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Are chin and symphysis morphology facial type–dependent? A computed tomography-based study

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Introduction: The chin is a major determinant of the facial profile; hence, it plays a major role in orthodontics and orthognathic surgery. It is thus essential to follow and better understand its expression in different facial types. The major objectives of the current study were to characterize morphometrically the chin and symphysis and reveal their association with different facial types. **Methods:** Computed tomography scans of the head and neck of 311 adults (163 males, 148 females; age range, 18-95 years) were classified into 3 facial types: short, average, and long. Height, width, projection, inclination, thickness, and area were measured on the chin and symphysis. **Results:** The majority of the population (70%) manifested an average facial type; the other 30% were almost equally distributed between short and long facial types. The long facial type was more common among females and the short facial type among males. Chin projection, area, and size were significantly greater in short-faced patients. Chin width in males was similar for all facial types, whereas, in females, chin width was the widest in the short facial type and the narrowest in the long facial type. Symphysis height was significantly greater in long-faced patients in both sexes. The mandibular incisors' inclination relative to the mandibular plane was not significantly associated with the chin or symphysis morphology. **Conclusions:** Chin and symphysis morphology is facial type–dependent. Orthodontists and maxillofacial surgeons should be aware of the complex relationship between facial types and chin/symphysis size and shape when planning treatment. (Am J Orthod Dentofacial Orthop 2021;160:84-93)

The chin is a major component of the lower third of the face. Its size is one of the important facial characteristics that determine a *balanced facial profile.*[1] Variability in chin dimensions contributes to changes in the facial curve from convex to concave; consequently, it affects facial profile classification.[2] It also plays a significant role in planning treatment for orthodontic patients; that is, the degree of chin prominence helps determine the mandibular incisors' placement during the treatment. This relationship is referred to as the Holdaway ratio.[3] Thus, when planning orthodontic treatment, one should consider chin size in terms of the stability of the outcomes and the esthetic benefits for the patient.

Although the functional significance of the chin shape is obscure, its association with facial types[4-6] is of significant clinical importance because it helps determine the direction of mandibular growth.[7] Björk,[4] for example, used symphysis inclination to predict the directionality of mandibular growth. In addition, Sassouni[5] associated *skeletal deep bite* with short (vertically) and broad (antero-posteriorly) symphysis as well

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as large *chin button*, and *skeletal open bite* with narrow (antero-posteriorly) and long (vertically) symphysis and lack of chin. However, neither Sassouni[5] nor Björk[4] provided quantitative data to support their assertions. Aki et al,[8] in a quantitative-based analysis, confirmed that males' symphysis morphology is associated with mandibular growth, namely, that short and wide symphysis is associated with the anterior growth of the mandible, whereas long and narrow symphysis is associated with the posterior growth direction. Females exhibited a similar tendency, although it was not statistically significant. The measuring method used by Aki et al[8] differed from that used in other studies,[9-13] because they did not include in their calculations the alveolar part of the symphysis when determining its shape. Khan et al[11] investigated chin dimensions among patients with different divergent patterns. No statistically significant differences were found between hyper-, normo-, and hypodivergent groups in any of the symphysis dimensions: vertical, sagittal, or transverse. However, this study was carried out using a very small number of samples that combined males and females. Arruda et al[14] examined the association between symphysis size and facial types. Their study was also based on small samples, and although a significant difference was noted in symphysis height between the sexes, they did not control for this parameter in their final test. Their findings confirm that dolichofacial types have narrower and higher symphyses, whereas brachyfacial types manifest shorter symphyses. A recent study by Gómez et al[12] sought to find a relationship between mandibular symphysis characteristics and craniofacial structures on the basis of a large number of 3-dimensional cone-beam computed tomographic images. However, many of the measurements of the symphysis were either linear or angular (ie, 2-dimensional) and were taken at the sagittal plane between the mandibular central incisors, which does not always coincide with the midsagittal plane. Using only linear measurements might be insufficient to explore the associations between symphysis and facial types. In a previous study,[15] we demonstrated that the association between masticatory forces and mandibular size and shape is better expressed by the shape measures than linear measures. The main findings of Gómez et al[12] suggest differences in symphysis vertical dimensions between sexes and facial types. In addition, the inclination of the mandibular incisors was positively correlated with symphysis concavity and inclination. Molina-Berlanga et al[16] also observed an association between mandibular incisor inclination and symphysis morphology, although their method of measuring the symphysis was different from the method used by Gómez et al.[12]

One of the drawbacks of many previous studies is the confusion between the chin and the symphysis, which is partially responsible for the inconsistent results. Although the chin is positioned at the anterior-inferior part of the mandibular symphysis, it evolved relatively recently (late Pleistocene) and is considered a unique trait of our species.[17] Therefore, separating the measurements of the symphysis from those of the chin is critical to evaluate how these 2 structures are associated with facial type.

This study aimed to develop a series of measurements for the chin (midsagittal and frontal aspects) and symphysis separately and to assess their association with facial types. The results of such a study should be of interest to both clinicians and basic science researchers.

