistical analysis software, was used. The minimum level of statistical significance was set at $p<0.05$.

(2) Selection of the most appropriate explanatory variables

In order to investigate a comprehensive relationship between mandibular condyle morphology and maxillofacial morphology, mandibular condyle morphology and the measurement items of maxillofacial morphology were set as dependent variables and explanatory variables respectively. Then, among all the measuring items for maxillofacial morphology, the item which imposed the greatest influence on mandibular condyle morphology as a variable was assessed based on Akaike's information criterion (AIC)[17]. Furthermore, each measuring item was classified into 2-4 classes optimized using AIC, and comparisons were made by obtaining the incidence of the each mandibular condyle morphology. A statistical software, CATDAT[17], was used for the evaluation using AIC.

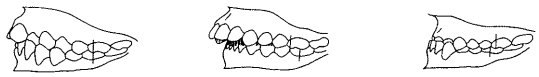

Fig. 4 Angle's classifications
(left) Angle class I, (middle) Angle class II, (right) Angle class III.

Results

1. Occlusion

Similar ratios were observed for Angle class I, II and III; i.e. 182 (32.4%), 181 (32.2%) and 199 (35.4%), respectively (Fig. 5).

2. Mandibular condyle morphology

Mandibular condyle morphology for types 1, 2, 3 and 4 were found in 332 (59.1%), 118 (21.0%), 60 (10.7%) and 52 (9.2%) subjects, respectively. Type 1, in which mandibular condyle morphology is nearly round, was seen in approximately 60% of the cases (Fig. 6).

3. Differences among occlusions

1) Mandibular condyle morphology

Occlusions were further classified according to the type of mandibular condyle morphology. For Angle class I, the numbers of subjects who showed mandibular condyle morphology types 1, 2, 3 and 4 were 102 (56.0%), 46 (25.3%), 18 (9.9%)and 16 (8.8%), respectively. For Angle class II, the numbers of subjects with morphology types 1, 2, 3 and 4 were 95 (52.5%), 55 (30.4%), 14 (7.7%) and 17 (9.4%), respectively. For Angle class III, the numbers of subjects for these morphology types were 135 (67.8%) for type 1, 17 (8.5%) for type 2, 28 (14.1%) for type 3 and 19 (9.6%) for type 4 (Table 1).

Type 1 mandibular condyle morphology was observed the most throughout all occlusions, and was observed more significantly in the Angle class III in comparison to those in the Angle class I ($p<0.05$) and class II ($p<0.01$). On the other hand, type 2 mandibular condyle morphology was seen less significantly in the Angle class III in comparison to those in the Angle class I and II ($p<0.01$). Type 3 mandibular condyle morphology was observed more significantly in the Angle class III, and numbered nearly twice as much as those in the Angle class II ($p<0.05$). Type 4 mandibular condyle morphology were

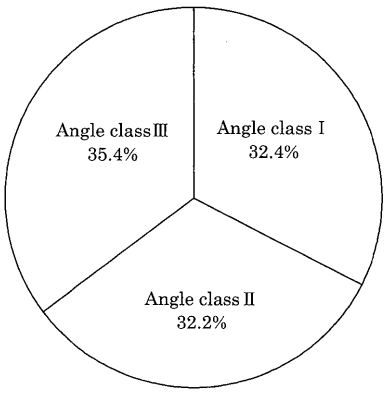

Fig. 5 The ratio of occlusions

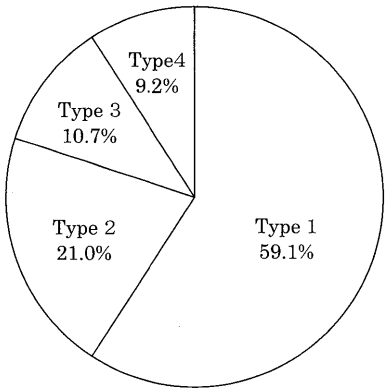

Fig. 6 The ratio of mandibular condyle morphology

Table 1 Mandibular condyle morphology in each occlusion

	Angle class I	Angle class II	Angle class III	Significant	
				$p < 0.05$	$p < 0.01$
Type 1	102 (56.0%)	95 (52.5%)	135 (67.8%)	I-III	II-III
Type 2	46 (25.3%)	55 (30.4%)	17 (8.5%)		I-III, II-III
Type 3	18 (9.9%)	14 (7.7%)	28 (14.1%)	II-III	
Type 4	16 (8.8%)	17 (9.4%)	19 (9.6%)		
Total	182 (100 %)	181 (100 %)	199 (100 %)		

