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Morphological study on the mental region of Chinese children

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We used cephalograms to investigate the correlation between the craniofacial morphology and the mandibular symphysis in Chinese children, measuring the angles between the mandibular plane and symphysis, and the angles between the symphysis and mandibular central incisor. We observed the correlations in males with skeletal Class I between ∠SNA and Idm-Me (mm); between ∠SNB and Idm-Me (mm); between ∠ANB and ∠Idm-X to MP; between FMA and ∠Idm-Me to MP, ∠X-Me to MP, and Thickness Pogonion; between IMPA and ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, and Thickness Pogonion; and between Gn-Cd and Idm-Me (mm), and Thickness Pogonion. In males with skeletal Class II, correlations were observed between ∠SNB and Thickness Pogonion; between ∠ANB and ∠Idm-Me to MP, and ∠L1 to X-Me; between FMA and ∠L1 to Idm-X, and ∠L1 to X-Me; between IMPA and ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, ∠L1 to Idm-X, and ∠L1 to X-Me; and between Gn-Cd and Idm-Me (mm), Thickness Point B, and Thickness Pogonion. In females with skeletal Class I, correlations were observed between FMA and ∠X-Me to MP, ∠L1 to Idm-X, and ∠Thickness Pogonion; between IMPA and ∠Idm-X to MP, ∠X-Me to MP, and ∠L1 to X-Me; and between Gn-Cd and Idm-Me (mm), and Thickness Pogonion. In females with skeletal Class II, correlations were observed between ∠SNA and ∠Idm-Me to MP, ∠Idm-X to MP, and ∠X-Me to MP; between ∠SNB and ∠Idm-Me to MP, ∠Idm-X to MP, and ∠X-Me to MP; between FMA and ∠L1 to Idm-X, and Thickness Point B; between IMPA and ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, ∠L1 to X-Me, and Thickness Point B; and between Gn-Cd and ∠L1 to X-Me, and Idm-Me (mm). These results suggested the importance of monitoring movement of the mandibular anterior teeth during orthodontic treatment because skeletal differences affect the inclination of these teeth and the morphology of the symphysis. (J Osaka Dent Univ 2023; 57: 263-273)

Key words : Cephalometric analysis ; Mandibular symphysis ; Orthodontic treatment ; Skeletal Class I and II craniofacial morphology

INTRODUCTION

When performing orthodontic treatment, the morphology and position of the mental region play an important role in determining the requirement for tooth extraction, the choice of the extraction site, the degree of movement of the mandibular anterior teeth, the method of movement, and the setting of treatment goals. The mental region, which occupies one-third of the lower face and forms the esthetic triangle along with the forehead, nose, lips, and neck[1], is an essential area for soft tissue profile esthetics. The mandibular symphysis, which forms the mental region, is a midline cross-sectional image of the junction of the mandibular body, observed on a lateral cephalometric radiograph. It has a significant influence on the inclination of the mandibular anterior teeth, the positional relationship between the maxilla and mandible, and the soft tissue morphology of the lateral aspect of the face.[2] Previous studies have reported on factors that influence the morphology of the symphysis, such as genetics[3] and endocrinology.[4] In particular, with regard to biomechanics, it is thought that differences in jawbone morphology may alter the external forces applied to the symphysis, such as occlusal forces, and influence the stress generated inside the symphysis, resulting in changes in bone remodeling.[5, 6] Several studies have evaluated the symphysis, in particular its morphology in skeletal mandibular protrusion (skeletal Class III malocclusion) in relation to anatomical factors,[7] genetic factors,[3] Angle's classification using cephalometric radiographs,[8, 9] and skeletal classification.[10-14] However, only a few reports have investigated the correlation between orthodontic measurements of skeletal Class I and the morphology of the symphysis, especially in Chinese patients.[15, 16] In this study, we examined the relationship between the maxillofacial morphology of Class I and Class II and the morphology of symphysis in growing Chinese children using standardized lateral cephalometric radiographs.

MATERIALS AND METHODS

Subjects

We selected 21 males and 23 females with Hellman dental age IIIB and skeletal Class I maxillofacial morphology and 22 males and 22 females with Hellman dental age IIIB and skeletal Class II maxillofacial morphology who visited an orthodontic clinic in Suzhou, Jiangsu, China for this study. We referred to the previously reported Chinese reference values[15-18] and defined skeletal Class I as ANB angle as being between 1.5° and 4.0°, and skeletal Class II as an ANB angle greater than 4.5°. Individuals were included who had no anomalies in tooth number, except for the wisdom teeth, and who had all teeth present from the central incisor to the second molar and with no morphological abnormalities.

Maxillofacial morphology

The measurements of ∠SNA, ∠SNB, ∠ANB, FMA, IMPA, Gn-Cd (mm) were recorded using cephalometric radiograph analysis to evaluate the maxillofacial morphology (Fig. 1). Measurement points and measurement items of the symphysis, reference planes, and others were set from the cephalometric radiographs based on previous studies (Fig. 2).[2, 9, 14, 19-21]

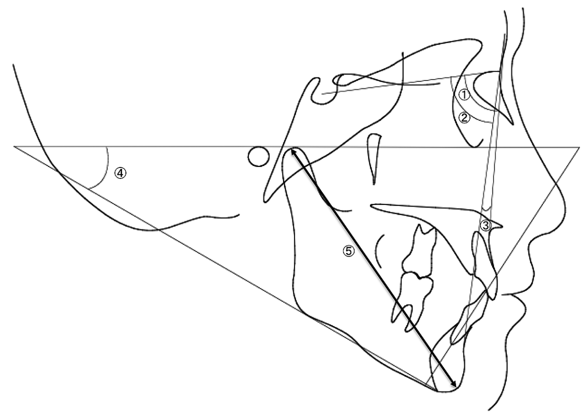

Fig. 1 Measurements on the lateral cephalogramm.
① ∠SNA (angle), ② ∠SNB (angle), ③ ∠ANB (angle), ④ FMA (angle), ⑤ IMPA (angle) and ⑥ Gn to Cd (mm).

