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Evaluation of Mandibular First Molars' Axial Inclination and Alveolar Morphology in Different Facial Patterns: A CBCT Study

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Abstract

Objective The purpose of this study was to evaluate and compare the axial inclination of the mandibular first molars and their respective bone morphology among individuals with different facial patterns.

Materials and Methods The sample comprised the cone beam computed tomographies (CBCTs) of 58 subjects divided into three groups according to the facial patterns: 18 brachyfacial (Group 1), with a mean age of 21.58 years; 23 mesofacial (Group 2), with a mean age of 19.14 years; and 17 dolichofacial subjects (Group 3), with a mean age of 19.09 years. Eight variables were evaluated on CBCT scans of each subject: buccal and lingual mandibular height, cervical and middle mandibular width, inclination of mandibular body, inclination of the mandibular molar buccal surface, molar width, molar angulation and tooth/bone angle. Intergroup comparisons were performed with one-way analysis of variance followed by Tukey tests.

Results Buccal mandibular height presented statistically significant difference in the three facial patterns. Lingual mandibular height and mandibular inclination showed to be statistically and significantly smaller in brachyfacial subjects than in the other two groups. Mandibular width presented a statistically significant difference between brachyfacial and mesofacial groups. Negative correlations could be observed between the facial pattern and the buccal and lingual mandibular heights and inclination of the mandibular body.

Conclusion Buccal mandibular height was significantly and progressively larger in brachyfacial, mesofacial, and dolichofacial subjects. Lingual mandibular height was significantly smaller in brachyfacial than in mesofacial and dolichofacial subjects. Mandibular width was significantly thicker in brachyfacial than in mesofacial subjects. Brachyfacial subjects had smaller mandibular inclination than mesofacial and dolichofacial subjects.

Keywords
- cone beam computed tomography
- mandible
- molar

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Introduction

Currently, it is known that there is a relationship between the growth pattern and the characteristics of the labial and lingual bone plates.[1,2] The alveolar ridge in patients with horizontal growth is larger when compared with balanced and vertical growth patients.[3,4] Other studies have shown that dolichofacial subjects present narrower alveolar ridge and mandibular symphysis.[5,6] These characteristics demonstrate that vertical growth patients have more restrictions in the possibilities of dental movements due to morphological limits.[1] Also, the transverse skeletal pattern is associated with the morphology of the outer cortex of the mandible.[7] This must be carefully evaluated by the orthodontist during all stages of orthodontic treatment and many studies are being performed, with cone beam computed tomography (CBCT), to precisely determine the limits of tooth movement.[3,5,6,8,9]

Morphological differences were found in several studies both in terms of bone plate thickness[10] and in morphology of the mental symphysis in the various facial patterns.[11,12] Differences in muscular pattern were also pointed out in tomographic studies performed by Chan et al[13] who found a strong correlation between thickness and inclination of muscles and facial pattern. Growing individuals with larger mandibular lifting muscles also present a tendency to have greater width of the zygomatic arch.

Tooth crown positioning has a high relevance in the prescriptions of orthodontic appliances, but root positioning should not be forgotten. Therefore, Tong et al[14] established the angulations and inclinations of the roots of the maxillary and mandibular teeth, in a tomographic study, to improve the accuracy in determining the ideal dental positioning. Gómez et al[12] found that lower incisor inclination showed a positive correlation with symphysis concavity and inclination. Maybe dental positioning and inclination are also different in the different facial patterns.

The question that arises is: are the mandibular morphology and dental positioning in the posterior region the same in all vertical facial patterns? Therefore, the objective of this study was to evaluate and compare the axial inclination of the mandibular first molars and their respective bone morphology among individuals with different facial patterns.

Materials and Methods

This study was approved by the Ethics in Research Committee of Bauru Dental School, University of São Paulo (protocol number 619.057), and all subjects signed informed consent.

Sample size calculation was based on an α of 0.05 and a β of 0.2 to detect a mean difference of 3.81 degrees, with a standard deviation (SD) of 3.9 in mandibular body inclination.[4] Thus, 17 individuals would be necessary in each group.

This retrospective study was performed using a sample selected from the records of the Tomographic Diagnostic Center at CEDT – Rio de Janeiro, Brazil. CBCT scans were previously performed for several different reasons not considered for the research.

The subjects were selected according to the following inclusion criteria: older than 14 years, presence of all permanent teeth, absence of metal prostheses or restorations in the maxillary posterior teeth, absence of history of periodontal disease, and no previous orthodontic treatment.

