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Original article

Mandibular symphysis dimensions in different sagittal and vertical skeletal relationships☆

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ABSTRACT

Background: The aim of this cross-sectional study was to compare the dimensions of mandibular symphysis (MS) between gender and the different sagittal and vertical skeletal relationships.
Material and Methods: Pre-treatment records of orthodontic patients were divided according to gender, sagittal (Class I, II and III) and vertical (decreased, average and increased mandibular plane [MP] angle) skeletal relationships. Measurements of MS parameters were performed on lateral cephalograms using IMAGEJ software. Comparisons between MS parameters and gender and the different skeletal relationships was performed using multifactorial and one-way ANOVA, and independent sample t-tests.
Results: A total of 104 records (25 males and 79 females) fulfilled the inclusion criteria. Males had significantly greater MS surface area, dentoalveolar length, skeletal symphysis length, total symphysis length, vertical symphysis dimension and symphysis convexity ($p < 0.05$). Skeletal Class II patients had significantly greater dentoalveolar and skeletal symphysis lengths while Class III had greater chin length, vertical symphysis dimension and symphysis convexity ($p < 0.05$). Patients with decreased vertical dimension had greater skeletal symphysis length ($p = 0.026$) and those with an average vertical relationship had greater chin length ($p < 0.001$).
Conclusions: The morphology of the mandibular symphysis is affected by gender, sagittal and vertical skeletal patterns. Males had increased mandibular symphysis surface area and linear dimensions. Class II patients had greater dentoalveolar length. Chin length was greater in patients with an average MP angle.
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1. Introduction

The morphology of the mandibular symphysis (MS) influences orthodontic diagnosis and treatment planning. The MS is considered a primary landmark for facial profile esthetic and determination of lower incisor positioning (Hoenig, 2007, Yu, et al., 2009, Molina-Berlanga, et al., 2013, Gómez et al., 2018). Moreover, the internal cortical structure of the symphysis inferior border is a stable landmark; hence it is used for mandibular superimposition, and the symphyseal morphology can also be used for prediction and assessment of mandibular growth pattern (Björk, 1969, Buschang, et al., 1992).

Mandibular symphysis unites at the age of 6–9 months and continues to grow until adolescence (Esenlik and Sabuncuoglu, 2012). The MS undergoes growth changes in a backward and upward direction, with deposition bone on all its surfaces excluding the zone above pogonion, where resorption occurs (Björk, 1969, Esenlik and Sabuncuoglu, 2012). The MS vertical growth changes were found to be pronounced during puberty (Buschang, et al., 1992). There is a significant individual variation in the morphology of the MS due to possibly multiple etiological factors such as genetics, ethnicity, facial type, and mandibular incisors inclination (Esenlik and Sabuncuoglu, 2012, Molina-Berlanga, et al., 2013, Al-

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Khateeb, et al., 2014, Maniyar, et al., 2014, Srebrzyńska-Witek et al., 2018).

Many studies have investigated the correlation of MS dimensions, bone thickness, and morphology with different sagittal and vertical skeletal jaw discrepancies. However, differences as well as similarities were found in in these studies (Chung, et al., 2008, Gracco, et al., 2010, Swasty, et al., 2011, Esenlik and Sabuncuoglu, 2012, Al-Khateeb, et al., 2014, Closs, et al., 2014, Moshfeghi, et al., 2014, Foosiri, et al., 2018). Thus far, there are no studies that investigated the MS morphology in relation to sagittal and vertical skeletal relationships in a Saudi sample. Such investigation will add to the current literature and stress the importance of chin and symphysis morphology and dimensions in the diagnosis and treatment planning of orthodontic problems as well as the significance of symphysis analysis in the prediction of skeletal growth (Skieller, et al., 1984, Buschang, et al., 1992, Aki, et al., 1994).

Therefore, the aims of this investigation were to: (1) compare MS dimensions between individuals with different sagittal and vertical skeletal relationships, (2) determine if there is a gender difference in the MS dimensions, and (3) determine if the interactions between the skeletal relationships and gender have any effect on the MS dimensions.

