



# The relationship of articular eminence and mandibular fossa morphology to facial profile and gender determined by cone beam computed tomography

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**Objective.** The aim of this study was to evaluate the relationship of the morphology of the articular eminence and mandibular fossa to facial profile and sex by using cone beam computed tomography (CBCT) images.

**Study Design.** CBCT examinations of 76 patients were conducted, and the patients were classified according to facial profile as dolichocephalic, mesocephalic, or brachycephalic. The inclination and height of the articular eminence and the inclination of the mandibular fossa of 152 temporomandibular joints were measured. Comparisons between these measurements and facial profile and gender were performed by 2-way analysis of variance with Tukey's post hoc test. Significance was established at  $\alpha = 0.05$ .

**Results.** Males with brachycephaly presented significantly greater values of eminence inclination compared with those with other facial types and greater values than patients with dolichocephaly for the measurements of eminence height and inclination of the fossa posterior wall ( $P \leq .05$ ). Females with brachycephaly presented significantly greater eminence height values compared with those with other facial profiles ( $P \leq .05$ ). No significant differences were observed between males and females.

**Conclusions.** The morphology of the articular eminence and the mandibular fossa is associated with facial profile, with males with brachycephaly showing greater inclination of the eminence and mandibular fossa. Articular eminence height in brachycephaly was greater in both sexes. (Oral Surg Oral Med Oral Pathol Oral Radiol 2019;128:660–666)

The temporomandibular joint (TMJ) plays a fundamental role in mastication as the condyle moves from the mandibular fossa toward the articular eminence of the temporal bone.<sup>1,2</sup> Thus, the articular eminence is closely related to this process because it is where the articular disk–condylar head complex slides during the opening and closing movements of the mandible,<sup>3–6</sup> and it defines the degree of rotation of the articular disk over the condylar head.<sup>5</sup> Studies have indicated that morphologic variations in the eminence can affect the functioning of the TMJ and trigger joint disorders.<sup>7,8</sup>

The morphology of the articular eminence can be evaluated according to its inclination and height.<sup>9</sup> *Anteroposterior inclination* is defined by the angle formed by the posterior wall of the articular eminence with a horizontal reference plane, which may be the Frankfort plane, the occlusal plane, or the palatal plane.<sup>3,8,10</sup> *Lateral inclination* is defined as the angle formed by the lateral wall and the roof of mandibular fossa.<sup>9</sup> *Height* is

defined as the perpendicular distance between the uppermost point on the mandibular fossa and the lowermost point on the articular eminence.<sup>9</sup> Although it is constituted of dense bone,<sup>1,9</sup> the articular eminence may be susceptible to variations because of dental absence,<sup>8,11</sup> skeletal malocclusions,<sup>7,12</sup> the effect of aging,<sup>6,8,10</sup> sex,<sup>5,6</sup> and masticatory loads.<sup>4,6</sup>

It is known that craniofacial morphology can influence the activity of masticatory muscles. Individuals with brachycephaly, which is characterized by a square and flat face, present greater muscle tone and, consequently, more biting force, in contrast to individuals with dolichocephaly, who have an elongated face, weaker masseter muscles, and, consequently, a weaker bite.<sup>13–16</sup> In response to the mechanical and functional requirements of mastication, the osseous components of the TMJ (the mandibular fossa and articular eminence of the temporal bone and the condylar head) can be subjected to the adaptive process of bone remodeling.<sup>1,12,17</sup>

Three-dimensional examinations such as cone beam computed tomography (CBCT), widely used in dentistry, have provided accurate evaluation of the hard tissues in the maxillofacial region, including the TMJ.<sup>3,12,17,18</sup>

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## Statement of Clinical Relevance

The morphologic features of the articular eminence and the mandibular fossa can be related to different facial profiles.

Because TMJ morphology can clarify the origin of bone disorders and alterations<sup>6</sup> and because of the complex relationship between the TMJ and the craniofacial skeleton, the objective of this study was to evaluate the relationship of the morphology of the articular eminence and mandibular fossa to facial profile and sex by using CBCT images. The null hypothesis stated that there was no significant correlation between articular eminence or fossa measurements and facial profile type or gender.