MATERIAL AND METHODS

This study was carried out on computed tomographic (CT) scans of the head and neck of 311 adults of Caucasian origin: 163 males and 148 females; the ages ranged between 18 and 95 years. All scans were taken at Carmel Medical Center, Haifa, Israel (Brilliance 64; Philips Medical System, Cleveland, Ohio), using the following parameters: slice thickness of 0.9-3.0 mm, pixel spacing 0.3-0.5 mm, 120 kV, 250-500 mAs, number of slices 150-950, and Matrix 512 × 512. The CT scans were carried out for diagnostic purposes unrelated to the present study between 2000 and 2013. The research was approved by the ethical board of the Carmel Medical Center (CMC 11-0066). Inclusion criteria were as follows: aged ≥18 years, intact mandibular incisors, and teeth at centric occlusion (maximum intercuspation). Exclusion criteria included the following: absence of mandibular incisors; presence of dental implants or metal restorations that could interfere with the measurements; evidence of orthodontic treatment (brackets, appliances, lingual fixed retainers); previous surgery in the head and neck region (medical files or signs on the skull); prominent facial and mandibular asymmetry; craniofacial, temporomandibular joint, and muscular disorders; trauma; and technically aberrant CT scans. The records of all those who met the inclusion criteria, who were not excluded, and who fit into a single category of facial type were selected. Of the more than 2000 subjects initially enrolled in this study, only 311 met the inclusion criteria, and therefore, they were selected for further analysis.

Patients were classified into 3 groups of facial types: the short facial type (SFT), the average facial type (AFT), and the long facial type (LFT) (Fig 1). The classification was based on 3 parameters: (1) the facial height index (FHI); (2) the steepness of the mandibular plane (MP), following the methods described by Bishara and

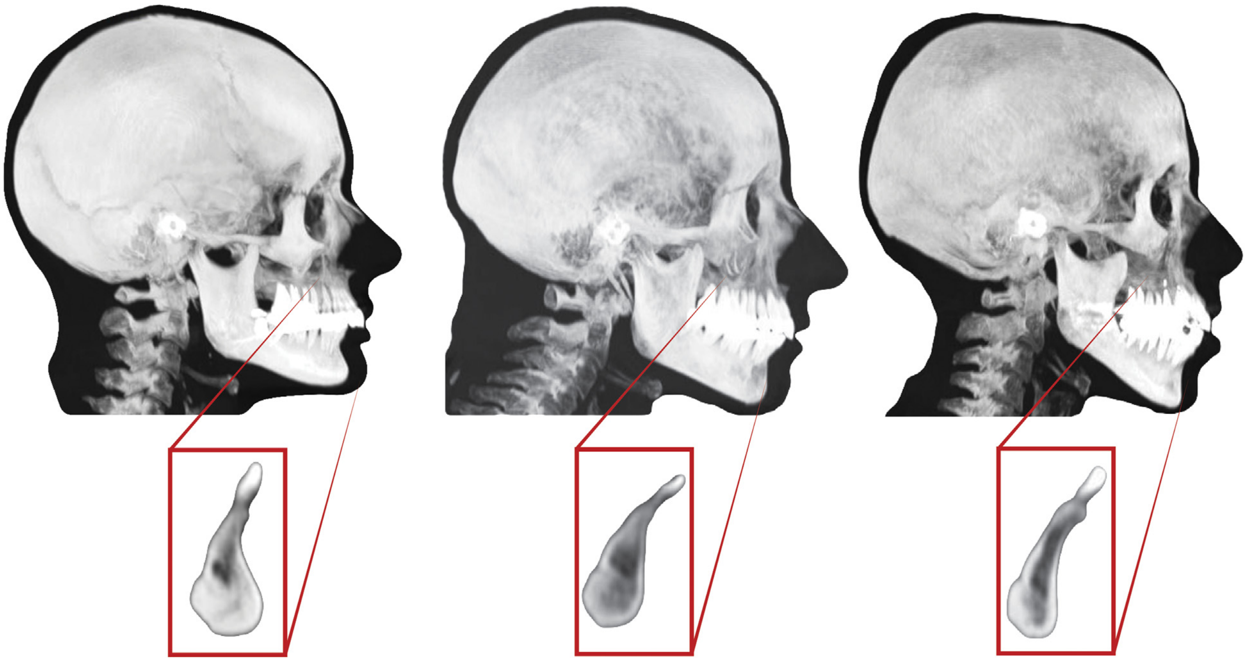

Fig 1. Examples of facial types and their respective chin and symphysis morphologies. The SFT is presented on the left, the AFT in the middle, and the LFT on the right (images taken from computed tomography).

Jakobsen[18] and Swasty et al[10]; and (3) the lower anterior facial height (LAFH). The latter was defined as the distance between the anterior nasal spine and the Menton (Me), measured perpendicular to the Frankfort horizontal (FH) plane.[3] *Short-face* group was characterized by low MP angle, high FHI, and short LAFH; *Average-face* group by average MP angle, FHI, and LAFH; and *Long-face* group by high MP angle, small FHI, and long LAFH. Only patients that manifested at least 2 characteristics of a given category were included in the study. Six patients were excluded from the study because they manifested 3 of the characteristics that fell into different facial categories.