A total of 58 subjects who met these criteria were selected and were divided into three groups according to the Ricketts vertical growth coefficient (VERT) index.[15]

Group 1 consisted of 18 brachyfacial subjects (8 males; 10 females): with a mean age of 21.58 years and with a VERT index above 0.5 (mean, 1.36; SD, 0.59). Group 2 consisted of 23 mesofacial subjects (11 males; 12 females): with a mean age of 19.14 years and with a VERT index between 0.5 and–0.5 (mean,–0.02; SD, 0.28). Group 3 comprised 17 dolichofacial subjects (9 males; 8 females): with a mean age of 19.09 years and a VERT index below–0.5 (mean,–1.44; SD, 0.39).

CBCT was taken in an I-Cat tomograph (www.imagingsciences.com) and the images were generated and measured in Nemoscan - NemoStudio Nx Pro (Nemotec; Madrid, Spain) program. Before the exam, the tomograph was adjusted to operate according to the following specifications: 120.0 KvP, 8.0 mA, exposure time of 20 seconds. The subjects were oriented to remain seated with the head positioned with the Frankfort plane parallel to the ground and the median sagittal plane perpendicular to the ground.

To encompass the dentoalveolar region of the maxilla and mandible, the acquisition image protocol used was the face exam with cephalocaudal extension of 13.0 cm, or the "extended face," with 22.0 cm for subjects with long face. The voxel thickness, and therefore the axial cuts, was 0.4 mm.

After importing the exam file to a conventional computer with the Nemoscan software, the position of the images was standardized before selecting the cuts to measure with the methodology proposed by Ferreira et al.[16] Subsequently, measurements of the eight proposed variables were performed using the coronal cut, as follows.

1. Buccal and lingual mandibular height (Bc and Lg Md Height): distance between the most superior point of the buccal and lingual mandibular bone plate and the lowest point of the mandible (►**Fig. 1**).
2. Cervical mandibular width (Cerv Md Width): distance between the most superior points of the buccal and lingual bone plates of the first mandibular molar (►**Fig. 2**).
3. Mandibular width (Md Width): the cervical mandibular width midpoint was established (►**Fig. 3A**), then a line was drawn connecting this midpoint to the lowest point of the mandible (►**Fig. 3B**). The midpoint of this line was stablished (►**Fig. 3C**) and from this point a perpendicular line was drawn representing the bone thickness of the mandible (►**Fig. 3D**).
4. Mandibular inclination (Md Inclination): it is the inner angle between the horizontal auxiliary plane of reference and the line from the midpoint of the cervical mandibular width to the lowest point of the mandibular body (►**Fig. 4**).

5. Inclination of the buccal surface (Buccal Inclination): angle formed between the buccal surface of the mandibular molar and the horizontal auxiliary reference plane. The buccal surface was represented as the line from the maxillary first molar buccal cusp tip to the cemento-enamel junction of the same surface (►**Fig. 5**).
6. Molar width: measured from the furthest points on the buccal and lingual molar surfaces, parallel to the occlusal surface (►**Fig. 6**).
7. Molar angulation: angle between a line from molar width midpoint, along its long axis, and the horizontal reference auxiliary plane (►**Fig. 7**).
8. Tooth/bone angle: angle between the molar and the mandibular body long axes (►**Fig. 8**).

The VERT index was performed on each subject's lateral cephalogram, which was obtained from the tomographic reconstruction. This index consisted of the global growth pattern proposed by Ricketts[15] (►**Fig. 9**) and classified subjects according to their facial pattern, in brachycephalic, mesocephalic, or dolichocephalic biotype.

Measurements were performed by a calibrated evaluator (M.C.F.) that was blinded to the three different groups.

Error Study

All measurements were performed twice with at least 30-day interval, in 24 randomly selected subjects. Random errors were evaluated using Dahlberg's formula ($S^2 = \sum d^2/2n$).[17] Systematic errors were evaluated using dependent *t*-tests,[18] and the results were considered significant at $p < 0.05$.

Fig. 1 Buccal (green) and lingual (yellow) mandibular heights. Note that the lowest point of the mandibular body is tangent to the horizontal auxiliary reference line.

Fig. 2 Measurement of mandibular cervical width.