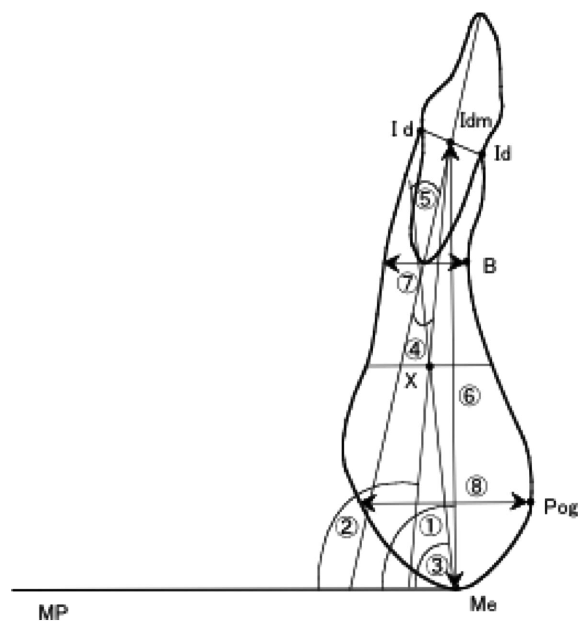

Fig. 2 Measurements on the mandibular symphysis.
① ∠Idm-Me to MP, ② ∠Idm-X to MP, ③ ∠X-Me to MP, ④ ∠L1 to Idm-X, ⑤ ∠L1 to X-Me, ⑥ Idm-Me (mm), ⑦ Thickness Point B (mm) and ⑧ Thickness Pogonion (mm).

Measurement points and reference plane

The measurement points were B (Point B): Anterior limit of mandibular apical base, B': Intersection of perpendicular lines from B to the mandibular plane, Pog (Pogonion): Most prominent point of the mandibular mental region with respect to the mandibular plane, Pog': Intersection of a perpendicular line drawn from Pog to the mandibular plane, Me (Menton): Lowest point of the mandibular symphysis, Id (Infradentale): Most anterior point of the alveolar process of the mandibular central incisors, Id' (Lingual infradentale): Most posterior point of the alveolar process of the mandibular central incisors, Idm: Midpoint of Id and Id', X: Midpoint on the symphysis where a perpendicular line passing through the midpoint of Idm and Me passes through, and MP (Mandibular plane): Tangent to the mandibular plane passing through Me.

Measurement items

The measurement items were ∠Idm-Me to MP: Angle between the whole symphysis and the MP, ∠Idm-X to MP: Angle between the alveolar part of the symphysis and the MP, ∠X-Me to MP: Angle between the base of the symphysis and MP, ∠L1 to Idm-X: Angle between the mandibular central incisor tooth axis and alveolar axis of the symphysis, ∠L1 to X-Me: Angle formed by the mandibular central incisor tooth axis and basal axis of the symphysis, Idm-Me (mm): Distance between Idm-Me at the height of the symphysis, Thickness Point B (mm): Distance within the symphysis of the perpendicular line drawn from point B to Idm-Me at the thickness at point B of the symphysis, and Thickness Pogonion (mm): Distance within the symphysis of the perpendicular line drawn from Pog to Idm-Me at the thickness at Pog of the symphysis.

Method of analysis

The mean and standard deviation of each measurement obtained from the cephalogram were calculated and compared. In addition, the correlation between each measured value was evaluated using EZR statistics software (N Office, Tokyo, Japan).

RESULTS

When Comparing the maxillofacial morphology between males and females, significant differences were noted in ∠SNA, ∠SNB, IMPA, and Gn-Cd (mm) in those with skeletal Class I and in Gn-Cd (mm) in those with skeletal Class II. On comparing skeletal Class I and Class II, significant differences were observed in ∠SNB, ∠ANB, IMPA, and Gn-Cd (mm) for males and in ∠SNA, ∠SNB, ∠ANB, FMA, IMPA, and Gn-Cd (mm) for females. When comparing the morphology of the symphysis between males and females, a significant difference was noted in ∠Idm-X to MP, ∠L1 to Idm-X, and Idm-Me (mm) in those with skeletal Class I, and in Idm-Me (mm) in those with skeletal Class II. On comparing skeletal Class I and Class II, a significant difference was noted in ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, ∠L1 to X-Me, and Idm-Me (mm) in males, while significant differences were noted in ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, ∠L1 to X-Me, Idm-Me (mm), and Thickness Pogonion in females (Tables 1-4).

In addition, to examine the correlation between each measurement based on the obtained data, the correlation coefficient r and the risk value p were calculated using the statistical processing software EZR, and a correlation was defined as an r value of 0.2 and greater and a p value of less than 0.05. As a result, in males with skeletal Class I, correlations were observed between ∠SNA and Idm-Me (mm); between ∠SNB and Idm-Me (mm); between ∠ANB and ∠Idm-X to MP; between FMA and ∠Idm-Me to MP, ∠X-Me to MP, and Thickness Pogonion; between IMPA and ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, and Thickness Pogonion; and between Gn-Cd and Idm-Me (mm), and Thickness Pogonion. In males with skeletal Class II, correlations were observed between ∠SNB and Thickness Pogonion; between ∠ANB and ∠Idm-Me to MP, and ∠L1 to X-Me; between FMA and ∠L1 to Idm-X, and ∠L1 to X-Me; between IMPA and ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, ∠L1 to Idm-X, and ∠L1 to X-Me; and between Gn-Cd and Idm-Me (mm), Thickness

Table 1 Characteristics of the skeletal Class I subjects in this study

Parameter	Males (n=21)	Females (n=23)	t-test (M and F)
∠SNA (angle)	83.30±2.44	82.09±1.87	*
∠SNB (angle)	80.23±2.73	79.26±1.94	*
∠ANB (angle)	3.08±1.06	2.83±0.72	NS
FMA (angle)	26.30±6.16	25.85±4.72	NS
IMPA (angle)	90.95±5.72	91.87±5.48	*
Gn-Cd (mm)	111.6±6.30	106.80±4.98	*
∠Idm-Me to MP (angle)	79.45±4.31	78.80±4.36	NS
∠Idm-X to MP (angle)	86.88±4.73	84.74±5.34	*
∠X-Me to MP (angle)	71.48±5.41	71.65±4.06	NS
∠L1 to Idm-X (angle)	5.48±3.03	7.54±3.12	*
∠L1 to X-Me (angle)	19.70±6.41	20.48±3.75	NS
Idm-Me (mm)	30.98±2.69	29.83±2.05	*
Thickness Point B (mm)	6.85±0.48	6.80±0.82	NS
Thickness Pogonion (mm)	11.73±1.24	11.87±1.02	NS

Mean±SD, NS: Not significant, *$p<0.05$.