All measurements were taken directly from the CT scans, using a multiplanner reformatting technique (*Extended Brilliance Workspace* portal, version 2.6.0.27; Philips Medical Systems, Cleveland, Ohio). Previous studies found that skull and facial bones measured from 3-dimensional CT are quantitatively accurate and valid.[19-21] To obtain comparable measurements, all skulls were positioned parallel to the FH plane. Landmarks were identified following Swennen et al[22] and Jacobson and Jacobson.[23] Most of the chin and symphysis measurements were carried out on the midsagittal section of the mandible. The location of this plane was determined regardless of the mandibular incisors' position. First, we performed a transverse section parallel to the FH plane through the pogonion (*red line*). Then, we performed a second section that passed through the most protruding anterior and posterior points at the symphysis region (*blue line*) (Fig 2). Chin and symphysis were considered as 2 separate structural entities. Linear, angular, and area measurements were carried out to evaluate chin and symphysis size, shape, and position from the CT scans.

The following chin measurements were used (Fig 3, *A* and *B*):

1. Height (mm): the distance between the B point and the Me.
2. Projection (mm): the maximum thickness of the chin, measured as the shortest distance between the pogonion and the chin height line.
3. Area (mm^2): the portion of the symphysis area that is located anterior to the chin height line.
4. Width (mm): the distance between the right and left mental tubercles.

The following symphysis measurements were used (Fig 3, *C* and *D*):

1. Height (mm): the distance between the most superior point on the alveolar bone and the Me.

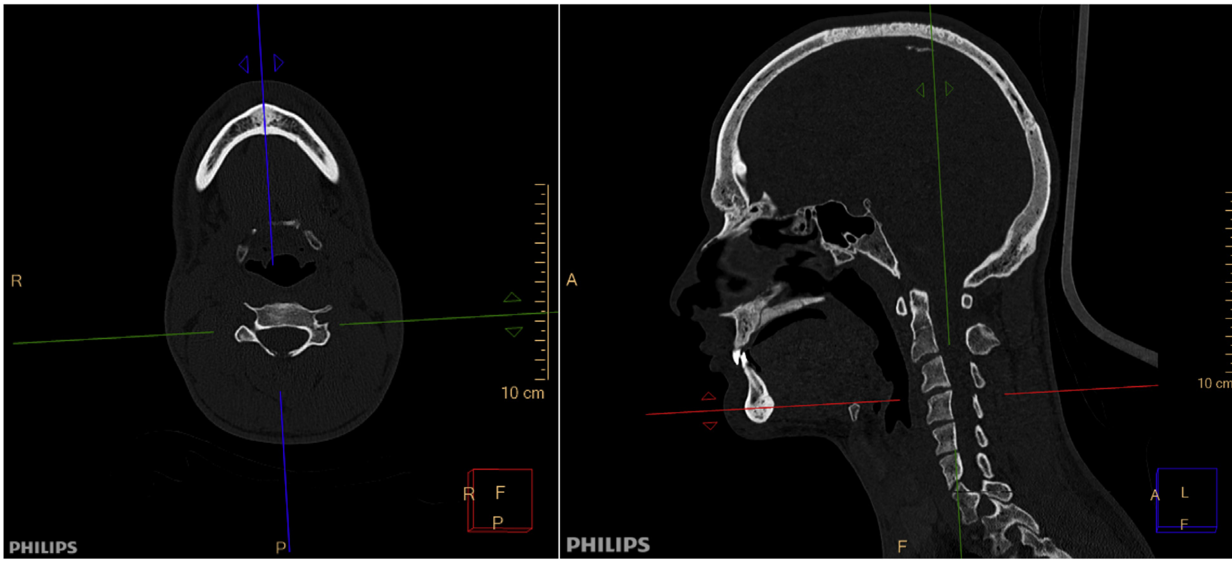

Fig 2. Determining the mandible's midsagittal plane: first, we performed a transverse section parallel to FH plane through the pogonion (*red line*); second, we performed a section that passes through the most protruding anterior and posterior points (*blue line*).

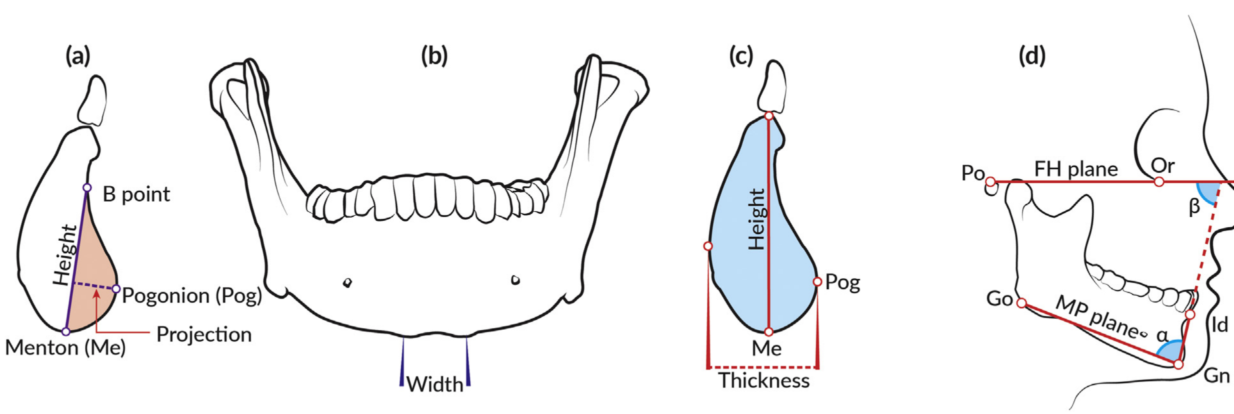

Fig 3. Measurements of the chin: **(A)** height, projection, and area (*in pink*), and **(B)** chin width; measurements of the symphysis: **(C)** height, thickness, area (*in light blue*), and **(D)** symphysis orientation (β angle) and inclination (α angle).

