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ORIGINAL RESEARCH

Morphological evaluation of the chin and symphysis and its relationship with occlusal planes in skeletal Class II malocclusions

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Abstract

Background: To investigate the correlation between the inclination of occlusal planes (OPs) and the morphologies of the chin and mandibular symphysis in skeletal Class II malocclusion. **Methods**: This retrospective study utilized cone beam computed tomography (CBCT) to explore the relationship of the occlusal plane (OP) inclinations with the chin and mandibular symphysis in different skeletal patterns. A total of 150 children aged 6–12 years were recruited for this study. The included cases were categorized into three groups: normodivergent skeletal Class I malocclusion (I_N), normodivergent skeletal class II malocclusion (II_N) and hyperdivergent skeletal Class II malocclusion (II_H). Each group consisted of 50 individuals. **Results**: In terms of the contours of the chin and mandibular symphysis, the I_N group had the broadest and shortest shapes, whereas the II_H group had the thinnest and tallest morphologies. No significant differences in chin volume were found among the three groups. Compared with those in I_N group, the anterior occlusal plane (AOP) and posterior occlusal plane (POP) were steeper in the groups with skeletal Class II malocclusion. In addition, there was a negative correlation between the OPs and the height and width of the chin and mandibular symphysis, as well as the position of the chin. **Conclusions**: In individuals with skeletal Class II malocclusion, the development of the height and width of the chin and mandibular symphysis may be related to the inclination of the OPs.

Keywords

Occlusal plane; Anterior occlusal plane; Posterior occlusal plane; Chin; Mandibular symphysis; Skeletal Class II malocclusion; CBCT

1. Introduction

The chin is a unique characteristic feature of a human face, which is in the region of the anterior-inferior mandibular symphysis [1]. Variations in chin position and shape have an impact on facial contours, which is crucial for the harmonious appearance of facial features [2]. The mandibular symphysis has been found to function as a predictor of the direction of mandibular growth [3].

Previous studies have shown that the shapes of the chin and mandibular symphysis are related to numerous factors such as genetics [4], chewing pressure [5], lower incisor inclination [6, 7] and the angle class [8]. Vertically, dolichofacial types have long and narrow mandibular symphyses; while brachyfacial types have short and wide mandibular symphyses [9]. The height of the mandibular symphysis is strongly correlated with the anterior facial height [10]. Sagittally, individuals with protruding mandibles have shorter and wider mandibular symphyses. Conversely, individuals with receding mandibles have taller and thinner mandibular symphyses [11]. The chin width in individuals with skeletal Class II malocclusion tends to be smaller than that in those with skeletal Class I and III malocclusions [10]. Investigations have shown that chin and mandibular symphysis morphologies are correlated with skeletal patterns.

With respect to skeletal Class II malocclusions, the patients' profile is characterized mostly by mandibular retrusion [12]. The application of functional appliances in adolescents with skeletal mandibular retrusion has been widely recognized to improve facial aesthetics and oral function [13]. The mandibular position may be affected by the occlusal plane, and the occlusal plane is steeper in skeletal Class II patients and flatter in skeletal Class III patients [14, 15]. As the occlusal plane is steeper, the soft and hard tissues of the pogonion are more posteriorly located than the Gysi Anterior Lingual Line (GALL) and Terry's Vertical Line (TVL) [16]. However, the occlusal plane (OP), which is not a straight but a curved line, is divided into the anterior occlusal plane (AOP) and the posterior occlusal plane (POP) [17]. The relationships between the AOP and POP tilt and the position and morphology of the chin require further exploration.

In this study, we explored the relationships between the inclination of the OPs and the position and shape of the chin and mandibular symphysis in individuals with skeletal Class II malocclusion. This may be helpful for early treatment of skeletal Class II children with functional appliances. Most of the existing studies used lateral cephalogram to measure the two-dimensional linear indices of the chin and mandibular symphysis. In this study, CBCT was used to measure the three-dimensional indices of chin volume in patients with different skeletal patterns.

2. Materials and methods

2.1 Subjects

A total of 150 participants, comprising 66 males and 84 females, were recruited for this study in the Stomatology Department of the Children's Hospital of Nanjing Medical University from February 2022 to January 2024.

2.2 Inclusion criteria

(1) Age between 6 and 12 years;

(2) Skeletal Class I ($0° <$ ANB (Angle between Nasion-A point and Nasion-B point) $< 5°$) or skeletal Class II (ANB $>5°$) malocclusion [18];

(3) Normodivergent malocclusion ($27° \leq$ SN-MP (Sella-Nasion plane to Mandibular Plane angle) $\leq 37°$) or hyperdivergent malocclusion (SN-MP $>37°$) [19].

2.3 Exclusion criteria

(1) No history of orthodontic treatment;

(2) No systematic disease; and

(3) No facial asymmetry and no tilted chin.

2.4 Groups

The 150 participants were divided into three groups, with each group consisting of 50 individuals. The three groups were as follows:

(1) Normodivergent skeletal Class I malocclusion (I_N);

(2) Normodivergent skeletal Class II malocclusion (II_N); and

(3) Hyperdivergent skeletal Class II malocclusion (II_H).

