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Original Article

Mandibular Symphysis Dimensions Across Different Sagittal and Vertical Skeletal Relationships: A Comparative Cephalometric Study

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Abstract

Background: The mandibular symphysis (MS) is a critical anatomical structure influencing facial aesthetics, orthodontic diagnosis, and treatment planning. Variations in MS morphology may reflect underlying sagittal and vertical skeletal discrepancies, thereby affecting orthodontic biomechanics and treatment limits.

Objective: To compare mandibular symphysis dimensions among different sagittal and vertical skeletal patterns in non-growing adults, with additional consideration of gender-based differences.

Methodology: A comparative cross-sectional study was conducted at the Armed Forces Institute of Dentistry, Rawalpindi. Lateral cephalograms of 230 non-growing adult patients aged 16–40 years with skeletal Class I, II, or III malocclusions were analyzed. Sagittal skeletal relationships were determined using the ANB angle with Wits appraisal as an adjunct, while vertical skeletal patterns were classified using the SN–mandibular plane angle. Mandibular symphysis parameters assessed included dentoalveolar length, skeletal symphysis length, chin length, total symphysis length, vertical symphysis dimension, symphysis convexity, and symphysis concavity.

Results: Females comprised 53.04% of the sample and males 46.96%. Significant differences in mandibular symphysis dimensions were observed across vertical skeletal patterns. High vertical patterns demonstrated significantly greater skeletal symphysis length, total symphysis length, and vertical symphysis dimensions ($p < 0.001$), along with a shorter chin length ($p = 0.008$) and increased symphysis concavity angle ($p = 0.002$). Sagittal skeletal patterns showed no significant differences in most symphysis parameters, except for symphysis convexity, which was significantly greater in skeletal Class II subjects ($p = 0.02$). Gender-specific analysis revealed distinct morphological variations, particularly in high vertical patterns.

Conclusion: Mandibular symphysis morphology is significantly influenced by vertical skeletal pattern, whereas sagittal skeletal relationship has a limited effect, except on symphysis convexity. These findings underscore the importance of vertical growth assessment in orthodontic diagnosis and treatment planning.

Keywords: Cephalometry, Facial Skeleton, Mandibular Symphysis, Malocclusion, Orthodontics.

Introduction

The mandibular symphysis (MS) is a fundamental component of the craniofacial complex and serves as an essential reference in orthodontic diagnosis, treatment planning, and facial aesthetic evaluation [1]. Its morphology directly influences the positioning of mandibular incisors, determines the limits of orthodontic tooth movement, and reflects underlying skeletal growth patterns [2]. An accurate understanding of MS dimensions is therefore crucial for achieving stable and esthetically pleasing orthodontic outcomes.

The morphology of the MS is known to vary in response to sagittal skeletal discrepancies [3]. In individuals with skeletal Class I relationships, the MS generally exhibits balanced proportions that provide adequate support for mandibular incisors and harmonious facial contours. In skeletal Class II malocclusion, increased dentoalveolar length and greater symphysis convexity have been reported, often attributed to compensatory proclination of the mandibular incisors in response to mandibular retrusion [4]. Conversely, skeletal Class III individuals typically demonstrate a more prominent chin, increased skeletal symphysis length, and reduced convexity, accommodating a prognathic mandibular position [5,6].

Vertical skeletal relationships further influence MS morphology and its functional capacity [7]. Hypodivergent individuals often exhibit a shorter and wider MS with thicker alveolar bone, providing greater resistance to orthodontic forces and enhanced periodontal support [8,9]. In contrast, hyperdivergent individuals characteristically present with a taller and narrower MS, thinner alveolar housing, and reduced tolerance for extensive orthodontic tooth movement, increasing the risk of dehiscence and gingival recession [10]. Normodivergent individuals generally display intermediate MS dimensions consistent with functional equilibrium and facial balance [11].