2. Thickness (mm): the distance between the pogonion and the most posterior point on the symphysis.
3. Area (mm^2): the total area of the symphysis in the midsagittal plane.
4. Inclination (°): the inclination of the symphysis relative to the MP, which is the angle (α) created between the line passing from the Infradentale to the Gnathion (Id-Gn line), and the line passing from Gonion to Gnathion.[24]
5. Orientation (°): the inclination of the symphysis relative to the FH, which is the angle (β) measured at the cross-point between the Id-Gn line and the FH plane.

Three indexes relating to the size and shape of the chin and symphysis were calculated: (1) the chin size index (%) = the ratio between the chin area and the symphysis area, multiplied by 100; (2) the chin shape index (%) = the ratio between the chin projection and the chin height, multiplied by 100; and (3) the symphysis shape index (%) = the ratio between the symphysis thickness and the symphysis height, multiplied by 100.

All linear and area measurements were controlled for mandible size (relative measures): linear measurements were divided by mandible body length, and area measurements were divided by body length squared. In addition, the inclination of the mandibular incisors was measured relative to MP (IMPA). Following Downs,[25] patients were classified into 3 groups: retroinclination, proclination, and normal inclination.

To determine the ability to accurately replicate the CT measurements, the intratester and intertester reliabilities for each measurement were calculated on 15 different patients. To check the intratester reliability, measurements were carried out twice with a 2-week interval by an independent researcher (T.S.T). For intertester reliability, the measurements were taken by an additional independent researcher (H.M). Intraclass correlation coefficient (ICC) analysis was carried out to examine the reproducibility of the measurements and was interpreted according to the categorization method of Cicchetti.[26]

Statistical analysis

The data were recorded and analyzed using SPSS (version 20.0; IBM, Armonk, NY). All measurements in the study were distributed normally. Assessment of normal distribution was based on a 1-sample Kolmogorov-Smirnov test, a Q-Q plot linear distribution, and a histogram with a normal curve. An independent-samples *t* test was carried out to identify significant differences in age between sexes. A chi-square test was carried out to detect any association between facial types and sex. A one-way analysis of variance (ANOVA) test was carried out to detect significant differences in age, chin, and symphysis characteristics between the facial types. Post-hoc multiple comparisons were carried out to detect significant differences between the groups. Two-way ANOVA was carried out to detect significant interactions between IMPA and facial type. The level of statistical significance was set at $P < 0.05$.

The datasets analyzed during the current study are available from the corresponding author on request.

RESULTS

ICC results showed high reproducibility for chin measurements, *excellent agreement* ($0.838 \leq ICC \leq 0.907$) for intratester variation, and *good agreement* ($0.715 \leq ICC \leq 0.785$) for intertester variation. All symphysis measurements showed *excellent agreement* ($0.903 \leq ICC \leq 0.986$) for intratester variation and *excellent agreement* ($0.852 \leq ICC \leq 0.980$) for intertester variation. All measurements used for facial-type classification showed *excellent agreement* for both intratester and intertester variation ($0.895 \leq ICC \leq 0.991$) ($P < 0.001$).

The study sample included 311 patients: 163 males (52.4%) and 148 females (47.6%). The mean age was 49 ± 20.3 years (range, 18-95 years). The mean age did not significantly differ between sexes and was 47.5 ± 19.5 years for males and 50.8 ± 21.1 years for females ($P = 0.153$). In addition, there was no statistical difference between the mean age of the different facial types in both males and females ($P > 0.188$).

The study sample included 216 *average-faced* patients (69.45%), 49 *long-faced* patients (15.75%), and 46 *short-faced* patients (14.8%). The AFT group comprised 115 males (53.2%) and 101 females (46.8%). The LFT group comprised 18 males (36.7%) and 31 females (63.3%). The SFT group included 30 males (65.2%) and 16 females (34.8%). A significant association was found between the facial types and sex ($P = 0.019$): LFT was more common among females and SFT among males.

Chin absolute and relative measures were compared between the facial types. In males, the chin was found to be significantly thicker and greater (projection, area, shape, and size index) in the SFT group, compared with the AFT and LFT groups (Table I). No significant differences were found in these parameters between the LFT and AFT groups ($P > 0.489$). Similar results were obtained when measurements were controlled for mandible size. Of particular interest is the fact that no significant differences in chin height and width were found between the 3 facial groups. In females, all chin parameters differed statistically between the facial types (Table II). Chin was significantly greater, wider, and thicker (projection, area, width, shape, and size indexes) in females with SFT ($P < 0.041$). The LFT group manifested the greatest chin height. Unlike males, chin width in females was significantly different between all the facial types ($P < 0.003$). SFT was characterized by having the widest chin, whereas LFT by the narrowest one.