**MATERIALS AND METHODS**

This study was approved by the Local Research Ethics Committee (protocol #121/2013). The images used were obtained from examinations previously conducted for orthodontic purposes, between 2015 and 2018, and therefore had no connection to the present research. The inclusion criteria were the following: (1) sufficient image sharpness and contrast to visualize the structures to be evaluated (articular eminence and mandibular fossa); (2) a field of view covering the entire skull in which both TMJs could be visualized; and (3) complete permanent dentition (absence of teeth was accepted only for third molars or premolars extracted for orthodontic reasons). The exclusion criteria were (1) absence of intercuspation; (2) noncentralization of the condylar head in the mandibular fossa; (3) active orthodontic treatment or treatment completed less than 2 years before the study; and (4) the presence of pathoses or fractures in the TMJ region. After applying the inclusion and exclusion criteria, 76 patients (35 males and 41 females) were selected, and 152 TMJs were evaluated.

**Acquisition of images**

All CBCT volumes were acquired by using the i-CAT Next Generation machine (Imaging Sciences International, Hatfield, PA), with the patient in maximum

intercuspation. The exposure parameters were 120 kVp, 37.07 mAs, acquisition time of 29.6 seconds, and 360-degree rotation. The field of view was 23.0 × 17.0 cm, and the acquisition voxel size was 0.25 mm.

**Measurement of articular eminence and mandibular fossa**

Initially, the CBCT examination results were analyzed by using Xoran software (Xoran Technologies LLC, Ann Arbor, MI), the proprietary software of the i-CAT CBCT system. In axial and sagittal reconstructions, CBCT images were spatially oriented by aligning the anterior and posterior nasal spine. Then, for the axial reconstruction, a line was drawn mid-laterally over the central region of the condylar heads. Thus, through the TMJ tool (“Mode of obtaining TMJ”), corrected coronal reconstructions parallel to the long axis of the condylar head and corrected sagittal reconstructions perpendicular to the long axis were acquired with 1-mm thickness, as described in other studies.<sup>6,9</sup> These reconstructions were performed in both the right and the left TMJs. Subsequently, angle measurements were obtained in CS 3-D Imaging Software 3.4.3 (Carestream Health Inc., Rochester, NY), since it is not possible to perform these measurements in Xoran.

The measurements and angles evaluated were adapted from Katsavrias et al.<sup>8</sup> and Verner et al.<sup>9</sup> The points and lines used to calculate measurements and angles are listed in [Table I](#). The anteroposterior inclination of the articular eminence was calculated by using 2 methods: method 1 (angle  $\alpha$ ) and method 2 (angle  $\beta$ ). The height of the articular eminence (AEh) was measured from the uppermost point of the mandibular fossa to the lowermost point of the eminence. The inclination of the lateral wall of the mandibular fossa (angle  $\delta$ ) was calculated as described in [Table I](#). Articular eminence and mandibular fossa measurements are illustrated in [Figure 1](#).

**Table I.** Definitions of measures from the articular eminence and mandibular fossa regions

<i>Symbols</i>	<i>Definition</i>
MF	Uppermost point from image of the mandibular fossa
AE	Lowermost point from image of the articular eminence
Line 1	Line parallel to the AE crossing point with the Frankfort plane
Line 2	Line parallel to the MF crossing point with the Frankfort plane
Line 3	Line tangent to the posterior inclination of the articular eminence
Line 4	Line connecting MF and AE
Line 5	Line perpendicular to the MF crossing point with the Frankfort plane
Line 6	Line tangent to the lateral wall of the mandibular fossa
Angle $\alpha$	Inclination of the posterior wall of the articular eminence: Intersection between lines 1 and 3 (Method 1)
Angle $\beta$	Inclination of the posterior wall of the articular eminence: Intersection between lines 1 and 4 (Method 2)
AEh	Articular eminence height (perpendicular distance between points MF and AE)
Angle $\delta$	Inclination of the lateral wall of the mandibular fossa: Intersection between lines 5 and 6

Adapted from Verner FS, Roque-Torres GD, Ramírez-Sotello LR, Devito KL, Almeida SM. Analysis of the correlation between dental arch and articular eminence morphology: a cone beam computed tomography study. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2017;124:420-431.