2.5 Three-dimensional images

Newtom VG was used for orthodontic examination. The cone-bone computed tomography (CBCT) data in DICOM (Digital Imaging and Communications in Medicine) format were exported into Dolphin Imaging 11.9.5 (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA).

2.6 Chin and mandibular symphysis measurements

Two-dimensional measurements of both the chin and the mandibular symphysis were made in a midsagittal section of the mandible [20] (Fig. 1).

In this study, the protuberance and height of the chin and mandibular symphysis were measured separately (Fig. 2A,B). To measure the chin volume, the dolphin volume sculpting tool was used to outline the chin region and calculate its volume (Fig. 2C,D). The specific measurements are shown in Table 1 (Ref. [10, 19]).

2.7 OPs measurements

Table 2 shows the landmarks used in this study. Lateral cephalograms were generated to measure the sagittal and vertical patterns, as well as the OPs cant [14] (Fig. 3, Table 1). The inclination of the OP, AOP and POP were measured using the FH (Frankfort Horizontal plane) as the reference plane.

2.8 Statistical analysis

Statistical analyses were performed with the GraphPad Prism 8 (GraphPad Software, Inc. (a subsidiary of Dotmatics), San Diego, CA, USA). A subset of the CBCT data was remeasured by the same observer after a two-week interval. The intra-class correlation coefficient (ICC) for all measurements ranged from 0.776 to 0.972, demonstrating excellent reliability and repeatability for each measurement. In addition to standard descriptive statistical calculations (means and standard deviations), ANOVA (Analysis of Variance) tests were used to assess differences among the three groups, and *post-hoc* analyses (Tukey tests) were employed to test for two-by-two differences. We also measured the differences of the age among the three groups (**Supplementary Table 1**). The data characteristics of the three groups were calculated separately for males and females by separating the inclusion criteria by sex (**Supplementary Tables 2 and 3**). Spearman's rank correlations were calculated for the inclination of OPs and the position and shape of the chin and mandibular symphysis in patients with skeletal Class II malocclusion (Table 3). For normodivergent skeletal Class I malocclusion, please refer to **Supplementary Table 4**. Statistically significant differences were determined at $p < 0.05$.

3. Results

3.1 Positional and morphological characteristics of the chin and mandibular symphysis in patients with skeletal Class II malocclusion

Among the three groups, the chin position (FH-NPo: Frankfort Horizontal plane to Nasion-Pogonion line angle) was most posterior in II_H patients and most anterior in I_N patients (Table 4). The results indicated that both the vertical and sagittal dimensions influence the chin position. Furthermore, we analyzed the chin and mandibular symphysis shape indices among the three groups. Compared with those in II_N ($p < 0.01$) and II_H ($p < 0.001$), the chin and mandibular symphysis shape indices in I_N were significantly greater (Table 4).

To measure the shapes of the chin and mandibular symphysis in the anteroposterior and vertical directions, we further analyzed the specific protuberance and height of the chin and mandibular symphysis in patients with skeletal Class II malocclusion. For chin and mandibular symphysis projections, there was no significant difference between the I_N and II_N groups