Symphysis size in males was found to be significantly different between the facial types ($P < 0.013$), except for the symphysis area ($P > 0.353$) (Table I). Symphysis height was the greatest in the LFT group and the shortest in the SFT group, whereas symphysis thickness was found to be significantly greater in the SFT group ($P = 0.013$). Interestingly, no such difference was found between the AFT and the LFT groups ($P = 0.953$). In addition, the SFT group manifested the highest shape index (mean, 52.0), compared with the AFT (mean, 45.5) and LFT groups (mean, 43.2) ($P < 0.001$). This implies that the symphysis of the SFT group is more square-shaped than that of the LFT or the AFT group. Symphysis inclination (relative to MP) and orientation (relative to

Table I. Morphometric characteristics of the chin and symphysis in different facial types in males

Measurement	Facial type	Mean	SD	Minimum	Maximum	P values: Absolute measures	P values: Relative measures	Post-hoc: Multiple comparison
Chin								
Height (mm)	SFT	22.36	3.119	15.78	28.90	0.366	0.653	–
	AFT	21.49	3.013	13.30	27.80			
	LFT	21.84	2.915	17.00	28.80			
Projection (mm)	SFT	4.60	0.890	3.10	7.10	0.001*	0.001*	SFT > AFT
	AFT	3.86	1.023	1.40	7.10			
	LFT	3.94	0.738	2.10	4.90			
Area (mm^2)	SFT	60.62	19.547	27.10	113.40	0.020*	0.035*	SFT > AFT
	AFT	50.43	17.812	13.80	113.30			
	LFT	55.95	18.097	24.00	107.70			
Width (mm)	SFT	30.08	5.756	19.60	40.40	0.065	0.109	–
	AFT	27.53	5.322	16.30	40.50			
	LFT	27.32	5.535	19.50	40.40			
Shape index (%)	SFT	20.61	2.966	14.55	26.73	0.005*	–	SFT > AFT
	AFT	18.03	4.176	5.32	27.84			
	LFT	18.07	2.833	11.80	21.46			
Size index (%)	SFT	18.43	5.335	9.46	31.09	0.024*	–	SFT > AFT
	AFT	15.44	5.274	5.29	28.89			
	LFT	16.27	5.321	7.69	28.02			
Symphysis								
Height (mm)	SFT	32.04	3.065	26.00	38.10	<0.001*	0.009*	LFT > AFT > SFT
	AFT	33.70	2.884	24.60	40.30			
	LFT	35.99	3.572	29.00	42.60			
Thickness (mm)	SFT	16.55	1.846	13.60	20.30	0.013*	0.019*	SFT > AFT
	AFT	15.30	2.165	11.20	23.20			
	LFT	15.46	1.324	13.10	18.20			
Area (mm^2)	SFT	327.80	48.003	230.50	428.50	0.353	0.403	–
	AFT	329.82	56.319	212.90	481.10			
	LFT	348.98	53.052	275.70	437.90			
Shape index (%)	SFT	52.04	7.197	37.81	68.85	<0.001*	–	SFT > AFT; SFT > LFT
	AFT	45.53	6.074	32.37	70.73			
	LFT	43.15	3.586	37.56	50.70			
Orientation (°)	SFT	85.23	7.154	67.40	102.00	<0.001*	–	SFT > AFT > LFT
	AFT	79.61	7.043	57.10	100.30			
	LFT	74.67	6.769	64.40	86.70			
Inclination (°)	SFT	78.43	4.531	66.00	86.00	<0.001*	–	SFT > AFT; AFT > LFT
	AFT	76.10	5.321	61.00	89.00			
	LFT	71.24	5.178	64.00	81.00			

*Statistical significance, P <0.05.

FH plane) were the greatest in the SFT group (78.43° and 85.23°, respectively) and were the lowest in the LFT group (71.24° and 74.67°, respectively). Similar results were obtained for females, except for symphysis inclination (P = 0.121), albeit this tendency was similar to males (Table II).

A summary of the 2-way ANOVA test is presented in Table III. No significant interaction was found between facial types and IMPA for any of the chin and symphysis parameters in both sexes. In addition, no significant associations were found between chin size parameters and IMPA (P >0.103). Regarding the symphysis parameters, a significant association was found between its inclination (relative to MP) and IMPA in both sexes (P <0.042) and between the symphysis area and IMPA in females only.

DISCUSSION

Many previous studies confused the chin and the symphysis and used diverse definitions and methodological methods for their evaluation, subsequently avoiding any comparisons between studies. This gave rise to the need to develop a unique set of measurements for both the chin and the symphysis. In addition, chin size is frequently confused with mandibular position and rotation. For example, macrogenia was erroneously

Table II. Morphometric characteristics of the chin and symphysis in different facial types, in females