The MS undergoes continuous remodeling throughout growth and adolescence, with bone apposition and resorption patterns adapting to functional demands, occlusal forces, and mandibular displacement [11]. Pubertal growth, in particular, is associated with pronounced vertical development of the MS, influenced by genetic, environmental, and ethnic factors [12]. These dynamic changes underscore the importance of evaluating MS morphology within the context of both sagittal and vertical skeletal frameworks.

Despite growing interest in MS morphology, studies simultaneously assessing its dimensions across combined sagittal and vertical skeletal patterns while accounting for gender differences remain limited. This comparative study aims to address this gap by systematically evaluating mandibular symphysis dimensions in non-growing adults with varying sagittal and vertical skeletal relationships. A clearer understanding of these morphological variations can assist clinicians in optimizing orthodontic treatment planning, predicting anatomical limitations, and minimizing adverse periodontal outcomes.

Methodology

Study Design

This comparative cross-sectional study was conducted to evaluate variations in mandibular symphysis dimensions across different sagittal and vertical skeletal relationships. The study design was selected to allow simultaneous comparison of morphological parameters among predefined skeletal groups using standardized cephalometric records obtained during routine orthodontic assessment.

Ethics

Ethical approval for the study was obtained from the institutional review committee of the Armed Forces Institute of Dentistry (AFID), Rawalpindi (Approval No. 918/Trg; dated 13 May 2020). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent had been obtained from all patients at the time of treatment, permitting the use of their diagnostic records for research purposes while ensuring confidentiality and anonymity.

Setting

The study was carried out at the Department of Orthodontics, Armed Forces Institute of Dentistry Hospital, Rawalpindi, Pakistan. Data collection was performed using existing orthodontic records from patients treated between January 10, 2024, and December 30, 2024.

Participants

A total of 230 non-growing adult patients aged 16–40 years of both genders were included through non-probability consecutive sampling. Eligible participants had skeletal Class I, II, or III malocclusions, irrespective of vertical growth pattern. Only patients with high-quality lateral cephalometric radiographs were included. Individuals with a history of previous orthodontic treatment, orthognathic or maxillofacial surgery, craniofacial syndromes, cleft lip or

palate, root resorption, or congenital anomalies were excluded. Mild to moderate dental crowding was permitted.

Variables

The primary outcome variables were mandibular symphysis dimensions, including dentoalveolar length, skeletal symphysis length, chin length, total symphysis length, vertical symphysis dimension, symphysis convexity angle, and symphysis concavity angle. Independent variables included sagittal skeletal pattern (Class I, II, III), vertical skeletal pattern (low, normal, high angle), gender, and age.

Data Sources/Measurement

Lateral cephalograms were obtained using a standardized Kodak K-9000 C digital cephalometric unit. All radiographs were manually traced on matte acetate paper and subsequently digitized. Sagittal skeletal relationships were determined using the ANB angle, with Wits appraisal employed as an adjunctive diagnostic measure to enhance classification accuracy. Vertical skeletal pattern was assessed using the SN–mandibular plane (SN-MP) angle, categorized as low (<28°), normal (28°–32°), or high (>32°). Mandibular symphysis tracing included identification of standard cephalometric landmarks. Linear measurements included dentoalveolar length (Id–B), skeletal symphysis length (B–Pog), chin length (Pog–Me), and total symphysis length (Id–Me). Angular measurements included vertical symphysis dimension (∠B–B1–Gn), symphysis convexity (∠B–Pog–Me), and symphysis concavity (∠Id–B–Pog). Point B1 was defined as the perpendicular projection of point B onto the mandibular lower border. Age and gender were recorded from patient records.

Bias

To minimize measurement bias, all cephalometric tracings and measurements were performed using standardized anatomical definitions and consistent tracing techniques. The use of adjunctive diagnostic parameters (ANB angle and Wits appraisal) reduced misclassification bias in sagittal skeletal grouping.

Selection bias was limited by including all eligible cases available during the study period.