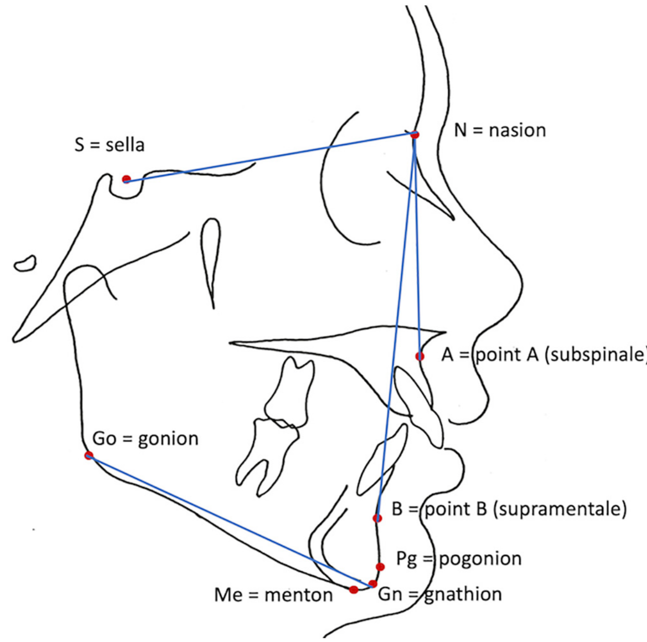

Fig. 1. Cephalometric landmarks, planes and angles.

2. Material and methods

This retrospective cross-sectional study was conducted at the Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia. The research was reviewed and approved by the Research Ethics Committee at the same institution (No. 099–06-19). Pretreatment records of orthodontic patients were screened for the following inclusion criteria: (1) age ranging between 15 and 25 years old, (2) complete pre-orthodontic records with high-quality and clear cephalometric radiographs, (3) healthy periodontal and bone condition (4) no craniofacial disorders or cleft lip and palate, (5) no previous of orthodontic treatment, (6) no previous periodontal surgical treatment, and (7) no previous facial or jaw trauma.

Patients who satisfied the inclusion criteria were categorized according to the following criteria: The sagittal skeletal relationship as determined by the ANB angle (Fig. 1). Thus, the sample was split into three skeletal sagittal groups: Class I (ANB = 2° ±2), Class II (ANB > 4°), or Class III (ANB < 0°). The vertical skeletal relationship was determined by the mandibular plane angle that is formed by intersection lines between Sella - Nasion and Gonion to Gnathion (Fig. 1). The sample, thus, was divided into three vertical groups: decreased (SN-GoGn < 30°), average (SN-GoGn = 30-34°) or increased (SN-GoGn > 34°) mandibular plane angle (Fig. 1). The selected cases were also categorized according to gender.

The mandibular symphysis (MS) was traced manually from lateral cephalograms onto matte acetate paper. Tracings were then scanned. The MS tracings were extracted using the Adobe Photoshop software (Adobe Creative Suite 6, San Jose, CA, USA).

The MS surface area was measured by calculating the total area confined within the outer border of the MS bounded superiorly by the line connecting the superior most point of the labial and lingual mandibular alveolar crest that covers the roots of the lower central incisor (Fig. 2a).

The following linear and angular measurements were taken: dentoalveolar length = distance between points Id and B, skeletal symphysis length = distance between B and Pog, chin length = distance between Pog and Me, total symphysis length = distance between Id and Me (Table 1 and Fig. 1b and c). The vertical symphysis dimension = angle formed by B, B1 and Gn, symphysis convexity = angle formed by B, Pog and Me, symphysis concavity = angle formed by Id, B and Pog (Table 1 and Fig. 1d to f).

The MS dimensions were calculated and compared using the ImageJ software (Image Processing and Analysis in Java), which is a Java-based image software processing program released in 1997 at the National Health Institute (Collins, 2007).

One trained investigator performed all the measurements. Twenty randomly selected lateral cephalograms were measurements twice with and interval of two weeks and the Dahlberg's test was calculated to assess method error (Kim, 2013).