Measurement	*Facial type*	*Mean*	*SD*	*Minimum*	*Maximum*	P *values* Absolute measures	P *values* Relative measures	*Post-hoc* Multiple comparison
Chin								
Height (mm)	SFT	20.91	2.380	16.50	25.30	0.023*	0.020*	LFT > AFT
	AFT	20.73	2.566	14.60	26.40			
	LFT	22.17	2.476	16.80	26.40			
Projection (mm)	SFT	4.68	1.382	2.10	6.80	0.006*	0.007*	SFT > AFT; SFT > LFT
	AFT	3.93	1.004	1.10	6.00			
	LFT	3.62	1.015	1.00	5.60			
Area (mm^2)	SFT	61.55	24.439	19.80	110.50	0.032*	0.077	SFT > LFT
	AFT	50.24	16.422	11.70	101.60			
	LFT	47.85	16.525	16.70	84.50			
Width (mm)	SFT	28.62	5.775	21.90	43.80	<0.001*	<0.001*	SFT > AFT > LFT
	AFT	23.36	5.278	11.60	36.30			
	LFT	19.72	3.840	10.80	29.10			
Shape index (%)	SFT	22.12	5.306	11.73	32.85	<0.001*	–	SFT > AFT > LFT
	AFT	18.88	3.917	7.53	26.91			
	LFT	16.36	4.265	4.55	24.67			
Size index (%)	SFT	20.69	7.722	6.11	34.04	0.030*	–	SFT > LFT
	AFT	17.94	5.828	4.79	33.46			
	LFT	15.87	5.075	6.09	26.77			
Symphysis								
Height (mm)	SFT	28.80	1.443	27.10	31.70	<0.001*	<0.001*	LFT > AFT; LFT > SFT
	AFT	30.09	2.251	24.00	36.50			
	LFT	32.80	2.040	27.90	35.90			
Thickness (mm)	SFT	15.96	1.838	13.50	20.20	0.001*	0.017*	SFT > AFT; SFT > LFT
	AFT	14.37	1.647	10.40	18.90			
	LFT	14.19	1.682	10.80	16.90			
Area (mm^2)	SFT	299.53	39.054	230.30	404.50	0.052	0.169	–
	AFT	282.38	42.270	189.20	414.10			
	LFT	303.83	54.103	210.80	396.20			
Shape index (%)	SFT	55.54	6.691	43.85	66.10	<0.001*	–	SFT > AFT > LFT
	AFT	47.92	5.698	34.32	61.36			
	LFT	43.28	4.667	31.95	51.25			
Orientation (°)	SFT	84.54	6.958	74.20	98.80	<0.001*	–	SFT > AFT > LFT
	AFT	79.09	6.630	65.40	94.10			
	LFT	72.88	5.487	52.90	83.30			
Inclination (°)	SFT	78.13	5.898	62.00	87.00	0.121	–	–
	AFT	75.91	5.925	56.00	91.00			
	LFT	74.48	4.999	64.00	85.00			

*Statistical significance, $P < 0.05$.

used in the case of mandibular protrusion and mandibular forward rotation, or microgenia in the case of retrognathic mandible and its backward rotation. To avoid confusion between jaw position and rotation, we measured the chin and the symphysis separately and measured each independently of facial or mandibular planes or symphysis inclination.

The results of the present study showed that patients with SFT had significantly greater chin projection, area, shape, and size indexes than did other facial types in both sexes. This implies that SFT patients, regardless of sex, have a greater chin thickness in the sagittal aspect and that their chin area occupies a greater portion of the total symphysis area. Previously it was suggested that SFT patients are characterized by a stronger masticatory function.[15,27-30] It is therefore plausible that a greater chin thickness acts as a reinforcement mechanism in patients with stronger masticatory muscle function to reduce stresses generated at the symphysis area and maintain its structural integrity. In addition, a square-shaped chin was much more common among SFT patients compared with AFT and LFT patients. These findings are in agreement with the previous observations of Björk and Sassouni.[4,5] Neither chin projection nor chin area was significantly different between LFT and AFT in both males and females. In addition, the chin

Table III. *P* values (from 2-way ANOVA) showing differences in chin and symphysis parameters by facial type, IMPA, and their interaction, for males and females

Measurement	*Sex*	*Facial type*	*IMPA group*	*Interaction*
Chin				
Height	Male	0.305	0.721	0.459
	Female	0.232	0.307	0.408
Projection	Male	0.009*	0.296	0.609
	Female	0.003*	0.240	0.590
Area	Male	0.061	0.450	0.702
	Female	0.024*	0.384	0.616
Width	Male	0.630	0.103	0.224
	Female	<0.001*	0.761	0.415
Symphysis				
Height	Male	<0.001*	0.056	0.089
	Female	<0.001*	0.582	0.613
Thickness	Male	0.353	0.692	0.427
	Female	0.053	0.204	0.961
Area	Male	0.062	0.738	0.285
	Female	0.087	0.008*	0.671
Orientation	Male	<0.001*	0.527	0.301
	Female	<0.001*	0.288	0.303
Inclination	Male	0.036*	0.042*	0.185
	Female	0.626	0.001*	0.396

*Statistical significance, $P < 0.05$.

size index was similar between LFT and AFT patients. This finding contradicts a previous assumption that LFT patients do not develop a real chin and that they manifest a *chinless* appearance.[4,5] However, chin width from the frontal aspect did not differ significantly between the facial types in males. This finding is in contrast to females, in whom chin width was a significant distinctive feature between the facial types: SFT females had the widest chin and LFT the narrowest. Indeed, chin width is considered one of the factors playing a role in the appearance and attractiveness of the face; narrowing genioplasty is a procedure used in plastic surgery to produce a more feminine contour and a slender lower face.[31-34]

Symphysis height (absolute and relative values) was found to be the longest in the LFT group and the shortest in the SFT group. This finding is in accordance with previous studies.[4-6,12,14] In addition, we found that SFT patients had the greatest symphysis sagittal thickness, with a more square-shaped appearance; this is in accordance with the research of Aki et al,[8] who observed short and wide symphyses in patients with anterior growth of the mandible. Although the height and thickness of the symphysis differ significantly between facial types, no such difference was found concerning the total symphysis area, regardless of sex. Although symphysis height and thickness are facial type–dependent, the symphysis area is not. The reason is that the expression of the height and thickness largely depends on local factors (eg, alveolar compensation to dental movements, mandibular rotation, or age-related changes), whereas the size of the symphysis area is mainly functionally selected. The symphysis area is essential for the proper transfer of forces across the mandible during mastication and counteracts high shearing forces at this region. Therefore, a large change in the total amount of bone (eg, genioplasty) in this area may hamper its ability to resist forces and moments and to maintain its structural stability.