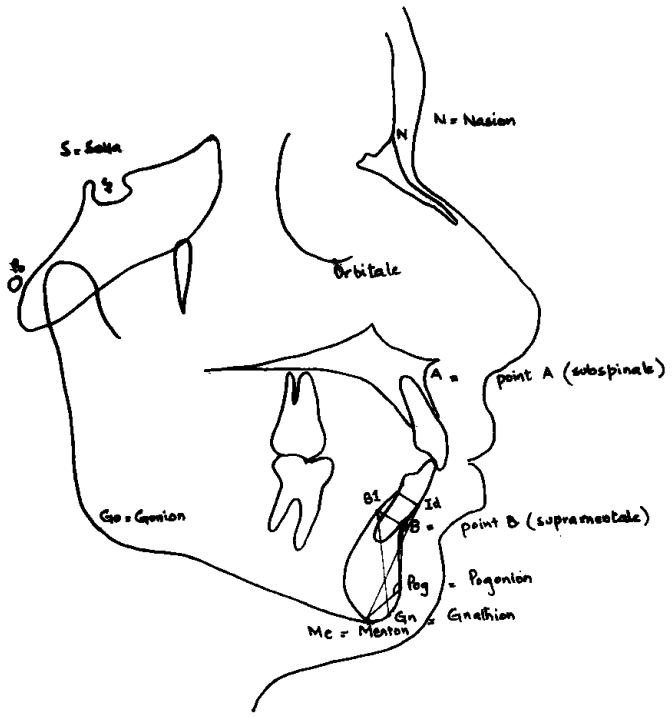


Figure 1: Landmarks for chin dimension.

Study Size

Sample size estimation using OpenEpi indicated a minimum requirement of 52 participants (26 per group) based on an 80% study power and 95% confidence level, using previously reported differences in dentoalveolar length. To strengthen statistical robustness and satisfy assumptions of normality, all available eligible cases were included, resulting in a final sample of 230 participants.

Quantitative Variables

Continuous variables such as age and mandibular symphysis dimensions were treated as quantitative variables and expressed as mean ± standard deviation. Categorical variables, including gender and skeletal classifications, were expressed as frequencies and percentages.

Statistical Methods

Statistical analysis was performed using R software version 4.3.2. One-way analysis of variance (ANOVA) was applied to compare mandibular symphysis dimensions across sagittal and vertical skeletal groups. Post-hoc comparisons were conducted using the Tukey test where applicable. Gender was treated as an effect modifier and controlled through stratified analyses. A p-value of <0.05 was considered statistically significant.

Results

Participants

A total of 230 non-growing adult participants aged 16–40 years were included in the final analysis. The mean age of the study population was 18.57 ± 4.24 years. Females constituted 53.04% (n = 122) of the sample, while males accounted for 46.96% (n = 108). With respect to sagittal skeletal classification, 50.43% of participants were skeletal Class I, 43.48% Class II, and 6.09% Class III. Regarding vertical skeletal patterns, half of the participants exhibited a normal vertical pattern, followed by low vertical (31.3%) and high vertical (18.7%) patterns (Table 01, Figure 02).

Descriptive Data

Mean values and standard deviations for mandibular symphysis dimensions were calculated across sagittal and vertical skeletal groups. Overall, dentoalveolar length, skeletal symphysis length, chin length, total symphysis length, vertical symphysis dimension, and angular measurements of symphysis convexity and concavity demonstrated measurable variability across vertical growth patterns. Gender-stratified descriptive analysis revealed generally larger linear symphysis dimensions in males compared to females, while angular measurements showed relatively smaller inter-gender variation.

Outcome Data

When analyzed by vertical skeletal pattern, dentoalveolar length did not differ significantly among high, low, and normal groups (p = 0.09). However, skeletal symphysis length, total symphysis length, and vertical symphysis dimension were significantly greater in individuals with a high vertical pattern compared with low and normal patterns (p < 0.001 for all). Chin length was significantly shorter in the high vertical group (p = 0.008). The symphysis concavity angle was also significantly larger in the high vertical group (p = 0.002), whereas symphysis convexity angle did not show a statistically significant difference across vertical patterns (p = 0.36) (Table 02).