Table 2 Findings from lateral cephalograms in each occlusion

	Class I (n = 182)		Class II (n = 181)		Class III (n = 199)		Significant	
	Mean	SD	Mean	SD	Mean	SD	$p < 0.05$	$p < 0.01$
SNA (°)	81.6	3.2	82.4	3.6	81.4	3.3	I-II	II-III
SNB (°)	78.8	4.2	77.0	4.2	82.8	4.1		I-II, I-III, II-III
ANB (°)	2.8	2.9	5.4	3.0	−1.4	2.9		I-II, I-III, II-III
Ramus inclination (°)	94.4	5.9	97.4	6.2	89.3	5.8		I-II, I-III, II-III
Occlusal plane angle (°)	9.6	4.9	11.4	4.7	9.7	4.3		I-II, II-III
Facial axis (°)	84.4	5.1	81.1	5.8	86.5	4.7		I-II, I-III, II-III
Mandibular plane angle (°)	29.4	7.5	32.0	8.5	30.7	6.7		I-II
Lower facial height (°)	48.5	5.5	50.3	6.3	49.5	4.7		I-II
Overjet (mm)	3.5	2.8	5.8	3.1	−0.9	2.6		I-II, I-III, II-III
Overbite (mm)	1.6	1.9	1.6	3.2	1.1	2.4	I-III	

not seen frequently in any occlusions, and there was no significant difference in terms of incidence among these occlusions.

2) Maxillofacial morphology

Significant differences among occlusions were observed throughout the 10 measurement items which had been used to characterize maxillofacial morphology. In other words, it was shown that molar occlusion could reflect difference in maxillofacial morphology (Table 2).

4. Correlations between mandibular condyle morphology and occlusion, and those between mandibular condyle morphology and maxillofacial morphology

1) Correlations between mandibular condyle morphology and maxillofacial morphology in the Angle class I

It was shown that the mandibular plane angle of type 4 mandibular condyle morphology was significantly smaller than that of type 3 in the Angle class I ($p<0.05$), and that the mandibular plane was

Table 3 Findings from lateral cephalograms for each mandibular condyle morphology in Angle class I

	Type 1 (n = 102)		Type 2 (n = 46)		Type 3 (n = 18)		Type 4 (n = 16)		Significant	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	$p < 0.05$	$p < 0.01$
SNA (°)	81.4	3.2	81.5	3.4	81.9	3.1	82.6	2.3		
SNB (°)	78.8	4.2	78.5	3.8	79.4	5.4	78.9	3.3		
ANB (°)	2.6	3.0	3.0	2.6	2.4	3.5	3.7	2.8		
Ramus inclination (°)	94.6	5.2	94.8	7.0	92.4	7.3	94.7	5.2		
Occlusal plane angle (°)	9.3	4.9	10.4	5.1	9.7	5.3	8.5	4.2		
Facial axis (°)	84.6	4.9	84.2	5.6	83.9	4.6	84.5	5.2		
Mandibular plane angle (°)	29.1	7.0	30.2	8.2	31.7	6.7	26.4	8.3	3-4,	
Lower facial height (°)	48.2	5.4	48.9	6.4	49.4	3.5	47.9	5.2		
Overjet (mm)	3.4	2.8	3.5	2.6	3.1	3.7	4.6	2.4		
Overbite (mm)	1.9	1.7	0.8	2.1	1.0	2.1	2.2	2.2	1-3, 2-4	1-2,