Our findings also suggest that the symphysis orientation in the SFT group is more upright, compared with the condition in the LFT group, in which the symphysis is more proclined. This difference in symphysis orientation is most probably because of mandibular rotation during growth. In contrast, symphysis was found to be more proclined relative to MP in the SFT group compared with the LFT group, which exhibited more retroclined symphysis relative to MP. This is in agreement with Aki et al[8] and Björk's[4] *structural signs* for mandibular growth. This compensatory symphysis inclination is important to keep the mandibular incisors within the bony envelope. Despite the rotation of the jaw during growth, the mandibular incisors must maintain their inclination relative to the cranial base (and not to the MP). Without appropriate changes in symphysis inclination, the anterior teeth would be positioned at a sharp angle to the orientation of the symphysis, the outcomes of which would have been root fenestration through the buccal aspect of alveolar bone.

Previous literature suggested that the mandibular incisors' inclination might affect the morphology of the symphysis because of dentoalveolar compensation, which occurs during growth.[12,16] Our study showed that the interaction between the mandibular incisors' inclination relative to MP (IMPA) and facial type has no impact on the morphology of the chin and mandibular symphysis. A significant association was found only between the IMPA and symphysis inclination, a finding that is in accordance with the research of Gómez et al.[12] This finding is not surprising because both parameters are measured relative to MP. It is therefore advisable to use symphysis orientation and not symphysis inclination when studying symphysis position.

No significant differences in chin height between the facial groups were found. Symphysis height, however, was significantly greater in LFT patients. This can be attributed to the taller alveolar process in this group. LFT patients are characterized by steep MP angles because of the backward rotation of the mandible during growth.[4,5,35] When the mandible rotates backward, the anterior bite is opened: to maintain the occlusal relationships between the mandibular and maxillary incisors, the mandibular anterior teeth erupt, and the alveolar process subsequently increases in height. The mandibular incisors erupt because of the dentoalveolar compensation after mandibular rotation.[36]

The conclusions were deduced on the basis of a given population of Caucasian origin. Although the study population was heterogeneous, the generalization of the results requires further study of populations of different geographic origins. Similarly, the association between chin and symphysis morphology and facial types needs further confirmation from other populations. Deducing data on mandibular growth patterns from chin and symphysis morphology is limited because only adults were included in this study. Documented information on previous orthodontic treatments was unavailable; nevertheless, we excluded patients who were undergoing orthodontic treatment during the CT scanning or showed indirect evidence of previous treatment.

CONCLUSIONS

This study is the first to comprehensively define and evaluate separately chin and symphysis and to show an association between their morphologies and facial types. The main findings are as follows:

1. LFT and SFT comprise approximately 30% of the adult population. Females tend to predominate in LFT, whereas males in SFT.
2. SFT patients are characterized by thicker and larger chins with a more square-shaped appearance, which occupy a relatively greater symphysis area. However, no such difference was evident between LFT and AFT patients.
3. Chin width can be considered a distinctive feature of facial types in females only. The narrower the chin, the more feminine is the facial appearance. No difference in chin width was evident between the male facial types.
4. LFT patients are characterized by higher symphysis, and SFT patients are characterized by a thicker symphysis. No difference in symphysis area exists between facial types.
5. Mandibular incisors' inclination is not associated with chin or symphysis morphology.

AUTHOR CREDIT STATEMENT

Tatiana Sella Tunis contributed to conceptualization, methodology, validation, investigation, visualization, and original draft preparation; Hila May contributed to validation and funding acquisition; Rachel Sarig contributed to formal analysis; Alexander Dan Vardimon contributed to software and draft review and editing; Israel Hershkovitz contributed to conceptualization, resources, supervision, and draft review and editing; and Nir Shpack contributed to methodology, resources, visualization, supervision, and draft review and editing.