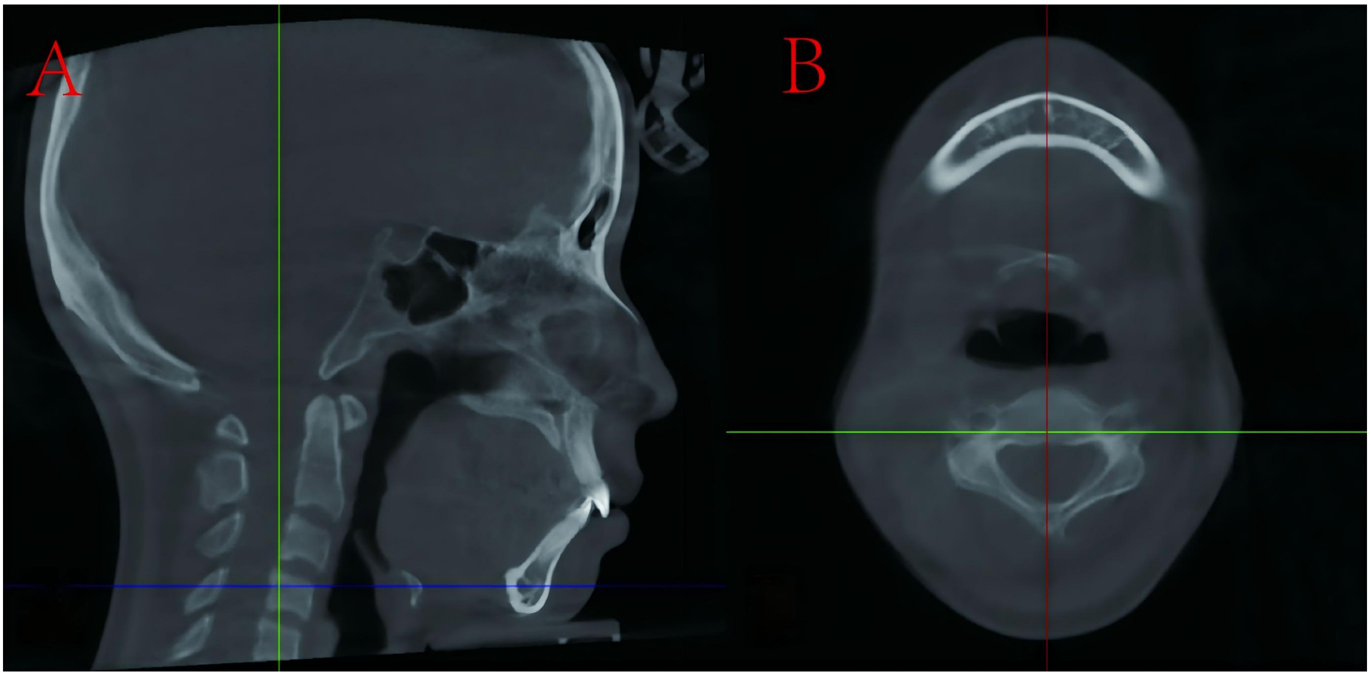

FIGURE 1. Determining the midsagittal plane of the mandible. (A) The blue line is parallel to the FH plane and passes through point Pog. (B) The red line crosses the widest anterior and posterior distance in the middle of the mandible.

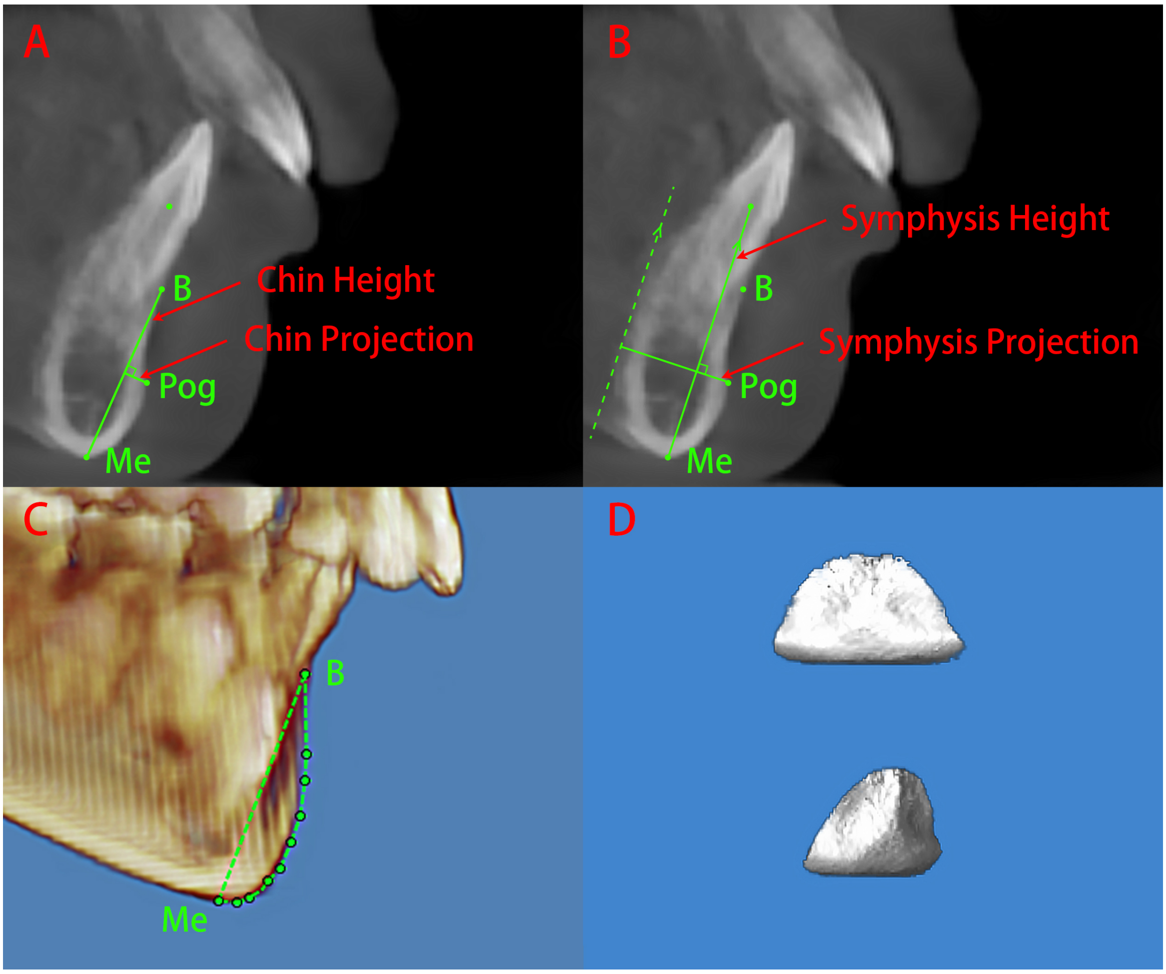

FIGURE 2. Chin and symphysis measurements. (A) Chin linear measurements: chin projection, chin height. (B) Symphysis linear measurements: symphysis projection, symphysis height. (C) Delimitation of chin volume. (D) 3D image of chin volume: front view and 45-degree profile view. Pog: Pogonion; Me: Menton.