2.1. Statistical analysis

The Statistical Package for Social Sciences (SPSS version 26; IBM Corporation, Armonk, NY, USA) was used. Kolmogorov-Smirnov tests showed that the data were approximately normally distributed. Means and standard deviations for MS measurements were calculated and tabulated. Multifactorial ANOVA was used to assess the interaction between the independent variables (gender, sagittal and vertical skeletal relationships). One-way ANOVA was used to compare within independent variables. Post hoc tests were performed using the Tukey's correction. The MS dimensions were also compared between gender using the independent sample t-tests. The significance level was set at $P < 0.05$.

3. Results

Intra-observer reproducibility for angular measurements showed a random error of <1.5° and <1.0 mm^2 for linear measurements. Thus, indicating intra-observer reproducibility of all measurements.

A total of 104 records fulfilled the inclusion criteria (25 males and 79 females); 41 patients had Class I, 32 Class II, and 31 had Class III skeletal relationship; 25 patients had an average MP angle, 14 had decreased and 65 increased MP angles (Table 2).

Multifactorial ANOVA was performed to determine if there is a significant main effect in relation to gender, sagittal and vertical skeletal pattern (Table 3). There was a significant interaction between gender and sagittal skeletal pattern in the dentoalveolar length, skeletal symphysis length and vertical symphysis dimen-

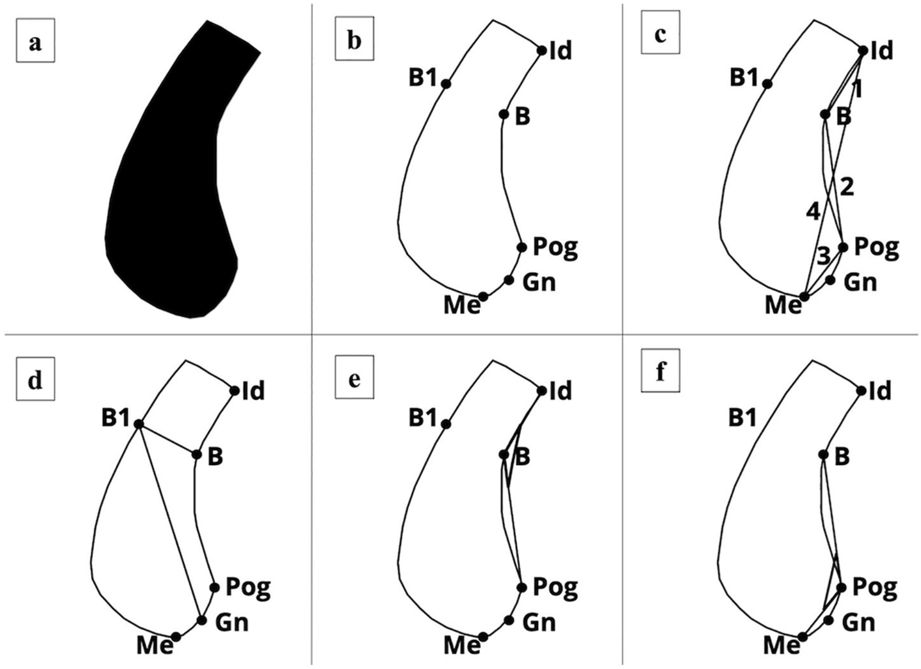

Fig. 2. (a-f). Surface area, points, angular and linear measurements used to evaluate the MS dimensions. (a) **MS surface area** as defined in Table 2. (b) **Cephalometric points** used to assess the MS linear and angular dimensions: Id, B, B1, Pog, Gn, Me. (c) **Linear measurements:** [1] IdB: dentoalveolar length, [2] BPog: skeletal symphysis length, [3] PogMe: chin length, [4] IdMe: total symphysis length. (d-f) **Angular measurements:** (d) vertical dimensions of the MS (BB1Gn); (e) MS convexity (BPogMe); (f) MS concavity (IdBPog). All points and measurements are defined in Table 2.

Table 1
Definition of the mandibular symphysis (MS) points.