Table 2 Characteristics of the skeletal Class II subjects in this study

Parameter	Males (n=22)	Females (n=22)	t-test (M and F)
∠SNA (angle)	83.52±2.30	83.18±2.10	NS
∠SNB (angle)	77.45±2.11	77.14±2.26	NS
∠ANB (angle)	6.07±0.89	6.05±1.11	NS
FMA (angle)	27.00±5.46	27.69±5.65	NS
IMPA (angle)	97.57±6.36	97.22±5.08	NS
Gn-Cd (mm)	108.50±6.98	104.02±5.31	*
∠Idm-Me to MP (angle)	83.21±4.45	82.73±4.21	NS
∠Idm-X to MP (angle)	89.93±6.14	90.39±5.22	NS
∠X-Me to MP (angle)	74.33±3.61	74.18±4.41	NS
∠L1 to Idm-X (angle)	7.26±2.61	7.45±2.60	NS
∠L1 to X-Me (angle)	24.12±4.62	23.59±4.26	NS
Idm-Me (mm)	32.02±2.81	31.05±2.42	*
Thickness Point B (mm)	6.83±0.66	6.43±0.48	NS
Thickness Pogonion (mm)	11.88±1.17	11.02±1.07	NS

Mean±SD, NS: Not significant, *$p<0.05$.

Point B, and Thickness Pogonion. In females with skeletal Class I, correlations were observed between FMA and ∠X-Me to MP, ∠L1 to Idm-X, and ∠Thickness Pogonion; between IMPA and ∠Idm-X to MP, ∠X-Me to MP, and ∠L1 to X-Me; and between Gn-Cd and Idm-Me (mm), and Thickness Pogonion. In females with skeletal Class II, correlations were observed between ∠SNA and ∠Idm-Me to MP, ∠Idm-X to MP, and ∠X-Me to MP; between ∠SNB and ∠Idm-Me to MP, ∠Idm-X to MP, and ∠X-Me to MP; between FMA and ∠L1 to Idm-X, and Thickness Point B; between IMPA and ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, ∠L1 to X-Me, and Thickness Point B; and between Gn-Cd and ∠L1 to X-Me, and Idm-Me (mm) (Tables 5-8).

DISCUSSION

Materials

In this study, we selected growing Chinese patients with Hellman dental age IIIB and skeletal Class I and II maxillofacial morphology. Comparing the maxillofacial morphology between males and fe-

Table 3 Comparison of measurements for skeletal Class I and Class II in males

Parameter	Skeletal Class I (n=21)	Skeletal Class II (n=22)	t-test (Class I and Class II)
∠SNA (angle)	83.30±2.44	83.52±2.30	NS
∠SNB (angle)	80.23±2.73	77.45±2.11	*
∠ANB (angle)	3.08±1.06	6.07±0.89	*
FMA (angle)	26.30±6.16	27.00±5.46	NS
IMPA (angle)	90.95±5.72	97.57±6.36	*
Gn-Cd (mm)	111.6±6.30	108.50±6.98	*
∠Idm-Me to MP (angle)	79.45±4.31	83.21±4.45	*
∠Idm-X to MP (angle)	86.88±4.73	89.93±6.14	*
∠X-Me to MP (angle)	71.48±5.41	74.33±3.61	*
∠L1 to Idm-X (angle)	5.48±3.03	7.26±2.61	*
∠L1 to X-Me (angle)	19.70±6.41	24.12±4.62	*
Idm-Me (mm)	30.98±2.69	32.02±2.81	*
Thickness Point B (mm)	6.85±0.48	6.83±0.66	NS
Thickness Pogonion (mm)	11.73±1.24	11.88±1.17	NS

Mean±SD, NS: Not significant, *$p<0.05$.

Table 4 Comparison of measurements for skeletal Class I and Class II in females

Parameter	Skeletal Class I (n=23)	Skeletal Class II (n=22)	t-test (Class I and Class II)
∠SNA (angle)	82.09±1.87	83.18±2.10	*
∠SNB (angle)	79.26±1.94	77.14±2.26	*
∠ANB (angle)	2.83±0.72	6.05±1.11	*
FMA (angle)	25.85±4.72	27.69±5.65	*
IMPA (angle)	91.87±5.48	97.22±5.08	*
Gn-Cd (mm)	106.80±4.98	104.02±5.31	*
∠Idm-Me to MP (angle)	78.80±4.36	82.73±4.21	*
∠Idm-X to MP (angle)	84.74±5.34	90.39±5.22	*
∠X-Me to MP (angle)	71.65±4.06	74.18±4.41	*
∠L1 to Idm-X (angle)	7.54±3.12	7.45±2.60	NS
∠L1 to X-Me (angle)	20.48±3.75	23.59±4.26	*
Idm-Me (mm)	29.83±2.05	31.05±2.42	*
Thickness Point B (mm)	6.80±0.82	6.43±0.48	NS
Thickness Pogonion (mm)	11.97±1.02	11.02±1.07	*

Mean±SD, NS: Not significant, *$p<0.05$.

males, males had significantly larger ∠SNA, ∠SNB, and Gn-Cd (mm) in those with skeletal Class I, while females had significantly larger IMPA. The ∠ANB of all participants with skeletal Class I was within the standard deviation of the reported ∠ANB of growing skeletal Class I Chinese children,[15, 17, 18] and was judged to be appropriate for the maxillofacial morphology of skeletal Class I. For individuals with skeletal Class II, the Gn-Cd (mm) was significantly larger in males. The ∠ANB expresses the anteroposterior relationship between the maxillary and mandibular apical bases, is often used to classify skeletal patterns, and was used as the basis for classification in this study. Since Angle's classification of malocclusion was proposed, the classification of maxillofacial skeletal types has tended to focus only on the anteroposterior positional relationship. However, many cases cannot be explained only by classification based on anteroposterior factors, and the classification is not always useful in predicting the direction of growth or deciding the treatment strategy.[22, 23]