TABLE 1. Measurement of craniofacial morphology.

Variable	Description
Dentoskeletal configurations (°)	
SN-MP	Angle between SN and MP planes
ANB	Angle between SNA and SNB planes
FH-NPo (°)	Angle between FH and NPo planes
OPs in mixed dentition	
AOP [19]	Maxillary OP anterior, a line drawn from the incisal edge of the maxillary central permanent incisor to the cusp tips of the maxillary second deciduous molar
POP [19]	Maxillary OP posterior, a line drawn from the cusp tips of the maxillary second deciduous molar to the midpoint of the maxillary first permanent molar at the occlusal surface
OP (downs) [10]	A dividing line between the upper and lower first mesial incisors and the upper and lower permanent molar occlusion
Occlusal plane (°)	
FH-OP	Angle between the FH plane and OP
FH-AOP	Angle between the FH plane and AOP
FH-POP	Angle between the FH plane and POP
OP difference (P-A)	Angle between AOP and POP
Chin	
Height (mm)	The distance between the B point and the me
Projection (mm)	The maximum thickness of the chin, measured as the shortest distance between the pogonion and the chin height line
Shape Index (%)	The ratio between the chin projection and the chin height, multiplied by 100
Volume (mm^3)	The plane of descent through point B is perpendicular to the plane of the inferior border of the mandible and lies in its anterior portion
Symphysis	
Height (mm)	The distance between the most superior point on the alveolar bone and the me
Projection (mm)	The distance between the pogonion and the most posterior point on the symphysis
Symphysis shape index (%)	The ratio between the symphysis thickness and the symphysis height, multiplied by 100

OP: the occlusal plane; OPs: occlusal planes; AOP: anterior occlusal plane; POP: posterior occlusal plane; SN-MP: Sella-Nasion plane to Mandibular Plane angle; ANB: Angle between Nasion-A point and Nasion-B point; SNA: Sella-Nasion-A point angle; SNB: Sella-Nasion-B point angle; FH-NPo: Frankfort Horizontal plane to Nasion-Pogonion line angle.

TABLE 2. Landmarks of cephalometric.

Landmarks	Definitions
S	Sella, the midpoint of the cavity of sella turcica
N	Nasion, the anterior point of the intersection between the nasal and frontal bones
Po	Porion, superior-most point on the external auditory meatus
Or	Orbitale, the lowest point on the inferior bony margin of the orbits
A	The deepest point on the concavity of the maxilla between ANS and the maxillary alveolus
B	The innermost point on the contour of the mandible between the mandibular incisor and chin
Pog	Pogonion, the most prominent point of the symphysis, measured in relation to the FH plane
Go	Gonion, point on the contour of the mandible obtained by bisecting the angle between the mandibular plane and the tangent to the posterior border of the mandible
Me	Menton, the most interior point on the chin
U6	The midpoint of the maxillary first permanent molar at the occlusal surface
L6	The midpoint of the mandibular first permanent molar at the occlusal surface
UE	The midpoint of the maxillary second deciduous molar at the occlusal surface
U1	The incisal point of the most prominent mandibular incisor
L1	The cusp tip of the mandibular first mesial incisors

ANS: Anterior Nasal Spine; FH: Frankfort Horizontal plane.