Across sagittal skeletal classifications, no statistically significant differences were observed in most mandibular symphysis dimensions, including dentoalveolar length, skeletal symphysis length, chin length, total symphysis length, vertical dimension, and concavity angle (p > 0.05). The only parameter demonstrating a significant difference was the symphysis convexity angle, which was greater in skeletal Class II compared with Class I and Class III subjects (p = 0.02) (Table 03).

Main Results

Gender-stratified analysis revealed distinct patterns in mandibular symphysis morphology. Among females, skeletal symphysis length, total symphysis length, and vertical symphysis dimension were significantly greater in the high vertical group compared with low and normal vertical patterns (p < 0.001). Chin length was significantly shorter in females with a high vertical pattern (p = 0.032), while dentoalveolar length and convexity angle did not differ significantly (Table 04).

In males, dentoalveolar length, total symphysis length, and symphysis concavity angle were significantly greater in the high vertical group (p < 0.05), whereas skeletal symphysis length, chin length, vertical dimension, and convexity angle did not show statistically significant variation.

When sagittal skeletal patterns were analyzed by gender, no significant differences were observed in most symphysis parameters in either females or males. However, in males, the symphysis convexity angle was significantly greater in skeletal Class II compared with Class I and Class III (p = 0.046). (Table 05).

The findings demonstrate that vertical skeletal pattern exerts a stronger influence on mandibular symphysis morphology than sagittal skeletal pattern, with high vertical growth patterns showing consistently larger linear dimensions and altered angular characteristics.

Table 1: Demographic and skeletal pattern of the participants.

Characteristic		N = 230
Age (Years)*		18.57 ± 4.24
Gender**	Female	122 (53.04%)
	Male	108 (46.96%)
Skeletal Class**	Class I	116 (50.43%)
	Class II	100 (43.48%)
	Class III	14 (6.09%)

*Mean ± SD; **n (%)

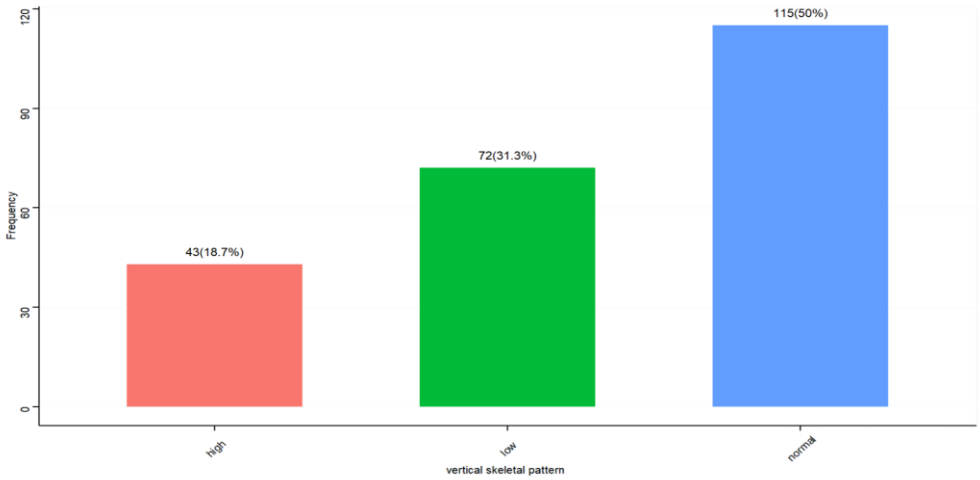


Figure 1: Distribution of vertical pattern of the patients.