Table 5 Correlation between measurments of the maxillofacial morphology and mandibular symphysis in skeletal Class I males

Maxillofacial morphology	Mandibular symphysis	*r*-value	*p*-value
∠SNA (angle)	∠Idm-Me to MP (angle)	−0.0388	0.867
	∠Idm-X to MP (angle)	−0.0555	0.811
	∠X-Me to MP (angle)	−0.0313	0.893
	∠L1 to Idm-X (angle)	0.24	0.294
	∠L1 to X-Me (angle)	0.204	0.376
	Idm-Me (mm)	0.595	0.00441
	Thickness Point B (mm)	−0.194	0.0399
	Thickness Pogonion (mm)	0.293	0.197
∠SNB (angle)	∠Idm-Me to MP (angle)	−0.167	0.471
	∠Idm-X to MP (angle)	−0.224	0.33
	∠X-Me to MP (angle)	−0.0868	0.708
	∠L1 to Idm-X (angle)	0.134	0.562
	∠L1 to X-Me (angle)	0.116	0.616
	Idm-Me (mm)	0.58	0.005
	Thickness Point B (mm)	−0.147	0.524
	Thickness Pogonion (mm)	0.23	0.315
∠ANB (angle)	∠Idm-Me to MP (angle)	0.385	0.0487
	∠Idm-X to MP (angle)	0.509	0.0184
	∠X-Me to MP (angle)	0.174	0.452
	∠L1 to Idm-X (angle)	0.206	0.377
	∠L1 to X-Me (angle)	0.166	0.473
	Idm-Me (mm)	−0.209	0.363
	Thickness Point B (mm)	−0.0522	0.822
	Thickness Pogonion (mm)	0.0564	0.808
FMA (angle)	∠Idm-Me to MP (angle)	−0.472	0.0309
	∠Idm-X to MP (angle)	−0.323	0.154
	∠X-Me to MP (angle)	−0.696	0.000761
	∠L1 to Idm-X (angle)	−0.016	0.945
	∠L1 to X-Me (angle)	0.186	0.419
	Idm-Me (mm)	−0.176	0.444
	Thickness Point B (mm)	0.0305	0.896
	Thickness Pogonion (mm)	−0.623	0.00257
IMPA (angle)	∠Idm-Me to MP (angle)	0.834	0.00000199
	∠Idm-X to MP (angle)	0.897	0.0000000353
	∠X-Me to MP (angle)	0.544	0.0091
	∠L1 to Idm-X (angle)	0.408	0.0665
	∠L1 to X-Me (angle)	0.295	0.194
	Idm-Me (mm)	0.209	0.354
	Thickness Point B (mm)	−0.104	0.654
	Thickness Pogonion (mm)	0.647	0.00152
Gn-Cd (mm)	∠Idm-Me to MP (angle)	0.137	0.552
	∠Idm-X to MP (angle)	0.167	0.469
	∠X-Me to MP (angle)	0.123	0.596
	∠L1 to Idm-X (angle)	0.258	0.259
	∠L1 to X-Me (angle)	0.193	0.403
	Idm-Me (mm)	0.705	0.000361
	Thickness Point B (mm)	−0.33	0.144
	Thickness Pogonion (mm)	0.664	0.00102

Table 6 Correlation between measurments of the maxillofacial morphology and mandibular symphysis in skeletal Class I females

Maxillofacial morphology	Mandibular symphysis	*r*-value	*p*-value
∠SNA (angle)	∠Idm-Me to MP (angle)	0.144	0.511
	∠Idm-X to MP (angle)	0.248	0.255
	∠X-Me to MP (angle)	−0.0046	0.483
	∠L1 to Idm-X (angle)	0.0439	0.842
	∠L1 to X-Me (angle)	0.314	0.144
	Idm-Me (mm)	0.372	0.0802
	Thickness Point B (mm)	−0.0811	0.713
	Thickness Pogonion (mm)	0.153	0.485
∠SNB (angle)	∠Idm-Me to MP (angle)	0.106	0.63
	∠Idm-X to MP (angle)	0.193	0.378
	∠X-Me to MP (angle)	−0.0161	0.942
	∠L1 to Idm-X (angle)	0.111	0.614
	∠L1 to X-Me (angle)	0.259	0.233
	Idm-Me (mm)	0.301	0.163
	Thickness Point B (mm)	−0.146	0.507
	Thickness Pogonion (mm)	0.246	0.257
∠ANB (angle)	∠Idm-Me to MP (angle)	0.09	0.683
	∠Idm-X to MP (angle)	0.125	0.501
	∠X-Me to MP (angle)	0.0316	0.0886
	∠L1 to Idm-X (angle)	−0.186	0.395
	∠L1 to X-Me (angle)	0.12	0.585
	Idm-Me (mm)	0.157	0.473
	Thickness Point B (mm)	0.183	0.403
	Thickness Pogonion (mm)	−0.268	0.216
FMA (angle)	∠Idm-Me to MP (angle)	−0.309	0.152
	∠Idm-X to MP (angle)	−0.132	0.547
	∠X-Me to MP (angle)	−0.426	0.0424
	∠L1 to Idm-X (angle)	−0.598	0.00216
	∠L1 to X-Me (angle)	−0.172	0.432
	Idm-Me (mm)	0.12	0.0586
	Thickness Point B (mm)	0.0937	0.671
	Thickness Pogonion (mm)	−0.645	0.000885
IMPA (angle)	∠Idm-Me to MP (angle)	0.918	0.22
	∠Idm-X to MP (angle)	0.896	0.0000762
	∠X-Me to MP (angle)	0.724	0.0000951
	∠L1 to Idm-X (angle)	0.371	0.00811
	∠L1 to X-Me (angle)	0.723	0.0000957
	Idm-Me (mm)	−0.00396	0.986
	Thickness Point B (mm)	0.0647	0.769
	Thickness Pogonion (mm)	0.274	0.206
Gn-Cd (mm)	∠Idm-Me to MP (angle)	0.00108	0.916
	∠Idm-X to MP (angle)	0.132	0.549
	∠X-Me to MP (angle)	−0.261	0.299
	∠L1 to Idm-X (angle)	−0.0337	0.879
	∠L1 to X-Me (angle)	0.385	0.0695
	Idm-Me (mm)	0.721	0.000105
	Thickness Point B (mm)	0.036	0.87
	Thickness Pogonion (mm)	0.469	0.0241