MS Points	Symbol	Definition
Point B	B	Most concave point on mandibular symphysis
Point B1	B1	Intersection between a line from point B to a tangent line drawn on the inner contour of symphysis
Point Id		(infradentale)
Id		Anterior superior point of the labial alveolar crest
Pogonion	Pog	Most prominent point on the labial surface of the symphysis
Gnathion	Gn	Most inferior anterior point of the symphysis between pogonion and menton
Menton	Me	Most lower point of the symphysis

sion, $p < 0.05$. Only a significant interaction between gender and vertical skeletal pattern was found in the dentoalveolar length, $p = 0.031$. Interaction between sagittal and vertical skeletal pattern was only significant in the symphysis surface area, Skeletal symphysis length and vertical symphysis dimension, $p < 0.05$. No interaction was found between gender, sagittal and vertical skeletal relationships, $p > 0.05$.

When comparing the symphyseal measurements between males and females, Table 4 shows that males exhibited statistically significant larger symphysis measurements than females ($p < 0.05$) except in chin length and symphyseal concavity ($p > 0.05$).

Comparisons between the sagittal skeletal relationships revealed a statistically significant difference between the groups in most of the measurements except for the symphyseal surface area and symphysis convexity, $p > 0.05$ (Table 5). Class II skeletal relationship had significantly greater dentoalveolar, skeletal symphysis and total symphysis lengths compared to Class I and Class III relationships. Chin length and symphysis concavity were significantly more in Class III relationship.

Table 6 shows the symphysis dimensions according to the vertical relationships. There was only a significant difference among the three categories in two measurements, $P < 0.05$. Skeletal symphysis length was more in subjects having decreased vertical profile and the chin length was significantly greater in the average vertical skeletal relationship group.

4. Discussion

This study investigated the relationship of linear and angular MS dimensions between and within genders and different sagittal and vertical skeletal relationships in a Saudi sample. The results of the current study showed a significant interaction between gender

Table 2
Distribution and frequency (%) of the studied sample.

Skeletal Relationship		Males (n = 25)	Females (n = 79)	Total (n = 104)
Sagittal	Class I	9 (36.0)	32 (40.5)	41 (39.4)
	Class II	11 (44.0)	21 (26.6)	32 (30.8)
	Class III	5 (20.0)	26 (32.9)	31 (29.8)
Vertical	Average	5 (20.0)	20 (25.3)	25 (24.0)
	Decreases	4 (16.0)	10 (12.7)	14 (13.5)
	Increased	16 (64.0)	49 (62.0)	65 (62.5)

Table 3
Multifactorial ANOVA for the angular and linear measurements between and within gender, sagittal and vertical skeletal relationships.

Measurements	Gender	Sagittal	Vertical	Gender × Sagittal	Gender × Vertical	Sagittal × Vertical	Gender × Sagittal × Vertical
Symphysis surface area (mm^2)	0.061	0.306	0.917	0.485	0.522	0.041	0.217
Dentoalveolar length (mm) (IdB)	<0.001	0.048	0.633	0.002	0.031	0.328	0.064
Skeletal symphysis length (mm) (BPog)	0.001	0.166	0.086	0.046	0.415	0.012	0.318
Chin length (mm) (PogMe)	0.661	0.017	<0.001	0.070	0.521	0.853	0.985
Total symphysis length (mm) (IdMe)	<0.001	0.875	0.991	0.344	0.249	0.370	0.310
Vertical symphysis dimension (°) (BB1Gn)	0.057	<0.001	0.130	<0.001	0.068	0.007	0.117
Symphysis convexity (°) (BPogMe)	0.043	0.588	0.348	0.175	0.456	0.271	0.428
Symphysis concavity (°) (IdBPog)	0.916	0.006	0.300	0.090	0.170	0.304	0.889

Table 4
Bivariate comparisons between genders for the angular and linear measurements.

Measurements	Male (n = 25)	Female (n = 79)	Difference	P-value
Symphysis surface area (mm^2)	32.00 (5.11)	29.63 (4.66)	2.37	0.033
Dentoalveolar length (mm) (IdB)	9.69 (1.34)	8.14 (1.23)	1.56	<0.001
Skeletal symphysis length (mm) (BPog)	18.52 (2.13)	16.53 (2.57)	1.99	0.001
Chin length (mm) (PogMe)	8.61 (1.45)	8.70 (1.55)	0.09	0.801
Total symphysis length (mm) (IdMe)	33.79 (2.7)	31.02 (2.92)	2.77	<0.001
Vertical symphysis dimension (°) (BB1Gn)	57.54 (9.22)	54.38 (5.71)	3.16	0.043
Symphysis convexity (°) (BPogMe)	126.58 (11.8)	132.16 (10.67)	5.57	0.029
Symphysis concavity (°) (IdBPog)	150.65 (7.16)	149.93 (6.21)	0.72	0.626

Data are presented as means (SD)

Table 5
Comparisons between the sagittal skeletal relationships for the angular and linear measurements.