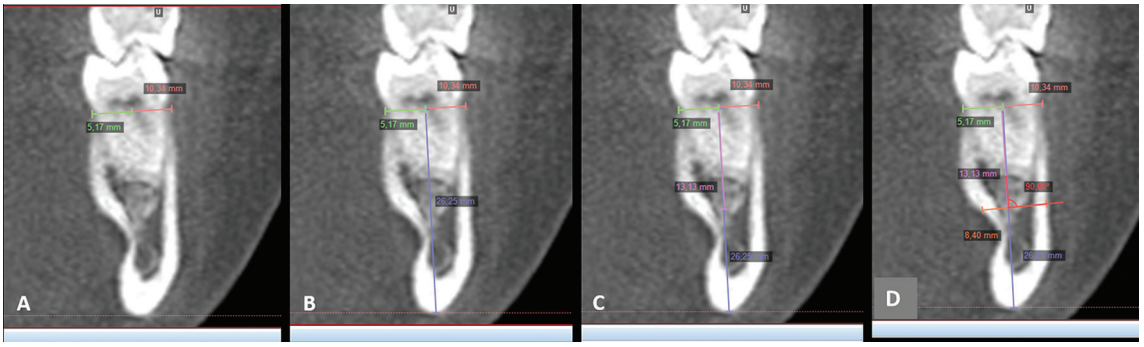

Fig. 3 (**A–D**) Sequence for measuring mandibular width.

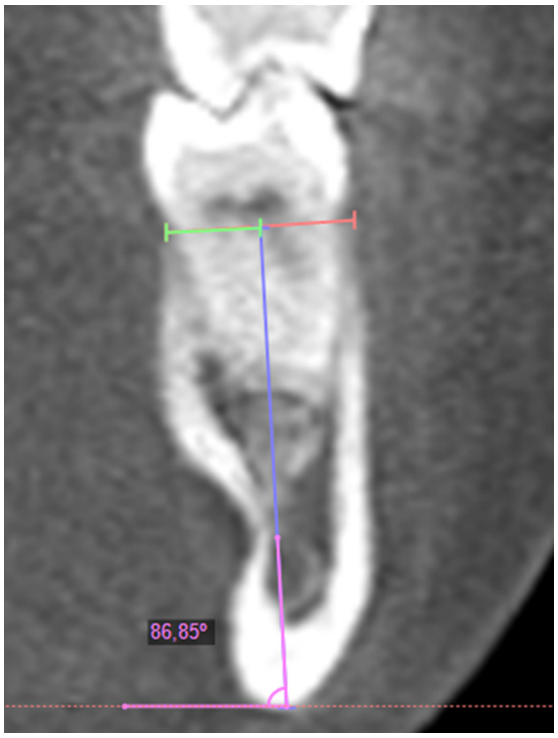

Fig. 4 Measurement of mandibular body inclination.

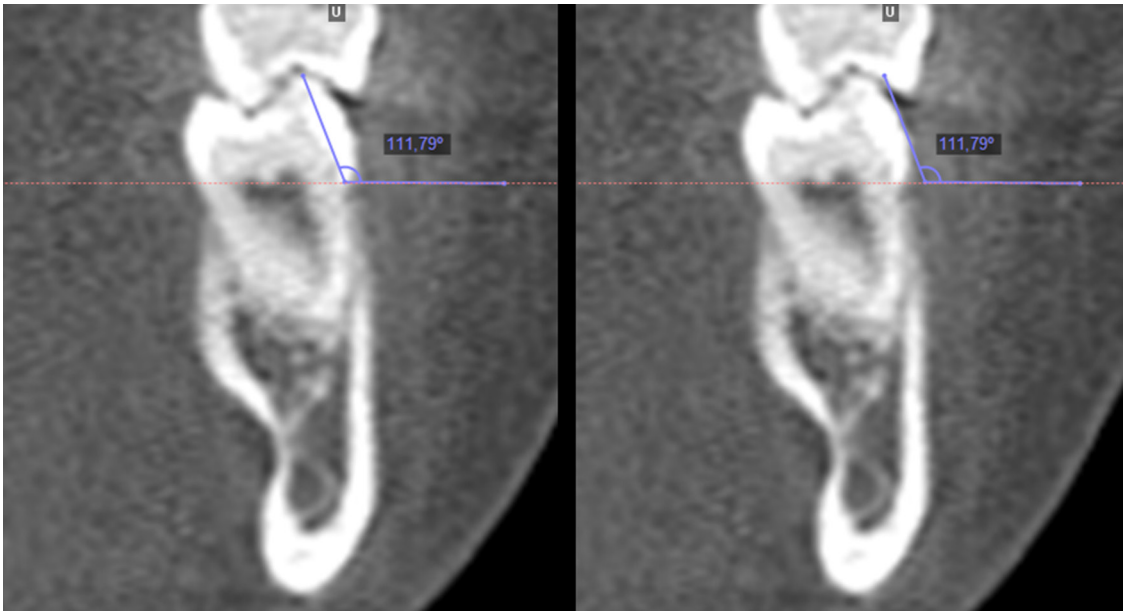

Fig. 5 Measurement of the buccal surface inclination angle.