Table 7 Correlation between measurments of the maxillofacial morphology and mandibular symphysis in skeletal Class II males

Maxillofacial morphology	Mandibular symphysis	*r*-value	*p*-value
∠SNA (angle)	∠Idm-Me to MP (angle)	0.282	0.204
	∠Idm-X to MP (angle)	0.243	0.275
	∠X-Me to MP (angle)	0.193	0.39
	∠L1 to Idm-X (angle)	0.216	0.334
	∠L1 to X-Me (angle)	0.358	0.102
	Idm-Me (mm)	0.311	0.159
	Thickness Point B (mm)	−0.0967	0.669
	Thickness Pogonion (mm)	0.299	0.177
∠SNB (angle)	∠Idm-Me to MP (angle)	0.0936	0.679
	∠Idm-X to MP (angle)	0.158	0.483
	∠X-Me to MP (angle)	0.0965	0.669
	∠L1 to Idm-X (angle)	0.204	0.364
	∠L1 to X-Me (angle)	0.202	0.367
	Idm-Me (mm)	0.37	0.09
	Thickness Point B (mm)	0.0707	0.754
	Thickness Pogonion (mm)	0.421	0.05
∠ANB (angle)	∠Idm-Me to MP (angle)	0.504	0.0167
	∠Idm-X to MP (angle)	0.251	0.26
	∠X-Me to MP (angle)	0.267	0.229
	∠L1 to Idm-X (angle)	0.0707	0.755
	∠L1 to X-Me (angle)	0.44	0.0402
	Idm-Me (mm)	−0.0858	0.711
	Thickness Point B (mm)	−0.419	0.052
	Thickness Pogonion (mm)	−0.237	0.287
FMA (angle)	∠Idm-Me to MP (angle)	−0.384	0.078
	∠Idm-X to MP (angle)	−0.343	0.119
	∠X-Me to MP (angle)	−0.412	0.0568
	∠L1 to Idm-X (angle)	−0.628	0.00194
	∠L1 to X-Me (angle)	−0.502	0.0173
	Idm-Me (mm)	0.047	0.835
	Thickness Point B (mm)	0.112	0.618
	Thickness Pogonion (mm)	−0.336	0.126
IMPA (angle)	∠Idm-Me to MP (angle)	0.823	0.00000263
	∠Idm-X to MP (angle)	0.714	0.000188
	∠X-Me to MP (angle)	0.746	0.0000668
	∠L1 to Idm-X (angle)	0.564	0.0063
	∠L1 to X-Me (angle)	0.742	0.0000773
	Idm-Me (mm)	−0.208	0.353
	Thickness Point B (mm)	−0.326	0.139
	Thickness Pogonion (mm)	−0.0943	0.676
Gn-Cd (mm)	∠Idm-Me to MP (angle)	−0.292	0.187
	∠Idm-X to MP (angle)	−0.0267	0.906
	∠X-Me to MP (angle)	−0.222	0.32
	∠L1 to Idm-X (angle)	−0.104	0.645
	∠L1 to X-Me (angle)	−0.0922	0.683
	Idm-Me (mm)	0.818	0.00000337
	Thickness Point B (mm)	0.598	0.00328
	Thickness Pogonion (mm)	0.682	0.000467

Table 8 Correlation between measurments of the maxillofacial morphology and mandibular symphysis in skeletal Class II females

Maxillofacial morphology	Mandibular symphysis	*r*-value	*p*-value
∠SNA (angle)	∠Idm-Me to MP (angle)	0.671	0.000636
	∠Idm-X to MP (angle)	0.562	0.0065
	∠X-Me to MP (angle)	0.468	0.0282
	∠L1 to Idm-X (angle)	−0.236	0.29
	∠L1 to X-Me (angle)	0.0147	0.948
	Idm-Me (mm)	−0.123	0.586
	Thickness Point B (mm)	−0.0214	0.425
	Thickness Pogonion (mm)	0.261	0.24
∠SNB (angle)	∠Idm-Me to MP (angle)	0.713	0.000198
	∠Idm-X to MP (angle)	0.553	0.00754
	∠X-Me to MP (angle)	0.551	0.00792
	∠L1 to Idm-X (angle)	−0.111	0.622
	∠L1 to X-Me (angle)	0.0295	0.896
	Idm-Me (mm)	−0.126	0.576
	Thickness Point B (mm)	0.0397	0.861
	Thickness Pogonion (mm)	0.29	0.19
∠ANB (angle)	∠Idm-Me to MP (angle)	−0.183	0.416
	∠Idm-X to MP (angle)	−0.064	0.777
	∠X-Me to MP (angle)	−0.237	0.289
	∠L1 to Idm-X (angle)	−0.221	0.32
	∠L1 to X-Me (angle)	−0.0322	0.887
	Idm-Me (mm)	0.0247	0.913
	Thickness Point B (mm)	−0.122	0.59
	Thickness Pogonion (mm)	−0.0967	−0.669
FMA (angle)	∠Idm-Me to MP (angle)	−0.376	0.0844
	∠Idm-X to MP (angle)	−0.38	0.0806
	∠X-Me to MP (angle)	−0.421	0.0521
	∠L1 to Idm-X (angle)	−0.458	0.0321
	∠L1 to X-Me (angle)	−0.346	0.115
	Idm-Me (mm)	0.0866	0.702
	Thickness Point B (mm)	0.429	0.0465
	Thickness Pogonion (mm)	−0.16	0.466
IMPA (angle)	∠Idm-Me to MP (angle)	0.82	0.00000306
	∠Idm-X to MP (angle)	0.879	0.0000000727
	∠X-Me to MP (angle)	0.603	0.003
	∠L1 to Idm-X (angle)	0.122	0.588
	∠L1 to X-Me (angle)	0.533	0.0106
	Idm-Me (mm)	0.276	0.214
	Thickness Point B (mm)	−0.433	0.0441
	Thickness Pogonion (mm)	0.39	0.0731
Gn-Cd (mm)	∠Idm-Me to MP (angle)	0.2	0.373
	∠Idm-X to MP (angle)	0.254	0.255
	∠X-Me to MP (angle)	0.117	0.604
	∠L1 to Idm-X (angle)	0.325	0.141
	∠L1 to X-Me (angle)	0.454	0.034
	Idm-Me (mm)	0.772	0.0000258
	Thickness Point B (mm)	−0.079	0.727
	Thickness Pogonion (mm)	0.395	0.0686