Table 2: Comparison of mandibular symphysis dimension in various vertical patterns

Characteristic	High N = 43	Low N = 72	Normal N = 115	p-value
Dentoalveolar Length (mm)	7.21 ± 2.50	6.38 ± 1.95	6.61 ± 1.83	0.09
Skeletal Symphysis Length (mm)	18.93 ± 3.40	16.35 ± 3.03	17.44 ± 3.44	<0.001*
Chin Length (mm)	11.37 ± 1.65	12.51 ± 2.08	12.00 ± 1.88	0.008*
Total Symphysis Length (mm)	33.74 ± 2.90	31.31 ± 3.01	32.27 ± 3.24	<0.001*
Vertical Dimensions of Symphysis (mm)	55.72 ± 5.58	51.18 ± 5.52	52.73 ± 5.77	<0.001*
MS Convexity Angle (degree)	130.26 ± 9.00	128.61 ± 8.69	130.24 ± 7.41	0.360
MS Concavity (degree)	147.37 ± 7.40	142.39 ± 6.62	145.10 ± 7.79	0.002*

MS, Mandibular symphysis; Values are given as Mean ± SD
*p<0.05 is considered statistically significant

Table 3: Comparison of mandibular symphysis dimension in sagittal skeletal pattern.

Characteristics	Class I N = 116	Class II N = 100	Class III N = 14	p-value	Post hoc p-values & Effect Size (Cohen's d) **
Dentoalveolar length (mm)	6.54 ± 2.22	6.85 ± 1.83	6.07 ± 1.44	0.29	I vs II: 0.45, d = 0.14 I vs III: 0.55, d = 0.22 II vs III: 0.28, d = 0.50
Skeletal symphysis length (mm)	17.29 ± 3.59	17.54 ± 3.27	16.93 ± 3.00	0.76	I vs II: 0.92, d = 0.07 I vs III: 0.82, d = 0.10 II vs III: 0.79, d = 0.19
Chin length (mm)	12.11 ± 1.84	12.03 ± 1.97	11.57 ± 2.56	0.61	I vs II: 0.98, d = 0.04 I vs III: 0.62, d = 0.22 II vs III: 0.55, d = 0.18
Total symphysis length (mm)	32.11 ± 3.18	32.53 ± 3.25	31.29 ± 2.97	0.32	I vs II: 0.67, d = 0.13 I vs III: 0.41, d = 0.27 II vs III: 0.34, d = 0.38
Vertical dimensions of symphysis (mm)	52.77 ± 5.61	52.76 ± 5.73	53.43 ± 8.49	0.91	I vs II: 0.99, d = 0.00 I vs III: 0.87, d = 0.09 II vs III: 0.84, d = 0.09
MS convexity angle (degree)	128.86 ± 7.83	131.24 ± 8.21	126.21 ± 8.46	0.02*	I vs II: 0.15, d = 0.30 I vs III: 0.42, d = 0.33 II vs III: 0.04, d = 0.60
MS concavity (degree)	144.69 ± 7.88	144.66 ± 6.64	144.64 ± 10.85	0.99	I vs II: 0.99, d = 0.00 I vs III: 0.99, d = 0.05 II vs III: 0.99, d = 0.05

MS, Mandibular symphysis; Values are given as Mean ± SD
*p<0.05 is considered statistically significant ** Tukey test

Table 4: Comparison of mandibular symphysis dimension in various vertical patterns stratified by gender.