Statistical Analysis

Normal distribution of the data was checked with Kolmogorov–Smirnov tests. All variables demonstrated normal distribution. Intergroup comparability regarding age was evaluated with one-way analysis of variance (ANOVA), and regarding sex and malocclusion type distribution, with chi-square tests.

Intergroup comparison of the variables was performed by one-way ANOVA, followed by Tukey tests, when necessary. Correlation between the VERT index and the studied variables was evaluated with Pearson tests.

All tests were performed with Statistica software (Statistica for Windows; version 7.0, Copyright StatSoft, Inc., Tulsa, Oklahoma, United States, 2005), at a significance level of 5%.

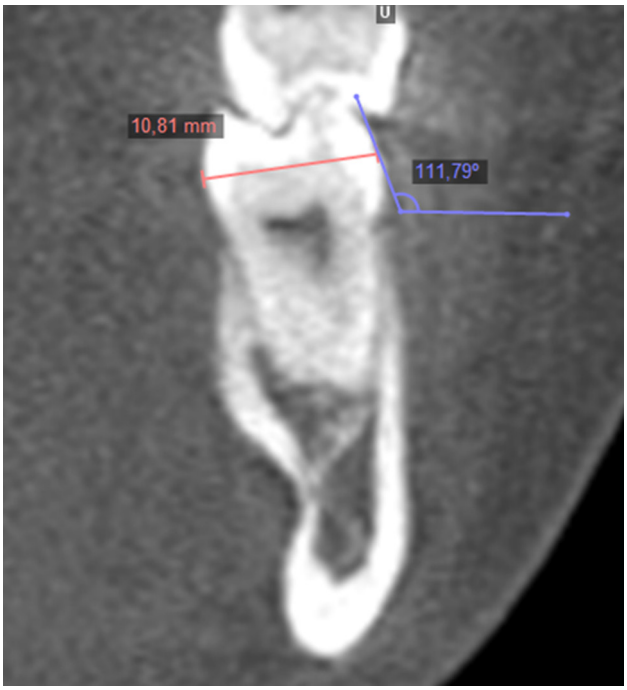

Fig. 6 Measurement of molar width.