Table 4 Findings from lateral cephalograms for each mandibular condyle morphology in Angle class II

	Type 1 (n = 95)		Type 2 (n = 55)		Type 3 (n = 14)		Type 4 (n = 17)		Significant	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	$p < 0.05$	$p < 0.01$
SNA (°)	82.8	3.3	81.2	4.0	82.5	2.9	83.9	3.3	2-4,	1-2,
SNB (°)	77.9	4.0	75.0	3.9	76.1	5.0	79.3	3.4	3-4,	1-2, 2-4
ANB (°)	4.9	2.8	6.2	3.1	6.4	3.5	4.6	2.2		1-2,
Ramus inclination (°)	95.4	5.5	101.2	5.6	100.4	5.9	93.8	4.8		1-2, 1-3, 2-4, 3-4,
Occlusal plane angle (°)	10.2	4.0	13.8	5.3	12.5	4.6	9.0	3.5	3-4,	1-2, 2-4,
Facial axis (°)	82.5	5.5	78.1	5.7	79.2	6.3	85.0	2.4	1-3,	1-2, 1-4, 2-4, 3-4
Mandibular plane angle (°)	30.4	7.9	35.8	9.0	34.3	8.4	27.0	4.6		1-2, 2-4, 3-4,
Lower facial height (°)	48.8	5.9	53.5	6.9	51.9	4.0	46.9	3.3		1-2, 2-4, 3-4,
Overjet (mm)	5.7	3.2	6.1	3.2	6.5	3.2	5.5	2.5		
Overbite (mm)	2.3	2.7	0.1	4.0	1.7	2.4	3.0	2.0		1-2, 2-4,

slightly more rotated in the anterosuperior direction in type 4 as compared to type 3. In addition, significant differences were observed in overbite between type 1 and 2 ($p<0.01$), type 1 and 3 ($p<0.05$), and between type 2 and 4 ($p<0.05$). These findings suggest that overlapping of incisors was small in type 2 and 3 mandibular condyle morphology (Table 3).

2) Correlations between mandibular condyle morphology and maxillofacial morphology in the Angle class II

In the Angle class II, significant differences were observed between type 1 and 2 mandibular condyle morphology ($p<0.01$) in 9 items except for overjet, and between types 2 and 4 in 8 items except for ANB and overjet. Significant differences were also observed between type 3 and 4 mandibular condyle morphology in the following 6 items: SNB, ramus inclination, occlusal plane angle, facial axis, mandibular plane angle and lower facial height, and between type 1 and 3 in ramus inclination ($p<0.01$), and between type 1 and 3 and types 1 and 4 in facial axis (Table 4). In other words, in the Angle class II, type 2 mandibular condyle morphology showed characteristic maxillofacial morphology such as a withdrawn mandible, a posteriorly inclined posterior margin of the mandibular ramus accompanied by a sharpened angle of the occlusal plane, as well as a large incisor overjet and a small overbite compared to those in type 1 or type 4. Also in type 3, the mandible was more withdrawn compared to that of type 4, and displayed a postero-inferior rotation. There was no significant difference between type 2 and 3, and similar maxillofacial morphology, such as withdrawn mandible and postero-inferior rotation, were observed.

Table 5 Findings from lateral cephalograms for each mandibular condyle morphology in Angle class III

	Type 1 (n = 135)		Type 2 (n = 17)		Type 3 (n = 28)		Type 4 (n = 19)		Significant	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	$p < 0.05$	$p < 0.01$
SNA (°)	81.2	3.0	82.0	3.8	81.1	3.9	82.5	3.7		
SNB (°)	82.6	4.0	82.3	4.6	82.9	4.3	83.9	4.2		
ANB (°)	−1.4	2.8	−0.3	3.0	−1.9	3.2	−1.4	3.1		
Ramus inclination (°)	89.6	5.8	91.3	5.3	87.7	6.4	87.9	4.9		
Occlusal plane angle (°)	9.6	4.3	9.2	5.3	10.3	4.3	10.1	4.1		
Facial axis (°)	86.5	4.6	85.7	6.1	86.7	4.9	86.8	4.1		
Mandibular plane angle (°)	30.4	6.6	31.7	8.9	31.5	6.2	30.5	5.8		
Lower facial height (°)	49.2	4.5	50.4	5.6	50.4	5.3	49.8	4.9		
Overjet (mm)	−1.1	2.5	0.8	3.2	−0.9	2.2	−1.1	2.8	2-3,	1-2,
Overbite (mm)	1.3	2.3	1.5	1.9	0.4	3.1	0.9	1.9		