	Sagittal Skeletal Relationship			
Measurements	Class I (n = 41)	Class II (n = 32)	Class III (n = 21)	P-value
Symphysis surface area (mm^2)	30.59 (4.96)	29.81 (5.28)	30.09 (4.35	0.787
Dentoalveolar length (mm) (IdB)	8.43 (1.14)	9.41 (1.36)	7.70 (1.30)	<0.001
Skeletal symphysis length (mm) (BPog)	17.17 (2.42)	17.83 (2.49)	15.93 (2.69)	0.012
Chin length (mm) (PogMe)	8.29 (1.58)	8.37 (1.50)	9.50 (1.13)	0.001
Total symphysis length (mm) (IdMe)	31.26 (3.25)	32.80 (2.75)	31.11 (3.00)	0.048
Vertical symphysis dimension (°) (BB1Gn)	53.80 (6.25)	53.47 (5.41)	58.63 (7.66)	0.002
Symphysis convexity (°) (BPogMe)	129.25 (12.46)	129.15 (11.70)	134.61 (7.56)	0.077
Symphysis concavity (°) (IdBPog)	149.42 (6.55)	147.38 (6.14)	153.82 (4.76)	<0.001

Data are presented as means (SD)

Table 6
Comparisons between the vertical skeletal relationships for the angular and linear measurements.

	Vertical Skeletal Relationship			
Measurements	Average (n = 25)	Decreased (n = 14)	Increased (n = 65)	P-value
Symphysis surface area (mm^2)	30.62 (4.97)	30.95 (3.98)	29.88 (5.08)	0.672
Dentoalveolar length (mm) (IdB)	8.54 (1.07)	8.28 (2.03)	8.55 (1.4)	0.810
Skeletal symphysis length (mm) (BPog)	15.79 (2.61)	17.47 (2.24)	17.37 (2.57)	0.026
Chin length (mm) (PogMe)	9.69 (1.39)	8.26 (0.92)	8.37 (1.52)	<0.001
Total symphysis length (mm) (IdMe)	31.02 (2.79)	31.73 (2.46)	31.94 (3.31)	0.457
Vertical symphysis dimension (°) (BB1Gn)	55.69 (5.05)	55.43 (8.88)	54.87 (6.98)	0.865
Symphysis convexity (°) (BPogMe)	128.48 (9.51)	129.53 (13.43)	131.99 (11.21)	0.370
Symphysis concavity (°) (IdBPog)	151.05 (5.29)	148.64 (6.38)	150.05 (6.84)	0.532

Data are presented as means (SD)

and sagittal, between gender and vertical skeletal patterns, and among the sagittal and vertical skeletal patterns in several MS measurements. In general, males had greater MS measurements than females. These results are somewhat consistent with previous reports (Arruda, et al., 2012, Al-Khateeb, et al., 2014, Gómez et al., 2018). For example, Arruda et al. (Arruda, et al., 2012) found no differences between genders, while Al-Khateeb. et al. (Al-Khateeb, et al., 2014) found the MS surface area and dentoalveolar length be larger in males. These gender differences could be attributed to the increased bite force exhibited in males compared to females (Sonnesen and Bakke, 2005, Al Qassar, et al., 2016). Holton et al. (Holton, et al., 2014) investigated the impact of form and function on the mandibular symphysis cortical bone morphology and found a significant correlation between the MS morphology and the function and stresses it sustains. This might explain some of the correlated findings between mandibular symphyseal morphology and its function or load based on its craniofacial articulation in different skeletal relationship (Al-Khateeb, et al., 2014).

In the current study, the interaction between gender and sagittal skeletal pattern in dentoalveolar length and chin length was similar, and the skeletal symphysis length and vertical symphysis dimensions were different from the results of Gomez et al.