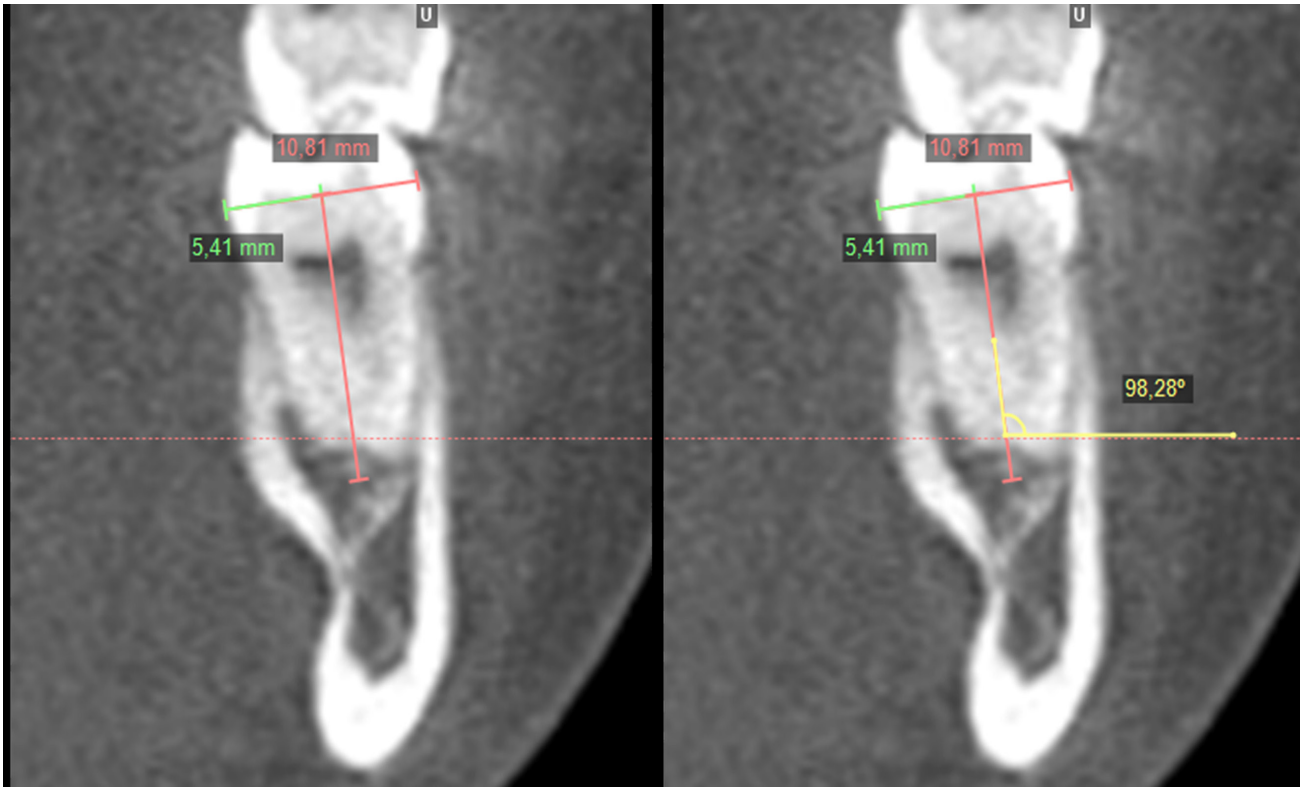

Fig. 7 Measurement of molar angulation.

Results

The random errors varied from 0.26 (molar width) to 1.03 mm (Lg Md Height) and from 1.02 degrees (tooth/bone angle) to 1.94 degrees (buccal inclination) and are within acceptable limits,[19,20] and there was no significant systematic error (►**Table 1**).

The three groups were comparable regarding age, sex, and malocclusion type distribution (►**Table 2**).

Buccal mandibular height was significantly and progressively larger in brachyfacial, mesofacial, and dolichofacial subjects (►**Table 3**). Lingual mandibular height was significantly smaller in brachyfacial than in mesofacial and dolichofacial subjects. Mandibular width was significantly thicker in

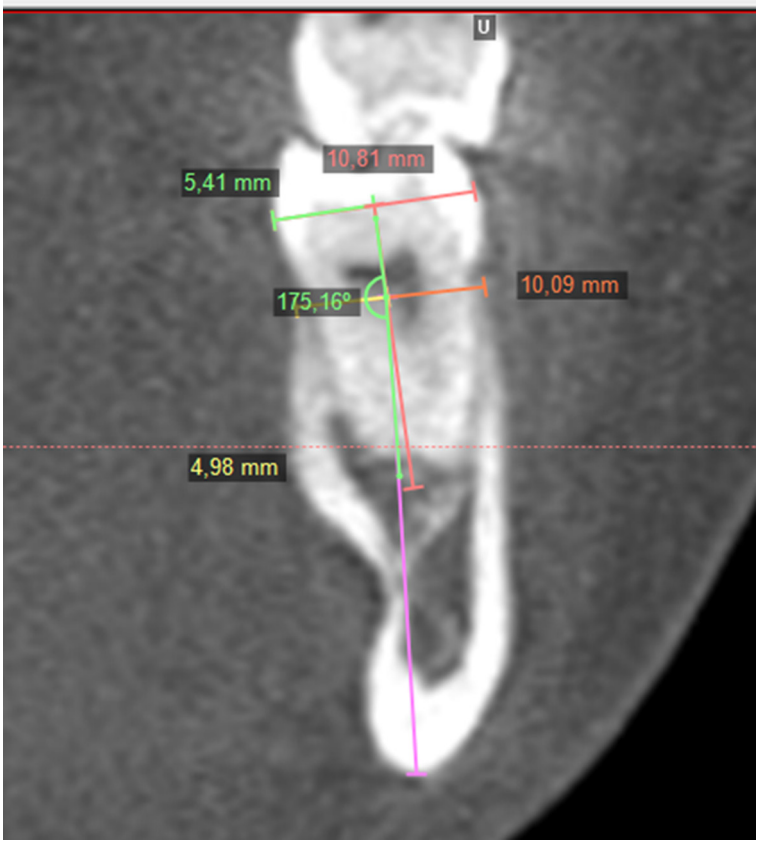

Fig. 8 Measurement of tooth/bone angle.