Morphology of the symphysis

According to Lundstöm's theory of the apical base,[24] although the development of the apical base is natural and is not affected by stimulation from orthodontic treatment or masticatory function, its morphology is greatly influenced by the occlusal condition and dental arch morphology. Worms[25] and Yoshitani[26] reported that in patients with skeletal Class III malocclusion, the anteroposterior malalignment of the jawbone leads to dental compensation through the lingual inclination of the anterior mandibular teeth. Lundstöm,[24] Ichikawa *et al.,*[10] and Nakagawa *et al.*[27] divided the apical basal structure of the symphysis into two parts: alveolar and basal symphyse. Enlow[28] added a site called the drift layer between these two sites and classified the structure into three layers. In this study, two points, point B and Pogonion, were used as the measurement sites, which are the same as the previously known alveolar and basal symphyse.

Regarding the relationship between malocclusion and the morphology of the symphysis, Ito[9] classified the general shape of the symphysis into five types: Type A (small overall thickness), Type B (small thickness at the root apex of the mandibular central incisor), Type C (large thickness at the root apex of the mandibular central incisor), Type D (gourd-shaped), and Type E (almost uniform thickness throughout). It was reported that in Angle's Class I malocclusion, Type C accounted for 55% and Type B for 30%, whereas Types A and D accounted for very few cases. In Angle Class II malocclusion, similar to Angle Class I malocclusion, Type C was the most common symphysis morphology (40%), followed by Type B (32.5%), while Types A and D were reported to be very rare. Although we did not examine the general shape of the symphysis in the present study, the thickness of the Pogonion in both males and females was increased in comparison with the thickness at point B, suggesting that most mandibular symphyses have a shape similar to Types B and C. This finding is similar to the results reported by Ito. Furthermore, he investigated the labial tongue diameter of the symphysis at point B and the maximum thickness of the symphysis in Angle Class I malocclusion.

Although the pogonion thickness used in this study does not necessarily correspond to the maximum thickness, the value presented was close to that of Ito's measurements. Ichikawa *et al.*[10] and Kanai *et al.*[29] also reported the morphology of the symphysis in different skeletal patterns. Ichikawa *et al.* measured the symphysis thickness of patients with skeletal Class I, II, and III malocclusions and reported that there was a significant difference in the thickness at point B between those with skeletal Class I and Class II malocclusions in both males and females, but not in the thickness at the Pogonion. In the comparison by sex, the thickness at the Pogonion in both skeletal Class I and Class II malocclusions was significantly smaller in females, and the thickness at point B was significantly different between males and females in skeletal Class II malocclusion, with females showing smaller values than males. In the present study, both skeletal Class I and Class II had smaller thicknesses at point B and the Pogonion in both sexes than those measured by Ichikawa *et al.* In the comparison between skeletal Class I and Class II, there was no significant difference in the thickness at point B and at the pogonion in males, while there was a significant difference in the thickness at the pogonion in females. In the comparison between males and females, no significant difference was found between Class I and Class II skeletal morphologies.

Comparing the vertical measurements of the symphysis with those reported by Ichikawa *et al.,* we found larger values for ∠L1 to Idm-X for both males and females, and smaller values for IMPA, ∠Idm-X to MP, ∠X-Me to MP, ∠L1 to Idm-X, ∠L1 to X-Me, and Idm-Me (mm) in skeletal Class I malocclusion. We found larger values for ∠X-Me to MP and ∠L1 to Idm-X among both males and females, and smaller values for IMPA, ∠Idm-X to MP, ∠L1 to X-Me and Idm-Me (mm) in skeletal Class II malocclusion. The study by Ichikawa *et al.* was conducted on adults. It showed that with growth and development, the angle between the symphysis and the mandibular central incisor and the symphysis and the mandibular plane changes, and the thickness of the symphysis increases.

Relationship between maxillofacial morphology and the morphology of the symphysis

Regarding parameters ∠SNA, ∠SNB, and Gn-Cd (mm), which are measurements that indicate the anteroposterior relationship of the maxillofacial morphology, we found a correlation between ∠SNA, ∠SNB and Idm-Me (mm), Gn-Cd (mm) and Idm-Me (mm), Thickness Point B, and Thickness Pogonion in males, and between Gn-Cd (mm) and Idm-Me (mm), and Thickness Pogonion in females with skeletal Class I malocclusion. For skeletal Class II, we observed a correlation between ∠SNB and Thickness Pogonion, Gn-Cd (mm) and Idm-Me (mm), Thickness Point B, and Thickness Pogonion among males. In females, there was a correlation between ∠SNA, ∠SNB and ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, Gn-Cd (mm) and Idm-Me (mm). Ichikawa *et al.*[10] found that, of the symphysis measurements, there was a significant difference in Thickness Point B between skeletal Class I and Class II malocclusions for both sexes, but no significant difference in symphysis length and Pogonion thickness between malocclusions. Ito[9] studied the symphysis thicknesses in Angle Class I, Class II, and Class III malocclusions, and reported that there was almost no difference in Thickness Point B and the maximum thickness between Class I and Class II malocclusions. However, Class III malocclusion tended to have smaller measurements. In addition, Jacobsen *et al.*[21] reported that the maximum thickness of the symphysis is smaller in Class III malocclusion cases than in normal occlusion cases. In the present study, a significant difference was noted in Thickness Pogonion in females between skeletal Class I and Class II. In addition, as both males and females with skeletal Class I and Class II showed a correlation between Gn-Cd (mm) and Idm-Me (mm), this indicated that there is a correlation between the mandibular bone length and symphysis length.