Table 6 AIC for mandibular condyle morphology and maxillofacial morphology

	AIC
Ramus inclination (°)	− 39.1
SNB (°)	− 34.7
ANB (°)	− 33.8
Lower facial height (°)	− 31.4
Overjet (mm)	− 31.0
Facial axis (°)	− 30.8
Overbite (mm)	− 28.1
Mandibular plane angle (°)	− 25.5
Occlusal plane angle (°)	− 25.0
SNA (°)	− 9.4

3) Correlations between mandibular condyle morphology and maxillofacial morphology in the Angle class III

In the Angle class III, significant differences were observed in overjet between type 1 and 2 ($p<0.01$) and between type 2 and 3 ($p<0.05$) mandibular condyle morphology. Only the measurement value obtained for type 2 was positive (Table 5). That is to say, it seems that in type 2 mandibular condyle morphology, incisors are frequently overlapped positively even in molar occlusions of Angle class III. No significant differences were observed in other measurement items.

5. Evaluation using AIC

When mandibular condyle morphology and maxillofacial morphology were analyzed as dependent variables and explanatory variables respectively, based on AIC the measurement item for maxillofacial morphology which showed the smallest value in AIC was ramus inclination (AIC: −39.1). This was followed by SNB, ANB, lower facial height, overjet, facial axis, overbite, mandibular plane angle, occlusal plane angle and SNA, suggesting that ramus inclination was the most significant model. That is to say, it was the most appropriate explanatory variable among all measuring items for maxillofacial morphology when mandibular condyle morphology was set as the dependent variables (Table 6).

When the incidences of mandibular condyle morphology for each level classified by AIC were investigated in each measurement item, it was found that the ratio of type 1 decreased while that of type 2 increased as the value of the ramus inclination increased. The ratios of type 2 decreased while type 4 increased slightly with increases of SNB. The larger the ANB value, the smaller the ratio of type 1 and the larger the ratio of type 2 became. The ratio of type 3 was high in the class with small, negative values. As the value for lower facial height increased, the ratio of type 1 decreased and that for type 2 increased. For overjets, the ratios of type 1 and 3 decreased, and the type 2 ratio increased as the overjet value increased. For facial axis, as the value increased, the ratio of type 1 increased while that for type 2 decreased. For overbite, the ratio of type 1 was small, type 2 was large, and type 3 was slightly large in the class with small values. In addition, the ratio of type 2 was also slightly large in the class with large values. When the value of the mandibular plane angle was large, the ratio of type 1 decreased while that for type 2 increased. For occlusal

Table 7 Incidences of mandibular condyle morphology in classified measuring items