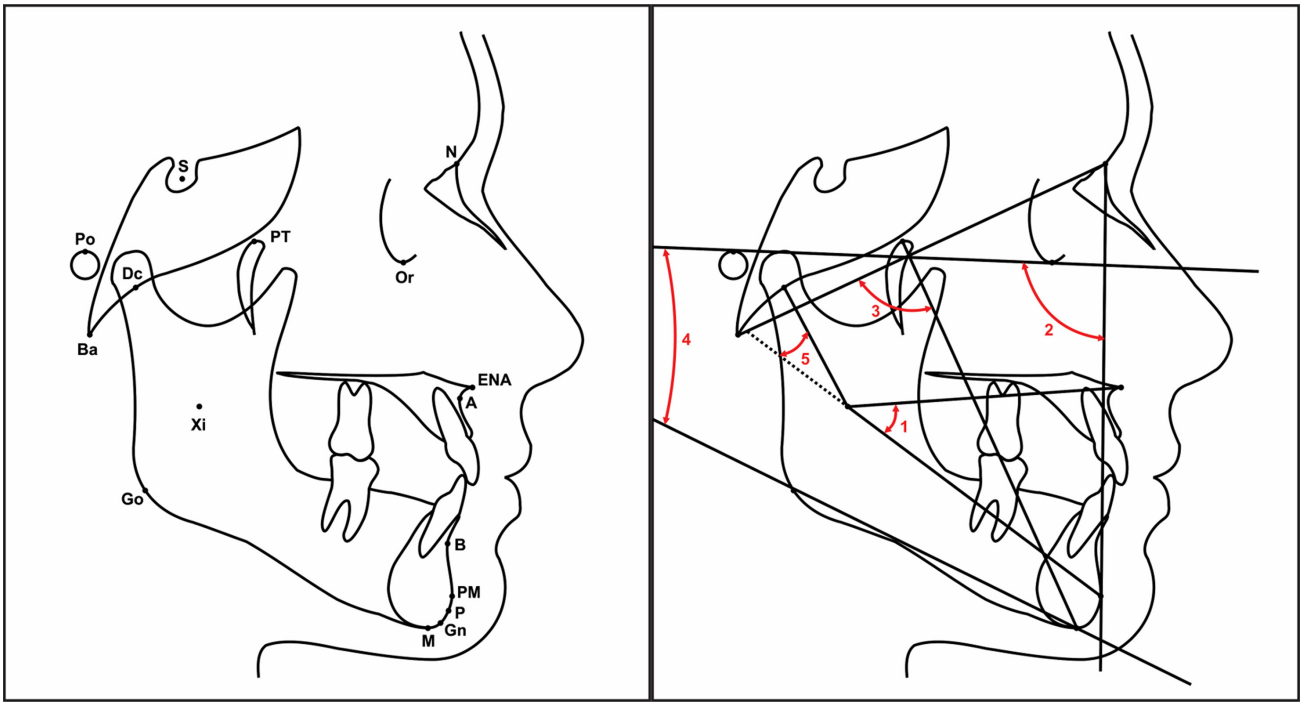

Fig. 9 Left: Anatomical tracing and landmarks used. Right: cephalometric variables used to calculate the Ricketts' vertical growth coefficient index. (1) Lower face height; (2) facial depth; (3) angle of the facial axis; (4) angle of the mandibular plane; (5) mandibular arch. PM, prominence of the menton; ENA, anterior nasal spine; Gn, gnation.

Table 1 Results of Dahlberg's formula and dependent t-tests to estimate the random and systematic errors, respectively (n = 24)

Variables	1st measurement		2nd measurement		Dahlberg	*p*-Value
	Mean	SD	Mean	SD		
Bc Md height (mm)	29.43	2.97	29.48	3.09	0.76	0.835
Lg Md height (mm)	29.42	2.82	29.65	3.29	1.03	0.455
Cerv Md width (mm)	10.08	0.70	10.09	0.81	0.48	0.974
Mid Md width (mm)	12.66	2.44	12.86	2.42	0.90	0.447
Md inclination (°)	90.56	4.91	90.84	5.30	1.33	0.722
Buccal inclination (°)	110.71	6.92	110.58	6.69	1.94	0.907
Molar width (mm)	10.37	0.47	10.30	0.51	0.26	0.364
Molar angulation (°)	96.63	5.94	97.49	5.60	1.76	0.149
Tooth/bone angle (°)	171.99	4.94	172.37	4.95	1.02	0.219
VERT index	1.33	0.66	1.32	0.65	0.07	0.477

Abbreviations: Bc, buccal; Cerv, cervical; Lg, lingual; Md, mandibular; SD, standard deviation; VERT, vertical growth coefficient.