Furthermore, this study used FMA as the vertical measurement of maxillofacial morphology. The inclination of the mandibular plane and the morphology of the symphysis are factors that determine the prognosis of orthodontic treatment; thus, the size of ∠FMA is important. When the inclination of the mandibular plane is large, it is difficult to achieve a normal overbite of the anterior teeth, and when the thickness of the symphysis is small, it is difficult to move the mandibular anterior teeth labiolingually, and it is difficult to achieve a normal overjet of the anterior teeth. Thus, both the inclination of the mandibular plane and the morphology of the symphysis have an important influence on the improvement of the anterior incisal relationships. In this study, the relationship between the vertical position of the maxillofacial plane, ∠FMA, and the form of the symphysis in males with skeletal Class I correlated with ∠Idm-Me to MP, ∠X-Me to MP, and Thickness Pogonion, while in females a correlation was noted with ∠X-Me to MP, ∠L1 to Idm-X, and Thickness Pogonion. In skeletal Class II the vertical position of the maxillofacial plane, ∠FMA, and the form of the symphysis were found to be correlated with ∠L1 to Idm-X and ∠L1 to X-Me in males, and with ∠L1 to Idm-X and Thickness Point B in females. Tanaka *et al.*[30] reported that the thickness of the symphysis at point B and the thickness of the root apex of the mandibular anterior teeth decreased as the mandibular plane angle increased. Haskell,[31] focusing on the inclination of the mandibular plane, reported that the mentum was smaller at low angles, especially in a vertically overgrown mandible with dysfunction. Kanai *et al.*[29] reported that in case of long-face maxillofacial morphology, although bone addition behind the alveolar bone of the symphysis is normal, the anterior portion tends to have difficulty in lip closure; the orbicularis oris and mentalis muscles are active, and the non-physiological muscle pressures are continuously applied to the labial alveolar bone, resulting in bone resorption, and the distance between the root of the teeth and the labial alveolar bone is shortened. In the present study, we also observed a negative correlation between FMA and the thickness of symphysis, which is similar to results previously reported.

In terms of the relationship between the inclination of the mandibular anterior teeth and the morphology of the symphysis, in males with skeletal Class I morphology, a correlation was noted between IMPA and ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, and Thickness Pogonion, while in females a correlation was noted between IMPA and ∠Idm-X to MP, ∠X-Me to MP, and ∠L1 to X-Me. In males with skeletal Class II, a correlation was observed between IMPA and ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, ∠L1 to Idm-X, and ∠L1 to X-Me, whereas in females, a correlation was noted with ∠Idm-Me to MP, ∠Idm-X to MP, ∠X-Me to MP, ∠L1 to X-Me, and Thickness Point B. Idm-Me showed a correlation with the inclination of the entire symphysis, while Idm-X had a correlation with the inclination of the alveolar portion of the symphysis. Ichikawa *et al.*[10] found that there was a significant difference in the inclination of the symphysis to the mandibular plane between males and females in ∠Idm-X to MP, and that compared to skeletal Class I, the alveolar part of the symphysis to the mandibular plane was more labially inclined in skeletal Class II and more lingually inclined in skeletal Class III morphology. However, the inclination of the base of symphysis was not significantly different between males and females or between malocclusions.

In the present study, all measurements of the inclination of the symphysis to the mandibular plane showed that skeletal Class II malocclusion in both sexes had a larger value than skeletal Class I, indicating a labial inclination of the symphysis. Ichikawa *et al.* also examined the inclination of the mandibular central incisor axis and symphysis, and reported that in skeletal Class I and Class II morphology, the mandibular central incisor showed a greater labial inclination than the inclination of the alveolar part of the symphysis. Regarding the angle between the mandibular central incisor axis and the base of the symphysis, the mandibular central incisors in patients with skeletal Class II malocclusion had a greater labial inclination than the inclination of the base of the symphysis compared to that of patients with skeletal Class I malocclusion. In the present study, correlations were observed between the inclination of the mandibular central incisor and the basal part of the symphysis in females with skeletal Class I, between the mandibular central incisor and the alveolar and basal part of the symphysis in males with skeletal Class II, and between the mandibular central incisor and the alveolar part of the symphysis in females with skeletal Class II. The mandibular central incisors of males and females with skeletal Class I and skeletal Class II showed a labial inclination in the alveolar portion of the symphysis, while the mandibular central incisors of individuals with skeletal Class II malocclusion showed an even greater labial inclination than that of the basal part of the symphysis compared to individuals with skeletal Class I. This is similar to previously reported results.

CONCLUSION

During orthodontic treatment, morphology and position of the mental region have an important role in determining the requirement for tooth extraction, the choice of the extraction site, the degree of movement of the mandibular anterior teeth, the method of movement, and the setting of treatment goals. The mandibular symphysis, which forms the mental region, has a significant influence on the inclination of the mandibular anterior teeth, the positional relationship between the maxilla and mandible, and the soft tissue profile. In orthodontic treatment, the degree of inclination of the mandibular plane and the morphology of the symphysis influence the treatment complexity. It is difficult to achieve a normal overbite of the anterior teeth when the inclination of the mandibular plane is large. When the thickness of the symphysis is small, it is difficult to move the mandibular anterior teeth labio-lingually, making it difficult to achieve a normal overjet of the anterior teeth. As a result, the degree of inclination of the mandibular plane as well as the morphology of the symphysis have a significant impact on improvement of the anterior overlap. In this study, there was a correlation between ∠SNA and ∠SNB, which are measurements indicating the anteroposterior relationship of the maxillofacial morphology, ∠FMA which shows the vertical relationship, and Gn-Cd (mm) which indicates the size of the mandible and the morphology of symphysis. Correlations were also noted between the degree of inclination of the mandibular anterior teeth and the degree of inclination of the symphysis. These findings suggest that when moving the mandibular anterior teeth during orthodontic treatment, it is important to remember that skeletal differences affect the degree of inclination of the mandibular anterior teeth and the morphology of the symphysis.