Characteristics	Female, N = 122				Male, N = 108			
	High N = 28	Low N = 34	Normal N = 60	p-value	High N = 15	Low N = 38	Normal N = 55	p-value
Dentoalveolar Length (mm)	6.82 ± 1.93	6.41 ± 2.16	6.40 ± 2.04	0.60	7.93 ± 3.28	6.34 ± 1.76	6.84 ± 1.56	0.031*
Skeletal Symphysis Length (mm)	19.14 ± 3.45	14.97 ± 2.82	16.50 ± 3.21	<0.001*	18.53 ± 3.40	17.58 ± 2.69	18.47 ± 3.41	0.40
Chin Length (mm)	11.04 ± 1.73	12.38 ± 2.40	11.93 ± 1.89	0.032*	12.04 ± 1.11	15.38 ± 2.40	13.93 ± 1.89	0.71
Total Symphysis Length (mm)	32.61 ± 2.42	29.91 ± 2.42	30.98 ± 2.65	<0.001*	35.87 ± 2.53	32.55 ± 2.96	33.67 ± 3.25	0.003*
Vertical Dimensions Of Symphysis (mm)	56.61 ± 5.47	51.03 ± 5.71	52.95 ± 5.94	<0.001*	54.07 ± 5.59	51.32 ± 5.41	52.49 ± 5.63	0.30
MS Convexity Angle (Degree)	127.79 ± 9.18	126.21 ± 6.57	129.38 ± 6.78	0.130	134.87 ± 6.75	130.76 ± 9.82	131.18 ± 7.99	0.30
MS Concavity (Degree)	147.75 ± 8.12	142.88 ± 7.10	144.45 ± 6.60	0.027*	146.67 ± 6.03	141.95 ± 6.21	145.80 ± 8.93	0.035*

MS, Mandibular symphysis; Values are given as Mean ± SD
*p<0.05 is considered statistically significant

Table 5: Comparison of mandibular symphysis dimension in sagittal skeletal pattern stratified by gender.

Characteristics	Female, N = 122				Male, N = 108			
	Class I N = 61	Class II N = 54	Class III N = 7	p-value	Class I N = 55	Class II N = 46	Class III N = 7	p-value
Dentoalveolar Length (mm)	6.36 ± 2.42	6.59 ± 1.62	7.00 ± 1.41	0.70	6.75 ± 1.97	7.15 ± 2.03	5.14 ± 0.69	0.041*
Skeletal Symphysis Length (mm)	16.25 ± 3.60	17.24 ± 3.34	16.14 ± 3.29	0.30	18.45 ± 3.24	17.89 ± 3.19	17.71 ± 2.69	0.60
Chin Length (mm)	11.98 ± 1.77	11.83 ± 2.32	10.86 ± 2.27	0.40	11.53 ± 1.27	11.22 ± 2.34	10.6 ± 2.28	0.46
Total Symphysis Length (mm)	30.67 ± 2.68	31.56 ± 2.72	30.57 ± 2.23	0.20	33.71 ± 2.94	33.67 ± 3.46	32.00 ± 3.61	0.40
Vertical Dimensions Of Symphysis (mm)	52.44 ± 6.30	54.26 ± 5.45	52.57 ± 8.14	0.30	53.13 ± 4.77	51.00 ± 5.61	54.29 ± 9.39	0.10
MS Convexity Angle (Degree)	126.95 ± 7.07	129.56 ± 7.54	127.43 ± 8.44	0.20	130.98 ± 8.15	133.22 ± 8.60	125.00 ± 8.96	0.046*
MS Concavity (Degree)	143.77 ± 6.65	145.67 ± 7.07	146.57 ± 12.65	0.30	145.71 ± 9.01	143.48 ± 5.97	142.71 ± 9.29	0.30

MS, Mandibular symphysis; Values are given as Mean ± SD

*p<0.05 is considered statistically significant

Discussion

The present study evaluated mandibular symphysis morphology across different sagittal and vertical skeletal patterns in non-growing adults and demonstrated that vertical skeletal pattern exerts a stronger influence on symphysis dimensions than sagittal skeletal classification. High vertical skeletal patterns were consistently associated with increased skeletal symphysis length, total symphysis length, vertical symphysis dimension, and greater concavity, along with a relatively shorter chin. In contrast, sagittal skeletal relationships showed minimal influence on most symphysis parameters, with the exception of symphysis convexity, which was greater in skeletal Class II individuals.