Table 2 Intergroup comparison of the ages of the subjects (one-way ANOVA), gender, and type of malocclusion (chi-square tests)

Variables	Group 1: brachyfacial (*n* = 18)	Group 2: mesofacial (*n* = 23)	Group 3: dolichofacial (*n* = 17)	*p*-Value
	Mean (SD)	Mean (SD)	Mean (SD)	
Age (y)	21.58 (7.43)	19.14 (5.19)	19.09 (6.89)	0.412
Sex				$\chi^2 = 0.25$
Male	8	11	9	DF = 2
Female	10	12	8	$p = 0.879$
Type of malocclusion Class I Class II Class III	9 8 1	12 9 2	3 13 1	$\chi^2 = 6.36$ DF = 4 $p = 0.173$

Abbreviations: ANOVA, analysis of variance; DF, degrees of freedom; SD, standard deviation; y, years.

Table 3 Intergroup comparison of the variables used (one-way ANOVA and Tukey tests)

Variables	Group 1: brachyfacial (*n* = 36)	Group 2: mesofacial (*n* = 46)	Group 3: dolichofacial (*n* = 34)	*p*-Value
	Mean (SD)	Mean (SD)	Mean (SD)	
Bc Md height (mm)	28.17 (2.40)[A]	30.42 (3.74)[B]	32.17 (3.10)[C]	0.000[a]
Lg Md height (mm)	28.24 (1.88)[A]	30.03 (3.69)[B]	31.65 (3.27)[B]	0.000[a]
Cerv Md width (mm)	10.18 (0.73)[A]	10.04 (0.76)[A]	10.16 (0.56)[A]	0.639
Mid Md width (mm)	13.79 (2.50)[A]	11.89 (2.08)[B]	12.76 (2.19)[AB]	0.001[a]
Md inclination (°)	89.06 (4.12)[A]	92.41 (4.40)[B]	92.67 (4.16)[B]	0.000[a]
Buccal inclination (°)	113.94 (5.33)[A]	112.25 (8.74)[A]	112.49 (5.63)[A]	0.522
Molar width (mm)	10.29 (0.36)[A]	10.25 (0.60)[A]	10.22 (0.64)[A]	0.869
Molar angulation (°)	97.56 (5.41)[A]	96.80 (7.32)[A]	95.37 (6.81)[A]	0.378
Tooth/bone angle (°)	172.28 (4.69)[A]	170.75 (6.44)[A]	172.12 (6.76)[A]	0.449

Abbreviations: ANOVA, analysis of variance; Bc, buccal; Cerv, cervical; Lg, lingual; Md, mandibular; SD, standard deviation.
Note: Different letters on the same line indicate the presence of a statistically significant difference.
[a]Statistically significant for $p < 0.05$.

Table 4 Results of the Pearson correlation test between the VERT index and the studied variables

Correlations	*r*-Value	*p*-Value
VERT × Bc Md height	−0.360	0.000[a]
VERT × Lg Md height	−0.316	0.001[a]
VERT × Cerv Md width	0.086	0.358
VERT × Mid Md width	0.163	0.080
VERT × Md inclination	−0.365	0.000[a]
VERT × Buccal inclination	0.075	0.418
VERT × Molar width	0.119	0.200
VERT × Molar angulation	0.106	0.255
VERT × Tooth/bone angle	0.055	0.554

Abbreviations: Bc, buccal; Cerv, cervical; Lg, lingual; Md, mandibular; VERT, vertical growth coefficient.
[a]Statistically significant for $p < 0.05$.

brachyfacial than in mesofacial subjects. Mandibular inclination was significantly smaller in brachyfacial than in mesofacial and dolichofacial subjects.

There were significant negative correlations of the VERT index with buccal and lingual mandibular heights and with mandibular inclination (►**Table 4**).