	Class interval			Type 1	Type 2	Type 3	Type 4	Total
Ramus inclination (°)	72.10	—	78.44	3 (50.0%)	0 (0%)	3 (50.0%)	0 (0%)	6 (100%)
	78.45	—	91.24	130 (63.4%)	24 (11.7%)	25 (12.2%)	26 (12.7%)	205 (100%)
	91.25	—	104.04	190 (60.7%)	70 (22.4%)	27 (8.6%)	26 (8.3%)	313 (100%)
	104.05	—	110.08	9 (23.7%)	24 (63.2%)	5 (13.2%)	0 (0%)	38 (100%)
SNB (°)	66.10	—	75.64	52 (43.0%)	48 (39.7%)	16 (13.2%)	5 (4.1%)	121 (100%)
	75.65	—	86.44	262 (64.4%)	68 (16.7%)	35 (8.6%)	42 (10.3%)	407 (100%)
	86.45	—	93.30	18 (52.9%)	2 (5.9%)	9 (26.5%)	5 (14.7%)	34 (100%)
ANB (°)	−8.90	—	−3.44	34 (63.0%)	2 (3.7%)	15 (27.8%)	3 (5.6%)	54 (100%)
	−3.45	—	5.54	249 (62.6%)	73 (18.3%)	35 (8.8%)	41 (10.3%)	398 (100%)
	5.55	—	12.3	49 (44.5%)	43 (39.1%)	10 (9.1%)	8 (7.3%)	110 (100%)
Lower facial height (°)	36.20	—	42.74	40 (71.4%)	11 (19.6%)	0 (0%)	5 (8.9%)	56 (100%)
	42.75	—	56.04	266 (61.0%)	73 (16.7%)	53 (12.2%)	44 (10.1%)	436 (100%)
	56.05	—	67.80	26 (37.1%)	34 (48.6%)	7 (10.0%)	3 (4.3%)	70 (100%)
Overjet (mm)	−6.70	—	−0.44	103 (72.5%)	8 (5.6%)	21 (14.8%)	10 (7.0%)	142 (100%)
	−0.45	—	16.00	229 (54.5%)	119 (26.2%)	39 (9.3%)	42 (10.0%)	420 (100%)
Facial axis (°)	68.30	—	70.84	2 (16.7%)	8 (66.7%)	2 (16.7%)	0 (0%)	12 (100%)
	70.85	—	81.64	86 (53.7%)	54 (33.7%)	13 (8.1%)	7 (4.4%)	160 (100%)
	81.65	—	92.44	227 (62.4%)	50 (13.7%)	42 (11.5%)	45 (12.4%)	364 (100%)
	92.45	—	97.50	17 (65.4%)	6 (23.1%)	3 (11.5%)	0 (0%)	26 (100%)
Overbite (mm)	−8.20	—	−3.59	2 (11.1%)	11 (66.1%)	4 (22.2%)	1 (5.6%)	18 (100%)
	−3.60	—	2.04	174 (55.8%)	74 (23.7%)	42 (13.5%)	22 (7.1%)	312 (100%)
	2.05	—	7.64	153 (67.7%)	31 (13.7%)	13 (5.8%)	29 (12.8%)	226 (100%)
	7.65	—	11.70	3 (50.0%)	2 (33.3%)	1 (16.7%)	0 (0%)	6 (100%)
Mandibular plane angle (°)	14.00	—	20.74	32 (59.3%)	13 (24.1%)	0 (0%)	9 (16.7%)	54 (100%)
	20.75	—	34.24	213 (61.6%)	56 (16.2%)	38 (11.0%)	39 (11.3%)	346 (100%)
	34.25	—	47.74	83 (55.3%)	42 (28.0%)	22 (14.7%)	3 (2.0%)	150 (100%)
	47.75	—	57.70	4 (33.3%)	7 (58.3%)	0 (0%)	1 (8.3%)	12 (100%)
Occlusal plane angle (°)	−3.90	—	3.09	19 (55.9%)	10 (29.4%)	1 (2.9%)	4 (11.8%)	34 (100%)
	3.10	—	11.49	199 (64.2%)	40 (12.9%)	34 (11.0%)	37 (11.9%)	310 (100%)
	11.50	—	19.89	109 (54.5%)	57 (28.5%)	24 (12.0%)	10 (5.0%)	200 (100%)
	19.90	—	24.40	5 (27.8%)	11 (61.1%)	1 (5.6%)	1 (5.6%)	18 (100%)
SNA (°)	71.30	—	78.44	46 (52.9%)	28 (32.2%)	11 (12.6%)	2 (2.3%)	87 (100%)
	78.45	—	86.84	268 (61.6%)	80 (18.4%)	46 (10.6%)	41 (9.4%)	435 (100%)
	86.85	—	90.30	18 (45.0%)	10 (25.0%)	3 (7.5%)	9 (22.5%)	40 (100%)

plane angle, the ratio of type 1 was small while type 2 was large in the class with large values (Table 7). These findings suggest that the ratio for type 1 mandibular condyle morphology decreases while that for type 2 increases as mandibles rotate in posterior or postero-inferior directions. On the other hand, the ratio for type 3 mandibular condyle morphology was large when the position of mandible was anterior.