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REFERENCES

1. Powell N, Humphreys B. Proportions of the aesthetic face. New York: Thieme-Stratton, 1984: 52-66.
2. Yogosawa F. Orthodontic treatment and the chin. *J Jpn Orthod Soc* 1985; **44**: 302-323. (Japanese)
3. Stanley MG, Arthur BL, Joan HV. The inheritance of symphyseal size during growth. *Angle Orthod* 1963; **33**: 222-231.
4. Maeda A, Suzuki H, Irie M, Morita S, Sasaki M, Inokuchi T, Okamoto S, Izumi M, Nagataki S. Surgical-orthodontic correction of mandibular prognathism due to acromegaly −a case report−. *J Jpn Orthod Soc* 1985; **44**: 375-387. (Japanese)
5. Suzuki H. An experimental study of the micro electric current on the bone formation in macaea irus. *J Kyusyu Dent Soc* 1976; **29**: 399-416. (Japanese)
6. Suzuki H. A study of osteoinduction using piezo electricity. *Dent Outlook* 1978; **51**: 433-440. (Japanese)
7. Atkinson SR. Some anatomic factors guiding treatment therapy. *Am J Orthod* 1942; **28**: 704-720.
8. Nanda SK. Morphology of the human chin from cephalometric measurements. *J Dent Res* 1965; **44**: 828.
9. Itoh T. Morphological and anthropometrical studies on the symphysis mandibulae region by cephalograms. *Nihon Univ dent J* 1971; **45**: 784-795. (Japanese)
10. Ichikawa K, Itoh R, Kiyose S, Kirose T, Kamogashira K, Matsumoto M. Morphological studies on the mandibular symphysis of skeletal Class I, II, III malocclusions. *J Jpn Orthod Soc* 1988; **47**: 433-441. (Japanese)
11. Sekiya T, Nakamura Y, Kim T, Kuwahara Y. Morphological study on the mandibiular symphysis in skeletal Class III malocclusion of young and adult Japanese female patients. *J Jpn Orthod Soc* 1993; **52**: 306-315. (Japanese)
12. Kaino H, Nakamura Y, Sekiya T, Kuwahara Y. Morphological study on mandibular symphysis in skeletal Class III malocclusion of Japanese female patients—Longitudinal study from 10 to 16 years old. *Jpn J Jaw Deform* 1998; **8**: 192-202. (Japanese)
13. Nakamura Y, Nagaoka K, Sekiya T, Kuwahara Y. Morphological changes of mandibular symphysis during the orthodontic treatment of Class III malocclusion in young patients. *Tsurumi Univ Dent J* 1991; **17**: 119-130. (Japanese)
14. Matsuda Y. Surgical-orthodontics in the skeletal Class III malocclusions −The morphology of mandibular symphysis and the positioning of lower incisors−. *J Jpn Orthod Soc* 1982; **41**: 109-116. (Japanese)
15. Chen YW, Inami K, Matsumoto N. A study of Steiner cephalometric norms for Chinese children. *J Osaka Dent Univ* 2015; **49**: 237-244.
16. Zhu C, Hosoyama C, Nakayama Y, Yasui K, Morikuni H, Nishiura A, MatsumotoN. Cephalometric analysis for Chinese adults with skeletal 1 craniofacial morphology. *J Osaka Dent Univ* 2022; **56**: 71-77.
17. Guo MK. Cephalometric standards of Steiner analysis established on Chinese children. *J Formos Medic Assoc* 1971; **28**: 97-102.
18. Wang SY. The norms of Steiner cephalometric analysis in Chinese children. *Chin Dent J* 1983; **2**: 60-65.
19. Kameda A, Hisa S, Oka K, Kobayashi S, Endo R, Moro Y, Takeda M, Chiba A. Morphological changes in the mandibular symphysis during orthodontic treatment using mainly lower horizontal elastics. *J Jpn Orthod Soc* 1985; **44**: 459-470. (Japanese)
20. Nanda SK. Morphology of the human chin from cephalometric measurements. *J Dent Res* 1965; **44**: 828.
21. Jacobson A, Evans WG, Preston CB. Mandibular prognathism. *Am J Orthod* 1974; **66**: 140-171.
22. Opdebeeck HM, Bell WH. The short face syndrome. *Am J Orthod* 1978; **74**: 509-521.
23. Sassouni V, Nanda S. Analysis of dentofacial vertical proportion. *Am J Orthod* 1964; **50**: 801-823.
24. Lundström AF. Malocclusion of the teeth regarded as a problem in connection with the apical base. *Int J Orthod & Oral Surg* 1925; **11**: 591-602.
25. Worms FW, Isaacson RJ, Speidel TM. Surgical orthodontic treatment planning. Profile analysis and mandibular surgery. *Angle Orthod* 1976; **45**: 1-25.
26. Yoshitani S. Morphological compensatory mechanisms in the craniofacial complex of adult mandibular prognathism. 1. Inclination of the mandibular incisors. *J Jpn Orthod Soc* 1985; **44**: 508-516. (Japanese)
27. Nakagawa M, Kawamoto T. Relationship between the mandibular symphysis and orthodontic measurement points on the craniofacial skeleton. *J Osaka Dent Univ* 1994; **57**: 335-362. (Japanese)
28. Enlow DH. Handbook of facial growth. 2nd ed. Philadelphia: WB Saunders, 1982: 21-30.
29. Kanai M, Yamaguchi T, Maki K. Cone-beam computed tomography evaluation of mandibular symphysis. *Dental Med Res* 2011; **31**: 16-23. (Japanese)
30. Tanaka R, Suzuki H, Maeda H, Kobayashi K. Study on the relationship between an inclination of the mandibular plane and a morphology of symphysis. *J Jpn Orthod Soc* 1989; **48**: 7-20. (Japanese)
31. Haskell BS. The human chin and its relations to mandibular morphology. *Angle Orthod* 1977; **49**: 153-166.