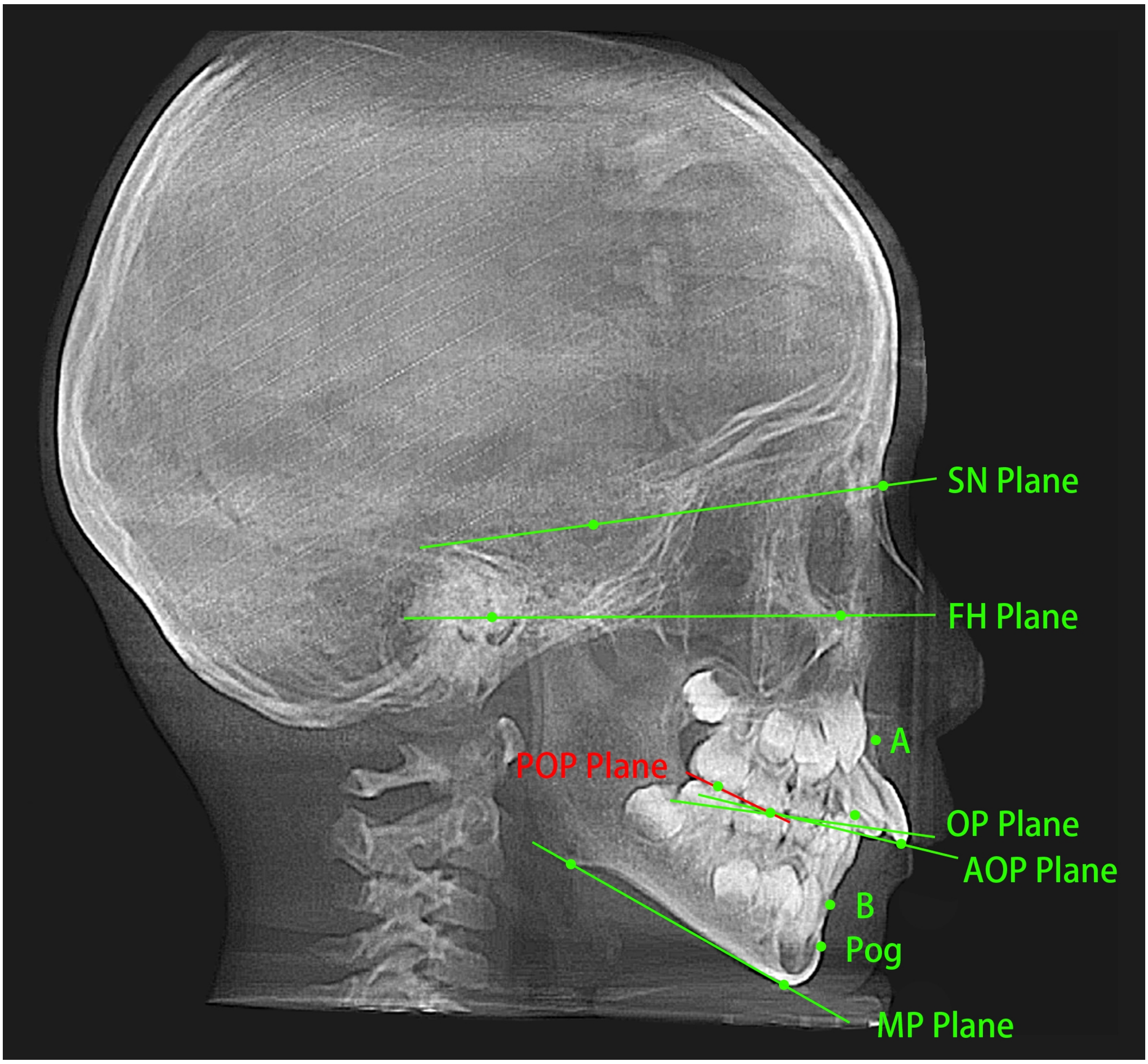

FIGURE 3. Landmarks and planes. POP: posterior occlusal plane; OP: the occlusal plane; AOP: anterior occlusal plane; Pog: Pogonion; MP: Mandibular Plane angle; SN: Sella-Nasion plane; FH: Frankfort Horizontal plane.

TABLE 3. Spearman's rank correlation between the inclination of OPs and the position and shapes of the chin and mandibular symphysis in individuals of normodivergent and hyperdivergent skeletal Class II malocclusions.

	FH-OP		FH-POP		FH-AOP	
	Coefficient (*r*)	*p* Values	Coefficient (*r*)	*p* Values	Coefficient (*r*)	*p* Values
FH-NPo	−0.6647	<0.0001****	−0.5373	<0.0001****	−0.4774	<0.0001****
Chin Height	−0.2501	0.0121*	−0.1698	0.0911	−0.2142	0.0323*
Chin projection	−0.4590	<0.0001****	−0.2297	0.0215*	−0.3015	0.0023**
Symphysis Height	−0.2352	0.0185*	−0.09707	0.3367	−0.2379	0.0172*
Symphysis Projection	−0.2991	0.0025**	−0.1332	0.1864	−0.2587	0.0094**
Chin Shape Index	−0.3496	0.0004***	−0.1320	0.1905	−0.1958	0.0508
Symphysis Shape Index	−0.1021	0.3121	−0.04372	0.6658	−0.06417	0.5259
Volume	−0.1130	0.2653	−0.08292	0.4145	−0.0873	0.3902

*Significance: *p < 0.05; **p < 0.01; ***p < 0.001; ****p < 0.0001.*

FH-NPo: Frankfort Horizontal plane to Nasion-Pogonion line angle; FH-OP: the inclination of the occlusal plane; FH-POP: the inclination of the posterior occlusal plane; FH-AOP: the inclination of the interior occlusal plane.

TABLE 4. Characterization of data from the measurement items in participants.