Discussion

1. Occlusion

With regard to the ratios of Angle's classification in patients with malocclusion, Ito et al[18] reported that, among all new patients seeking orthodontic treatment, 35.1% were classified as Angle class I, 33.3% as class II, and 25.9% as class III. Hirose et al[19] also reported similar results. As similar results were also obtained in this study, it seems that the subjects selected in this study can be considered to be a general group of patients possessing malocclusions.

2. Mandibular condyle morphology

With regard to TMJs, there have not been many studies reported in which mandibular condyle morphology was investigated in a large number of subjects as in this study, although there are many reports which were obtained based on questionnaires or those associated with TMJ disorders in epidemi-

cal assessments in common groups such as school screening or in investigations covering patients with malocclusion. Suzuki[20] investigated mandibular condyle morphology of edentulous patients and reported that, in patients younger than 65 years of age, 64.0% were classified as type 1, 12.0% as type 2, 14.0% as type 3 and 10.0% as type 4, and Ueda[14] reported that the ratio of patients who showed round mandibular condyle morphology was 58.8%. Although the ratio of type 1 morphologies in this study was similar to those in the studies of Ueda[14] and Suzuki[20] conducted in patients under 65 years of age, the ratio of type 2 was 21.0%, which is slightly higher than in other studies. This difference is thought to have resulted from the fact that patients with malocclusion were not covered by the studies conducted by Ueda and Suzuki, while they were covered in this study.

3. Occlusion and mandibular condyle morphology

Type 1, which shows nearly round morphology for mandibular condyle, was seen more significantly in Angle class III. Sugisaki et al[21] have reported that round type mandibular condyles were seen more in the Angle class III, less in the Angle class II. With regard to occlusion in orthodontic patients with TMJ disorder, there are not many cases with Angle class III, reversed occlusion[7][10], and as reported by Fushima et al[11], in reversed occlusions, the incidence of TMJ disorders was low due to the fact that the deviations were anterior in most cases even when mandibular condyle deviations were present due to occlusal interference. In addition, Yoshino[22] has reported that the centric relation corresponds to the centric occlusion in most reversed occlusion cases, and that the position of the jaw is relatively stable while it is functioning. It seems that round type mandibular condyle morphology was observed more frequently in Angle class III since jaw function abnormality did not develop frequently and deformation in mandibular condyle morphology due to the pressure against TMJs did not occur. In addition, in the Angle class III, opening or closing movement of the mouth is mostly controlled by rotation alone without any anterior sliding. It seems that morphological changes, if any, might occur with mandibular condyles in the upward direction rather than in the anterior direction, and occur more frequently with type 3 than with type 2.

Yoshino[22] has also reported that the difference between the centric relation and the centric occlusion is greater in the Angle class II in comparison to the other occlusions. In addition, in cases of Angle class II, namely in cases with large horizontal overlaps, protruded mandibles are frequently seen in occlusions in clinical observations. This condition seems to induce deformities in anterior parts of mandibular condyles if it occurs frequently or lasts for extended periods of time. In this study, type 2 was observed relatively more in terms of ratio in the Angle class II, although the difference was not significant.

4. Mandibular condyle morphology, occlusion and maxillofacial morphology

1) Angle class I

It was shown that the mandibular plane angle of type 4 mandibular condyle morphology is significantly smaller compared to that of type 3 and relatively smaller than the other types, and that the mandibular plane seemed slightly rotated toward the antero-superior direction. Bjork[23] has shown that the TMJ grows antero-superiorly when the mandible presents counterclockwise rotation, suggesting that this might be correlated with type 4 mandibular condyle morphology.