The finding of significantly increased symphysis height and total length in high vertical patterns is consistent with previous reports that describe vertical elongation of the mandibular symphysis in hyperdivergent individuals.7 [13]. Linjawi et al [13]. similarly reported greater vertical symphysis dimensions in subjects with increased mandibular plane angles, suggesting that vertical facial growth is accompanied by adaptive elongation of the symphyseal region. This elongation likely reflects compensatory remodeling in response to altered occlusal forces and mandibular rotation, which are characteristic of hyperdivergent growth patterns.

The shorter chin length observed in individuals with high vertical skeletal patterns aligns with the findings of Uengkajornkul et al. [14], who reported reduced anterior chin projection in patients with skeletal open bite tendencies. This morphological characteristic may be attributed to posterior mandibular rotation and reduced horizontal growth of the pogonion region, leading to a less prominent chin despite increased vertical dimensions. Clinically, this has important implications for orthodontic camouflage and orthognathic planning, particularly in patients where chin projection contributes significantly to facial aesthetics.

With regard to sagittal skeletal relationships, the absence of significant differences in most mandibular symphysis dimensions contrasts with some earlier studies that reported larger dentoalveolar and skeletal symphysis dimensions in Class II individuals [13]. These discrepancies may be explained by differences in sample composition, age range, ethnic background, and measurement techniques. In the present study, the relatively small proportion of Class III subjects may have limited the statistical power to detect subtle differences among sagittal groups. Nevertheless, the significantly greater symphysis convexity observed in Class II subjects is consistent with

prior findings [14,15] and may reflect compensatory proclination of mandibular incisors and increased labial curvature of the symphysis in response to mandibular retrusion.

Gender-stratified analysis revealed notable sexual dimorphism in mandibular symphysis morphology. Females with high vertical patterns exhibited significantly greater skeletal and total symphysis lengths along with reduced chin length, whereas males demonstrated greater dentoalveolar length, total symphysis length, and concavity angle in the same vertical pattern. These findings support previous observations that males generally exhibit more robust mandibular dimensions due to prolonged growth duration and greater masticatory muscle forces [15]. Such gender-specific variations highlight the importance of individualized orthodontic assessment, particularly when planning extensive incisor movement or surgical interventions.

From a clinical perspective, the strong association between vertical skeletal pattern and symphysis morphology underscores the need for careful evaluation of the mandibular symphysis prior to orthodontic treatment. Hyperdivergent patients with tall and narrow symphyses may have limited alveolar housing for incisor movement and an increased risk of periodontal complications [10]. Understanding these anatomical constraints allows clinicians to optimize treatment mechanics, avoid excessive tooth movement, and improve long-term stability.

Despite its strengths, this study has certain limitations. Manual tracing of cephalometric radiographs may introduce measurement error, although standardized techniques were employed to minimize variability. The single-center study design may limit generalizability to other populations, and the relatively small number of skeletal Class III subjects warrants cautious interpretation of findings related to this group. Future studies incorporating three-dimensional imaging modalities such as CBCT and larger, multi-center samples could provide more comprehensive insights into symphysis morphology and its clinical implications.

Conclusion

Mandibular symphysis dimensions vary significantly according to vertical skeletal growth pattern, with high vertical patterns exhibiting greater skeletal symphysis length, total symphysis length, vertical dimensions, and increased concavity, along with a shorter chin. Sagittal skeletal relationships have a limited influence on symphysis morphology, except for increased convexity observed in skeletal Class II individuals. Gender-based differences further modulate symphysis dimensions, emphasizing the importance of individualized assessment. These findings reinforce the clinical relevance of vertical growth pattern evaluation in orthodontic diagnosis and treatment planning to ensure biomechanically sound and periodontally safe outcomes.

Authors' Contributions:

All authors meet the ICMJE criteria for authorship.

Author 1: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 2: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 3: Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 4: Analysis and interpretation of data, critical revision, final approval, agreed to be accountable for all the work.
Author 5: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 6: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.

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