	Mean ± SD			Significance			*Post-hoc*
Class	I_N (n = 50)	II_N (n = 50)	II_H (n = 50)	I_N *vs.* II_N	I_N *vs.* II_H	II_N *vs.* II_H	Multiple comparison
ANB	3.4 ± 1.1	6.6 ± 1.1	7.2 ± 1.3	****	****	0.023*	$\mathrm{II}_H > \mathrm{II}_N > \mathrm{I}_N$
SN-MP	33 ± 2.6	34 ± 2.1	41 ± 3.5	ns	****	****	$\mathrm{II}_H > \mathrm{I}_N, \mathrm{II}_H > \mathrm{II}_N$
FH-OP	11 ± 3.4	12 ± 3.8	15 ± 3.0	ns	****	****	$\mathrm{II}_H > \mathrm{I}_N, \mathrm{II}_H > \mathrm{II}_N$
FH-POP	17 ± 3.8	20 ± 3.7	22 ± 3.4	0.002**	****	0.031*	$\mathrm{II}_H > \mathrm{II}_N > \mathrm{I}_N$
FH-AOP	12 ± 4.1	14 ± 4.1	16 ± 4.5	0.004**	****	ns	$\mathrm{II}_N > \mathrm{I}_N, \mathrm{II}_H > \mathrm{I}_N$
POP-AOP	5.7 ± 4.7	5.0 ± 4.1	5.1 ± 5.5	ns	ns	ns	-
FH-NPo	86 ± 2.9	84 ± 2.6	82 ± 2.5	***	****	0.006**	$\mathrm{I}_N > \mathrm{II}_N > \mathrm{II}_H$
Chin Projection	3.5 ± 0.59	3.3 ± 0.59	3.0 ± 0.42	ns	***	0.020*	$\mathrm{I}_N > \mathrm{II}_H, \mathrm{II}_N > \mathrm{II}_H$
Chin Height	17 ± 1.5	18 ± 1.7	18 ± 1.6	0.030*	***	ns	$\mathrm{II}_N > \mathrm{I}_N, \mathrm{II}_H > \mathrm{I}_N$
Chin Shape Index	21 ± 3.0	19 ± 2.7	17 ± 2.1	0.002**	****	***	$\mathrm{I}_N > \mathrm{II}_N > \mathrm{II}_H$
Symphysis Projection	14 ± 1.2	13 ± 1.3	13 ± 1.2	ns	***	0.011*	$\mathrm{I}_N > \mathrm{II}_H, \mathrm{II}_N > \mathrm{II}_H$
Symphysis Height	28 ± 2.1	28 ± 2.0	29 ± 2.3	ns	****	ns	$\mathrm{II}_H > \mathrm{I}_N$
Symphysis Shape Index	49 ± 5.4	47 ± 5.1	43 ± 4.0	0.031*	****	***	$\mathrm{I}_N > \mathrm{II}_N > \mathrm{II}_H$
Chin Volume	1067 ± 264	1097 ± 352	1047 ± 267	ns	ns	ns	-

I_N: normodivergent skeletal Class I malocclusion; II_N: normodivergent skeletal Class II malocclusion; II_H: hyperdivergent skeletal Class II malocclusion; ns: no significance; SD: standard deviation; POP-AOP: posterior occlusal plane-anterior occlusal plane; ANB: Angle between Nasion-A point and Nasion-B point; SN-MP: Sella-Nasion plane to Mandibular Plane angle; FH-OP: the inclination of the occlusal plane; FH-POP: the inclination of the posterior occlusal plane; FH-AOP: the inclination of the interior occlusal plane; FH-NPo: Frankfort Horizontal plane to Nasion-Pogonion line angle.
*Significance: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.0001$.*

(Table 4). However, the chin and mandibular symphysis projections in II_H patients were smaller than those in I_N and II_N patients. The results revealed a greater effect of the vertical dimension on the chin and mandibular symphysis projections.

Vertically, the chin height was significantly shorter in the I_N group than in II_N and II_H groups (Table 4). The II_N and II_H groups did not significantly differ in chin height. The results revealed a greater effect of sagittal orientation on the chin height. For mandibular symphysis height, a significant difference was only between the I_N and II_H groups (Table 4). The results revealed significant differences only in the presence of dual factors in the vertical and sagittal directions.

Overall, the results indicated that the chin and mandibular symphysis morphologies were broader and shorter in the I_N group, and thinner and taller in the II_H group. No statistically significant differences were found in chin volume among the groups.

3.2 Steepness of the OPs in patients with skeletal Class II malocclusion

To study the inclination of the OPs in patients with skeletal Class II malocclusion of different vertical patterns, we compared FH-OP, FH-POP and FH-AOP among the three groups (Table 4). The results revealed that FH-OP was not significantly different for normodivergent patterns in either skeletal Class I or II malocclusions, but was steeper in II_H than in I_N and II_N (Table 4). These findings suggested that the vertical skeletal pattern might impact the FH-OP pattern more than the sagittal skeletal pattern.

The FH-POP was steepest in the II_H group, followed by that in the II_N and I_N groups (Table 4). The results suggested that the POP might be influenced by both sagittal and vertical skeletal malocclusions. Regarding the AOP, the FH-AOP was not significantly different between the II_N and II_H groups but was flatter in the I_N group than in the II_N and II_H groups (Table 4). The results revealed that the sagittal skeletal pattern might exert a greater influence on the FH-AOP than the vertical skeletal pattern does.

3.3 Correlations between the inclination of the OPs and the position and shape of the chin and mandibular symphysis in patients with skeletal Class II malocclusion

After understanding the characteristics of the OPs, chin and mandibular symphysis, we conducted correlation analyses to elucidate the relationships among these factors. The results indicated that OP indices, such as AOP, POP and OP, were negatively correlated with FH-NPo (Table 3). The results revealed that the steeper the OPs were, the more posterior the chin position was.

Several statistically significant negative correlations were observed between the OP indices and the chin and mandibular symphysis morphology. FH-OP (Table 3) was negatively correlated with chin projection, chin height, mandibular symphysis projection, mandibular symphysis height and the chin shape index.