Discussion

The present study used CBCT to perform a morphological description of the mandibular first molar area, linear and angularly. There was high intergroup homogeneity and comparability (►**Table 2**). The exclusion of subjects under 14 years of age was important for greater homogeneity of the sample, since a difference in thickness of the mandibular cortical bone between adults and adolescents has been observed.[21] To divide the groups according to the facial pattern, the VERT index[15] was used, although others chose the Frankfort-mandibular plane angle.[4,9] The VERT index[15] was chosen because it is a mean of five factors instead of only one measurement to define the facial biotype of each subject.

CBCT scans were used as the only three-dimensional method with low radiographic exposure that provides information with acceptable accuracy on alveolar cortical bone morphology, presenting a substantially lower radiation dose than conventional computed tomography.[22,23] This methodology has already been used in several works in the literature because it is possible to properly analyze dental and bone structures,[4,9-11,24] especially the thickness of the cortical alveolar bone, since it excludes the magnification factor, and there is no imaging overlap.[25-28]

Buccal mandibular height was significantly and progressively larger in brachyfacial, mesofacial, and dolichofacial subjects, and lingual mandibular height was significantly smaller in brachyfacial than in mesofacial and dolichofacial subjects (►**Table 3**). Some differences with other investigations[2,4,11] can be justified because of the variables and methodologies employed, although these authors also report strong association between bone structures and muscular pattern.

Mandibular width was thicker in the brachyfacial group in relation to the mesofacial group (►**Table 3**). Swasty et al[11] found that subjects with long faces had less wide mandibular cross-section compared with individuals with short and average faces.

Mandibular inclination was significantly smaller in the brachyfacial group compared with the mesofacial and dolichofacial groups, corroborating the findings of Tsunori et al[4] (►**Table 3**).

No differences were found in cervical mandibular width, buccal inclination, molar width, molar angulation, and tooth/bone angle between the different facial patterns (►**Table 3**). This contrasts with the study of Masumoto et al[9] probably consequent to the methodology used. In the current study, molar inclination was evaluated in relation to the mandibular body, which presented varying inclinations in the different facial patterns. Masumoto et al[9] evaluated molar inclination in relation to the inferior border of the mandibular section of both sides.

There were significant negative correlations of the VERT index with buccal and lingual mandibular heights and with mandibular inclination, meaning that the greater the brachyfacial pattern, the shorter the buccal and lingual mandibular heights and the smaller the mandibular inclination (►**Table 4**). Tsunori et al[4] found similar results regarding mandibular inclination, but no differences in mandibular heights among the different facial types. However, they had a small sample, with only nine short-face subjects and seven long faces compared with 23 average face individuals. Swasty et al[11] also had different results, but evaluated the mandible in multiple different sections and areas.

Clinical Considerations

The shape of the mandible is not only controlled by genetic factors such as the individuals' craniofacial growth pattern, but also influenced by biomechanical factors such as the orientation of the masticatory muscles and the forces generated by them.[29]

The morphology of the alveolar ridge is a limiting factor for tooth movement and should be considered individually in the orthodontic treatment plan.[30] One of the most critical orthodontic movements is expansion of the dental arches.[31] Such mechanics can decentralize the teeth of the supporting bone tissue, resulting in dehiscences, bone fenestrations, and gingival recessions, depending on the initial morphology of the periodontium as well as the amount of movement. Greater understanding of the morphology of the posterior bone plate of the mandible helps the orthodontist to discern between patients who could and who should not be subjected to expansionist mechanics.[30]

The results of the present study indicated that brachyfacial individuals present important morphological differences,

indicating that mandibular arch expansion can be performed more safely in patients with this facial pattern. It should also be considered that inclination of the mandibular bone plate is a limiting factor for expansion movements in the mesofacial and dolichofacial patients. As the mandibular inclination was greater in these two facial types, the teeth in these individuals are more uprighted, and during transverse movements the lingual cusps can experience extrusion, so prescription of the brackets should be different for different facial patterns. Knowing the anatomical details of subjects comprehensively and understanding the side effects of tooth movement mean recognizing the limits and practicing orthodontics with more security.[30]

Conclusion

- Buccal mandibular height was significantly and progressively larger in brachyfacial, mesofacial, and dolichofacial subjects.
- Lingual mandibular height was significantly smaller in brachyfacial than in mesofacial and dolichofacial subjects.
- Mandibular width was significantly thicker in brachyfacial than in mesofacial subjects.
- Brachyfacial subjects had smaller mandibular inclination than mesofacial and dolichofacial subjects.

Conflict of Interest
None declared.

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