In type 2 and 3 mandibular condyle morphology, it was shown that the incisor overbite was small. The anterior and superior parts of mandibular condyle of these types are flattened, and the functional factor involving little anterior guidance of incisors might be associated with these mandibular condyle morphology.

2) Angle class II

The maxillofacial morphology of mandibular condyle type 2 in the Angle class II was characterized by a withdrawn mandible, which presented a clockwise rotation with small incisor overjet showing an open-bite tendency. Similar maxillofacial morphology was seen in type 3, although it was not as obvi-

ous as in type 2. Bjork[23] classified the directions of growth at the TMJ into three types using an implant study, and concluded that postero-superior growth was observed at the TMJ in those cases presenting withdrawn mandible and skeletal open-bite. In addition, Burke et al[24] have reported that those patients showing vertical growth patterns in mandible have withdrawn mandibular condyle with less upper space. The postero-superior growth direction of mandibular condylar is thought to affect mandibular condylar morphology of type 2 in this study, suggesting correlations with distinctive maxillofacial morphology.

3) Angle class III

In the Angle class III, type 2 mandibular condyle morphology was characterized by positive incisor overjet. Generally speaking, overjet of incisors becomes negative when molar occlusions are in class III. In other words, the lower jaw is positioned anterior to the upper jaw. However, in this study, positive values were observed in type 2 mandibular condyle morphology, suggesting positive overlaps, although overjet was negative in types 1, 3 and 4 in the Angle class III. This suggests that the type of occlusion, namely the presence or absence of incisor overjet, correlates with the morphology of anterior region of mandibular condyle, although there are more type 1 in terms of ratio in the Angle class III, and it seems possible that positive incisor overjet caused functional disorder such as the restriction of anterior guidance of mandibular condyle, and induced type 2 mandibular condyle morphology.

5. Evaluations using AIC

Analyses were performed using AIC in order to investigate the correlation between mandibular condyle morphology and maxillary morphology. The smaller the value obtained using AIC, the better explanatory variable it is[25]. Takeuchi et al[26] investigated the correlation between maxillofacial morphology and the position of mandibular condyle against mandibular fossa, and showed that there was a negative relation between ramus inclination and the distance between mandibular condyle and mandibular fossa. Enlow[27] stated that bases of Angle class II and III malocclusions were rotation of mandibular condyle and inclination of mandibular ramus induced by rotation of middle cranial fossa, and reported that mandibular ramus tended to incline posteriorly in Angle class II and anteriorly in class III. Kreiborg et al[28] and Gazit et al[29] investigated patients with progressive muscular atrophy, and suggested that the rotational force of mandibles in posto-inferior direction relatively increased as a function of masseter muscle decreases, and that morphological change in mandible was induced by bone resorption of the anterior margin of mandibular ramus or bone deposition in the posterior margin. These reports support the results obtained in this study suggesting that the inclination angle of mandibular ramus is the most significant explanatory variable for mandibular condyle morphology.

For measurement items other than ramus inclination, since AIC values which represent the horizontal relationship of mandible were small and values which represent vertical relationships were large, it was shown that horizontal measurement items for mandible were more appropriate as explanatory variables for mandibular condyle morphology than vertical measurement items. Sato et al[30] showed that incoordination of horizontal maxillofacial morphology could induce mandibular condyle deformations, and Sekiya[31] reported that antero-posterior relationships between maxilla and mandible could affect mandibular ramus inclinations and TMJ process morphology. On the other hand, Pullinger et al[2] stated that there was a stronger correlation between TMJ symptom and incisor overlap relationship and vertical occlusion than for horizontal occlusion. Considering the results of this study based on these reports, it can be said that explanatory variables for horizontal factors are relatively more correlated with mandibular condyle morphology compared to the vertical factors in the positional relationship seen with postero-superior or antero-inferior mandibular rotation rather than simple antero-posterior or superior-inferior rotation.

On the other hand, as the AIC value for SNA was large, it is thought that horizontal position of maxilla is measurement item that contain relatively less

information as explanatory variables for mandibular condyle morphology in comparison with measurement items for mandible.