FH-POP exhibited a weak but significant correlation with chin projection (Table 3). FH-AOP was negatively correlated with chin projection, chin height, mandibular symphysis projection and mandibular symphysis height (Table 3). The results revealed that the inclinations of the OP and AOP were more strongly correlated with the chin and mandibular symphysis morphology.

4. Discussion

The OP, which is the contact of the upper dentition with the lower dentition, is a guiding surface that affects the spatial position of the mandible [21]. In cases of skeletal class II malocclusion, the mandibular position, which significantly impacts the facial aesthetics of these individuals, can be modified by adjusting the height of the upper dentition and alveolus [12, 22]. During growth and development, the occlusal plane could be modified through functional correction. Treatment with functional advancement appliances was shown to cause significant labial tilt of the mandibular incisors and clockwise rotation of the occlusal plane [23]. Additionally, the occlusal plane could be adjusted in fixed appliance treatment using various methods, including Class II elastics [24], microimplants [25], high-pull J-hook headgear [26] and others [7]. Class II elastics were commonly used to treat patients with Class II malocclusion and could result in the elongation of maxillary anterior teeth and mandibular molars, leading to a clockwise rotation of the occlusal plane [24]. This backward rotation of the occlusal plane could cause a corresponding backward rotation of the mandible, which was particularly detrimental to the lateral appearance of individuals with skeletal Class II malocclusion. When headgear was employed for vertical control, the occlusal plane could be effectively lowered by applying pressure to the upper teeth, which was a crucial factor in the successful treatment of skeletal Class II malocclusion in children [27].

In a long-term study of the occlusal plane, the POP of Class II malocclusions was steeper than that of Class I malocclusions in individuals who had already completed their growth [1]. During growth and development, the POP in Class I malocclusions remained relatively flat from 6 to 14 years old. In contrast, the POP in Class II malocclusions during the growth stage was steeper than that of Class I malocclusion. Additionally, a significant association was observed between a steep occlusal plane and a reduction in mandibular prognathism among individuals with Class II malocclusion. Therefore, during the growth and development period, flattening the occlusal plane in patients with skeletal Class II malocclusion may contribute to the development of the chin.

In addition to the chin position, the shape of the chin and that of the mandibular symphysis also play crucial roles in enhancing facial aesthetics [20]. Despite the aesthetic associations of the chin and mandibular symphysis morphologies with lateral appearance, the characteristics of the chin and mandibular symphysis in different sagittal malocclusions have been overlooked. The mandibular symphysis refers to the portion of the mandible that includes the alveolus above and the base below the anterior mandible, whereas the chin is defined as the base below the anterior mandible bounded by point B [28]. Previous studies have often confused the chin and mandibular symphysis [11, 29]. Therefore, we investigated the relationships between the OPs and the morphologies of the chin and mandibular symphysis in patients with skeletal class II malocclusion, excluding the interference of other malocclusions. Furthermore, new measurements describing the morphologies of the chin and mandibular symphysis were implemented [20].

Many studies have pointed out the factors related to mandibular symphysis morphology, such as genes, muscle activity, mandibular incisor teeth and others. Mandibular symphysis shape is strongly controlled by genes. Patients with β-thalassemia have thinner and smaller mandibular symphysis [4]. As for muscle activity, the mandibular symphyses are fibrous joints adapted to the growth of the jaw, responsible for transferring force from the working side of the mandible to the balanced side [30]. Tongue movement and shut-opening activity can be seen in the fetus, and the ossification of the mandibular symphysis in the fetus may be related to the tension received [31]. One study indicated that the mandibular symphysis was higher and narrower in skeletal Class II malocclusion than in skeletal Class I malocclusion, which might be related to overactivity of the mentalis muscle in skeletal Class II patients [32]. As for the relationship between the mandibular incisors and the morphology of the mandibular symphysis, the mandibular symphysis is more inclined to the lingual side with less thickness and height when the mandibular incisors were absent [33]. However, there have been no studies investigating the correlation between the OPs and the morphologies of the chin and mandibular symphysis.

Our findings demonstrated that the shapes of the chin and mandibular symphysis were broadest and shortest in I_N patients and thinnest and tallest in II_H patients (Table 4). However, no significant differences in chin volume were found among the three groups (Table 4). Regarding the correlation between the OPs and the morphologies of the chin and mandibular symphysis in individuals with skeletal Class II malocclusion, our findings revealed that the height and width of the chin and mandibular symphysis decreased as the OP and AOP tilt increased (Table 3). The results of our study suggested that a steep occlusal plane might be related to the height and width of the chin and mandibular symphysis. In previous studies, the morphologies of the chin and mandibular symphysis were found to be correlated with the skeletal patterns [10, 34, 35]. The widths of the chin and mandibular symphysis were also determined to have an inverse correlation with the mandibular plane (MP) among different vertical skeletal patterns [9, 36]. Additionally, there was a high degree of agreement between MP and OP [37]. The chin and mandibular symphysis widths were narrower in proportion to the steepness of the OP and MP. The results indicated that the widths of the chin and mandibular symphysis were not only related to the vertical facial pattern, but also associated with the inclination of the OPs.