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REFERENCES

1. Czarnecki ST, Nanda RS, Currier GF. Perceptions of a balanced facial profile. Am J Orthod Dentofacial Orthop 1993;104:180-7.
2. Guyuron B, Michelow BJ, Willis L. Practical classification of chin deformities. Aesthetic Plast Surg 1995;19:257-64.
3. Proffit WR, Fields HW Jr, Sarver DM. Contemporary Orthodontics. 5th ed. St Louis: Elsevier Health Sciences; 2013.
4. Björk A. Prediction of mandibular growth rotation. Am J Orthod 1969;55:585-99.
5. Sassouni V. A classification of skeletal facial types. Am J Orthod 1969;55:109-23.
6. Björk A, Skieller V. Normal and abnormal growth of the mandible. A synthesis of longitudinal cephalometric implant studies over a period of 25 years. Eur J Orthod 1983;5:1-46.
7. Mauchamp O, Sassouni V. Growth and prediction of the skeletal and soft-tissue profiles. Am J Orthod 1973;64:83-94.
8. Aki T, Nanda RS, Currier GF, Nanda SK. Assessment of symphysis morphology as a predictor of the direction of mandibular growth. Am J Orthod Dentofacial Orthop 1994;106:60-9.
9. Tsunori M, Mashita M, Kasai K. Relationship between facial types and tooth and bone characteristics of the mandible obtained by CT scanning. Angle Orthod 1998;68:557-62.
10. Swasty D, Lee J, Huang JC, Maki K, Gansky SA, Hatcher D, et al. Cross-sectional human mandibular morphology as assessed in vivo by cone-beam computed tomography in patients with different vertical facial dimensions. Am J Orthod Dentofacial Orthop 2011;139(4 Suppl):e377-89.
11. Khan MY, Kishore MS, Bukhari SA, Rachala MR, Sashidhar NR. Alveolar and skeletal chin dimensions associated with lower facial height among different divergent patterns. J Clin Diagn Res 2016;10:ZC75-80.
12. Gómez Y, García-Sanz V, Zamora N, Tarazona B, Bellot-Arcís C, Langsjoen E, et al. Associations between mandibular symphysis form and craniofacial structures. Oral Radiol 2018;34:161-71.
13. Akhare DP, Rajagopal DA, Shenoy DU, Banerjee DS, Hazarey DA, Karia DH, et al. Evaluation and comparison of the morphological dimension of mandibular symphysis in skeletal Class I and Class II individuals with different growth patterns- a cephalometric study. Int J Res Health Sci Nurs 2018;4:14-25.
14. Arruda KEM, Valladares Neto J, Almeida GDA. Assessment of the mandibular symphysis of Caucasian Brazilian adults with well-balanced faces and normal occlusion: the influence of gender and facial type. Dental Press J Orthod 2012;17:40-50.
15. Sella-Tunis T, Pokhojaev A, Sarig R, O'Higgins P, May H. Human mandibular shape is associated with masticatory muscle force. Sci Rep 2018;8:6042.
16. Molina-Berlanga N, Llopis-Perez J, Flores-Mir C, Puigdollers A. Lower incisor dentoalveolar compensation and symphysis

dimensions among Class I and III malocclusion patients with different facial vertical skeletal patterns. Angle Orthod 2013;83:948-55.
17. Schwartz JH, Tattersall I. The human chin revisited: what is it and who has it? J Hum Evol 2000;38:367-409.
18. Bishara SE, Jakobsen JR. Longitudinal changes in three normal facial types. Am J Orthod 1985;88:466-502.
19. Nalçaci R, Öztürk F, Sökücü O. A comparison of two-dimensional radiography and three-dimensional computed tomography in angular cephalometric measurements. Dentomaxillofac Radiol 2010;39:100-6.
20. Olmez H, Gorgulu S, Akin E, Bengi AO, Tekdemir I, Ors F. Measurement accuracy of a computer-assisted three-dimensional analysis and a conventional two-dimensional method. Angle Orthod 2011;81:375-82.
21. Yitschaky O, Redlich M, Abed Y, Faerman M, Casap N, Hiller N. Comparison of common hard tissue cephalometric measurements between computed tomography 3D reconstruction and conventional 2D cephalometric images. Angle Orthod 2011;81:11-6.
22. Swennen GR, Schutyser FA, Hausamen J. Three-dimensional Cephalometry: A Color Atlas and Manual. Heidelberg, Germany: Springer; 2005.
23. Jacobson A, Jacobson RL. Radiographic Cephalometry: From Basics to 3-D Imaging. 2nd ed. Chicago: Quintessence Publishing; 2006.
24. Steiner CC. Cephalometrics for you and me. Am J Orthod 1953;39:729-55.
25. Downs WB. Variations in facial relationships; their significance in treatment and prognosis. Am J Orthod 1948;34:812-40.
26. Cicchetti DV. Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. Psychol Assess 1994;6:284-90.
27. Ingervall B, Thilander B. Relation between facial morphology and activity of the masticatory muscles. J Oral Rehabil 1974;1:131-47.
28. Weijs WA, Hillen B. Relationships between masticatory muscle cross-section and skull shape. J Dent Res 1984;63:1154-7.
29. Kiliaridis S. Masticatory muscle influence on craniofacial growth. Acta Odontol Scand 1995;53:196-202.
30. Woods MG. The mandibular muscles in contemporary orthodontic practice: a review. Aust Dent J 2017;62(Suppl 1):78-85.
31. Berry DS, McArthur LZ. Some components and consequences of a babyface. J Pers Soc Psychol 1985;48:312-23.
32. Park S, Noh JH. Importance of the chin in lower facial contour: narrowing genioplasty to achieve a feminine and slim lower face. Plast Reconstr Surg 2008;122:261-8.
33. Lee S, Kim BK, Baek RM, Han J. Narrowing and lengthening genioplasty with pedicled bone graft in contouring of the short and wide lower face. Aesthetic Plast Surg 2013;37:139-43.
34. Deschamps-Braly J. Feminization of the chin: genioplasty using osteotomies. Facial Plast Surg Clin North Am 2019;27:243-50.
35. Bjork A. Variations in the growth pattern of the human mandible: longitudinal radiographic study by the implant method. J Dent Res 1963;42:400-11.
36. Solow B. The dentoalveolar compensatory mechanism: background and clinical implications. Br J Orthod 1980;7:145-61.