(Gómez et al., 2018). In the current study, there was only an interaction between gender and the vertical skeletal pattern in MS dentoalveolar length, while Gomez et al. (Gómez et al., 2018), reported significant interactions between the vertical symphysis dimension and symphysis convexity, in contrast to our findings These differences could be attributed to the ethnic background between the studied populations. In the current study, the skeletal Class II relationship had significantly the greatest dentoalveolar length while Class III had the least dentoalveolar length.

We found that the average vertical relationship had significantly greater chin length compared to the other vertical relationships. No difference in MS angular measurement was reported between genders, sagittal and vertical skeletal relationships. Previous studies found the vertical symphysis dimension to be reduced Class II skeletal relationship (Al-Khateeb, et al., 2014, Torgut and Akan, 2019), while it was not significantly different in the current study.

Previous studies have evaluated the symphyseal morphology in adolescents with different mandibular growth patterns (Aki, et al., 1994, Moshfeghi, et al., 2014). They found that the symphyseal ratio (height/depth) was small in a mandible with a vertical growth pattern and large in a mandible with a horizontal growth pattern. They also found that the ratio was greater in females than males (Aki, et al., 1994, Moshfeghi, et al., 2014). In the current study, skeletal symphysis length was greater in decreased vertical pattern and chin length was greater in subjects with an average skeletal pattern.

A recent study investigated the relationship between symphysis morphology and skeletal pattern (Ahn, et al., 2019). They found a significant relationship between MS shape and the vertical facial skeletal pattern. Another study also found that MS alveolar morphology in both Class I and Class III patients was associated with the vertical facial pattern and patients with Class III sagittal relationship with decreased face height had a widened alveolar bone (Molina-Berlanga, et al., 2013). Other studies found that the mandibular symphyseal thickness was greater in individuals with short-face compared to long-face individuals and they found that individuals with short-face had bony better support of the mandibular incisors compared to long faced individuals (Gracco, et al., 2010, Swasty, et al., 2011, Sadek, et al., 2015, Foosiri, et al., 2018). In our study, no relationship was found between different vertical relationships. However, we did find differences between the different vertical skeletal pattern in chin length and skeletal symphyseal length.

The mandibular symphysis morphology has been assessed in numerous studies using different methods and measurements. One study investigated the MS characteristics in adults with skeletal Class III having either an anterior crossbite or an anterior open bite and compared them to adults with normal occlusion (Chung, et al., 2008). They found that MS width was narrower, and the alveolar height was significantly lower in Class III open bite cases compared to those with Class III anterior crossbite and normal occlusion. They considered the absence of occlusal load due to open bite as an essential factor in affecting the MS morphology in Class III patients. A similar finding was also reported when investigating skeletal Class II female patients (Esenlik and Sabuncuoglu, 2012). These collective findings suggest more range of tooth movement in skeletal Class II subjects and subjects with short-faced. The findings of the current study also reflect the importance of considering the chin and symphysis morphology and dimensions in the diagnosis and treatment planning of orthodontic problems. More notably is the importance of symphysis analysis in the diagnosis and prediction of skeletal growth problems (Skieller, et al., 1984, Buschang, et al., 1992, Aki, et al., 1994). Thus, the current study recommends that orthodontists must customize the treatment plan of each orthodontic case.

MS morphology is affected by multiple factors that warrant further investigations with larger sample size. A limitation to the current study is the small number of males compared to females which could have resulted in gender differences. Another limitation is that the sample was selected from one center, hence the results cannot be generalized. Therefore, multicenter cohort studies with larger sample sizes and equal distribution between gender and skeletal relationships are recommended.

5. Conclusions

In conclusion and to the best of our knowledge, this is the first study that investigated mandibular symphysis dimensions between gender and the different sagittal and vertical skeletal relationships in a Saudi population. Males and females exhibit distinct mandibular symphysis morphology. Class II skeletal relationship was associated with greater dentoalveolar length, skeletal symphysis length, and total symphysis length. Class III skeletal relationship was associated with increased vertical symphysis dimension and symphysis concavity. The average vertical skeletal pattern was associated with increased chin length. While the decreased vertical skeletal pattern was associated with increased skeletal symphysis length.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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