In this study, OP and AOP were significantly negatively correlated with chin position, which suggested that a steeper OP might be associated with a more posterior chin position (Table 3). Previous investigations introduced the concept of jaw rotation and indicated that a steeper OP could be associated with a more posterior chin position [16, 38]. Among the three groups, we observed that the inclination of the AOP was significantly greater in patients with skeletal class II malocclusion than in those with skeletal class I malocclusion (Table 4). The OP compensates for the sagittal relationship between the maxilla and mandible, with the inclination of the mandibular incisors playing a crucial role in achieving anterior occlusal relationships [39]. The OP compensates for the sagittal relationship between the maxilla and mandible, with the inclination of the mandibular incisors playing a crucial role in achieving anterior occlusal relationships [40]. This demonstrates that the lower incisor is associated with the mandibular symphysis morphology and can be modified through orthodontic treatment to alter the mandibular symphysis morphology [33].

In addition, the POP inclination was steepest in patients with hyperdivergent skeletal class II malocclusion and flattest in patients with normodivergent skeletal class I malocclusion (Table 4). The chin position was negatively correlated with the POP (Table 3). A study has shown that counterrotation of the mandible can be obtained by upward pressure on the upper dentition, increasing the prominence of the chin [41].

The findings of the present investigation suggest that OPs might have correction with the development of chin and mandibular symphysis morphologies in individuals with skeletal Class II malocclusion. Adolescence is the key period for early correction of children with skeletal Class II malocclusion. Early treatment methods for children aged 6 to 12 years, such as Twin-Block, Activator and mandibular advancement with clear aligners, can effectively improve their Skeletal Class II profile [42]. For patients older than 12 years age, the B point was shifted back, and the chin became more pronounced after extraction orthodontic treatment [43]. However, the majority of early orthodontic studies examined the effects on the position of chin, there was a lack of research exploring the influence of orthodontic treatment on chin and mandibular symphysis morphologies.

High-pull headgear activators can flatten the OPs, so that the jaw can be reversed rotation, if later combined with fixed correction can better reduce the inclination of POP, to achieve a more stable therapeutic effect [27]. For patients with severe skeletal Class II mandibular retrusion, it is difficult to obtain a satisfactory amount of sagittal forward movement of the mandible due to the relatively steep occlusal plane [44]. In the surgical treatment, Silveira *et al*. [45] pointed out that for patients requiring a large amount of mandibular forward movement, a counterclockwise rotation of the occlusal plane could reduce the resistance to mandibular vertical and sagittal movement, allowing for better mandibular advancement. Therefore, flattening the occlusal plane during the growth and development period may potentially facilitate the development of the chin; however, further long-term studies are needed to confirm this.

There were some limitations in this study. First, this study was a cross-sectional design. This paper discussed the relationship between the inclination of the occlusal plane and the position and morphologies of the chin and mandibular symphysis. However, the reason behind this phenomenon was not explained. It was needed to further explore the relationship between changes in the inclination of the occlusal plane and changes in the mandibular symphysis shapes following the intervention of functional appliances. Furthermore, the number of patients with hypodivergent skeletal Class II malocclusion was too small at the time of collection. Therefore, the vertical classification in this study was only divided into normodivergent and hyperdivergent malocclusions. If the hypodivergent skeletal Class II malocclusion group was included, it may be more beneficial for assessing the influence of the vertical dimension.

5. Conclusions

1. The shapes of the chin and mandibular symphysis were the broadest and shortest in individuals with I_N and were thinnest and tallest in individuals with II_H. There was no statistically significant difference in chin volume.
2. In individuals with skeletal Class II malocclusion, there was a negative correlation between the inclination of the OPs and the height and width of the chin and mandibular symphysis, as well as the chin position.

ABBREVIATIONS

OPs, occlusal planes; OP, the occlusal plane; AOP, anterior occlusal plane; POP, posterior occlusal plane; CBCT, cone beam computed tomography; I_N, normodivergent skeletal Class I malocclusion; II_N, normodivergent skeletal class II malocclusion; II_H, hyperdivergent skeletal Class II malocclusion; GALL, Gysi Anterior Lingual Line; TVL, Terry's Vertical Line; MP, the mandibular plane; ICC, intra-class correlation coefficient; FH, Frankfort Horizontal plane; ANB, Angle between Nasion-A point and Nasion-B point; SN, Sella-Nasion plane; DICOM, Digital Imaging and Communications in Medicine; ANOVA, Analysis of Variance; NPo, Nasion-Pogonion.

AVAILABILITY OF DATA AND MATERIALS

The raw data used in this paper are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

LXEY, YTC, SYL, XW and AXG—designed the research study; reviewed and edited the manuscript. LXEY—collected and measured the data. LXEY, HBJ and JYW—analyzed the data and wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Committee on Ethics at the Children's Hospital of Nanjing Medical University and was conducted following the tenets of the Declaration of Helsinki for research involving human subjects (Approval No: 202402020-1). All legal guardians signed informed consent forms and the patient's personal information was kept confidential.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1985188055974068224/attachment/Supplementary%20material.docx.

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