Furthermore, according to the results obtained for the incidences of mandibular condyle morphology for each group classified using AIC, it was found that type 1 mandibular condyle morphology decreased and type 2 increased as mandible rotated in posterior or postero-inferior direction. In contrast with this, type 3 mandibular condyle morphology increased as mandible was positioned increasingly anteriorly. These findings further support the results of this study suggesting that there is a deep correlation between mandibular condyle morphology and maxillofacial morphology.

Conclusions

The following conclusions were reached as the result of investigations into correlations between mandibular condyle morphology and occlusion, and between mandibular condyle morphology and maxillofacial morphology, covering 281 female patients with malocclusions.

1. Type 1 mandibular condyle morphology was observed most frequently throughout all occlusions, especially in the Angle class III. Type 2 was seen less frequently in the Angle class III, and type 3 was seen more frequently in the Angle class III than in the Angle class II. Type 4 was not observed very often throughout the occlusions.

2. In the Angle class I, type 2 and 3 mandibular condyle morphology presented maxillofacial morphology featuring small incisor overbites. In addition, a slight antero-superior rotation of the mandible was observed in type 4. In the Angle class II, type 2 and 3 presented posterior or postero-inferior rotations of the mandible. In the Angle class III, positive incisor overlap was seen only with type 2.

3. According to analysis using AIC, it was assumed that the most significant correlation was between mandibular ramus inclination and mandibular condyle morphology. In addition, it was found that horizontal relationship rather than vertical relationship for mandible might be relatively more associated with mandibular condyle morphology.

In this study, the correlations among mandibular condyle morphology, occlusion and maxillofacial morphology were investigated. In the future, it is necessary to observe the changes with passing time and examine how they affect one another in morphological development.

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不正咬合者における下顎頭形態と咬合関係および顎顔面形態の相互関連性

[1]東京女子医科大学医学部歯科口腔外科学（主任：扇内秀樹教授）
[2]東京歯科大学口腔健康臨床科学講座歯科矯正学分野（主任：柿澤　卓教授）
[3]東京女子医科大学医学部衛生学公衆衛生学教室（二）（主任：山口直人教授）
荒川（アラカワ）　忠博（タダヒロ）[1]・末石（スエイシ）　研二（ケンジ）[2]・清水（シミズ）　悟（サトル）[3]・扇内（オギウチ）　秀樹（ヒデキ）[1]

本研究は，下顎頭形態と咬合関係および顎顔面形態の関連性を検討することを目的として行った．281名の女性不正咬合患者を対象とし，顎関節断層X線写真，側面頭部X線規格写真および口腔内模型を資料とした．下顎頭の形態を4つの型に分類し，臼歯部の咬合関係をAngle分類に準じ3つの型に分類した．また10項目の計測項目より顎顔面形態を評価した．それらのデータより，下顎頭形態と咬合関係，下顎頭形態と顎顔面形態との関連を検討した結果，以下の結論を得た．

1．下顎頭形態1型が全ての咬合関係において最も多く認められ，特にAngle III級において多く認められた．下顎頭形態2型はAngle III級において少なく，下顎頭形態3型はAngle III級においてII級に比べ多く認められた．下顎頭形態4型はいずれの咬合関係においても少なかった．

2．AngleI級においては，下顎頭形態2型，3型が前歯部被蓋の浅い顎顔面形態を示した．また下顎頭形態4型では下顎の前上方回転が軽度に認められた．AngleII級においては，下顎頭形態2型および3型が下顎の後方位，後下方回転という顎顔面形態を示していた．Angle III級においては，下顎頭形態2型のみが前歯部の被蓋が正被蓋であった．

3．AICによる分析の結果，下顎頭形態と最も関連の深い計測項目はramus inclinationであったことから，下顎枝の傾斜と下顎頭形態との間に最も関連があることが推定された．また下顎骨の水平的関係が垂直的関係よりも，相対的に下顎頭形態に関連していることも推定された．