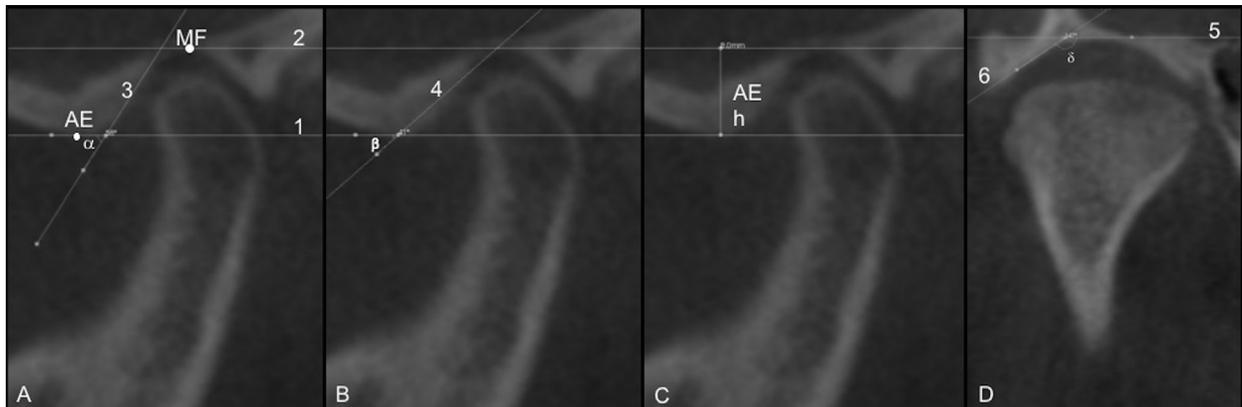


Fig. 1. Articular eminence and mandibular fossa measurements in a brachycephalic female patient. (A–C), Cone beam computed tomography (CBCT) sagittal reconstructions showing measurements of articular eminence inclination ( $\alpha$  and  $\beta$  angles) and height. (D), CBCT coronal reconstruction showing measurement of the lateral inclination of the mandibular fossa ( $\delta$  angle).

**Image assessment**

The images were independently assessed, and articular eminence and mandibular fossa measurements made, by 3 radiologists, with experience in the evaluation of CBCT images, on a 24-inch high-resolution LCD monitor (MDRC 2124; Barco Inc., Duluth, GA) in a dimly lit environment. A maximum of 5 images were evaluated to avoid visual fatigue in the evaluators. The images could be adjusted for better contrast, brightness, and zoom, as needed by each observer. In the statistical analysis, the means of the examiners were used. After 30 days, 25% of the sample was reevaluated.

**Facial profile classification**

For this analysis, 2 oral radiologists, with experience in the evaluation of CBCT images and in cephalometric analysis, performed the evaluations independently, which resulted in perfect agreement. The CBCT examination results were evaluated with CS 3-D Imaging Software 3.4.3 (Carestream Health Inc., Rochester, NY). Classification of facial profiles was performed in the most central sagittal reconstruction of the skull,<sup>19,20</sup> with the plane passing through the anterior and posterior

nasal spine parallel to the horizontal Frankfort plane.<sup>21</sup> The patients were categorized into dolichocephalic, mesocephalic, and brachycephalic facial profile categories (Figure 2) by using the Vert index by Ricketts et al.<sup>22</sup> In this method, 5 mandibular measurements were used: facial axis, facial depth, mandibular plane, lower facial height, and mandibular arch (Figure 3). To determine the facial profile, the arithmetical mean of the difference for each of these measurements was calculated, with the standard value of a harmonic face divided by the standard deviation. Therefore, with values  $-0.5$  or less, patients were classified as dolichocephalic; with values between  $-0.49$  and  $+0.49$ , mesocephalic; and with values  $+0.50$  or greater, brachycephalic.<sup>16</sup> The sample consisted of 23 dolichocephalic, 26 mesocephalic, and 27 brachycephalic types of profiles.

**Data analysis**

Intra- and interexaminer agreements were calculated by using the intraclass correlation coefficient. To compare the articular eminence and mandibular fossa measurements according to facial profile and sex, the analysis of variance (2-way analysis of variance) with Tukey’s post

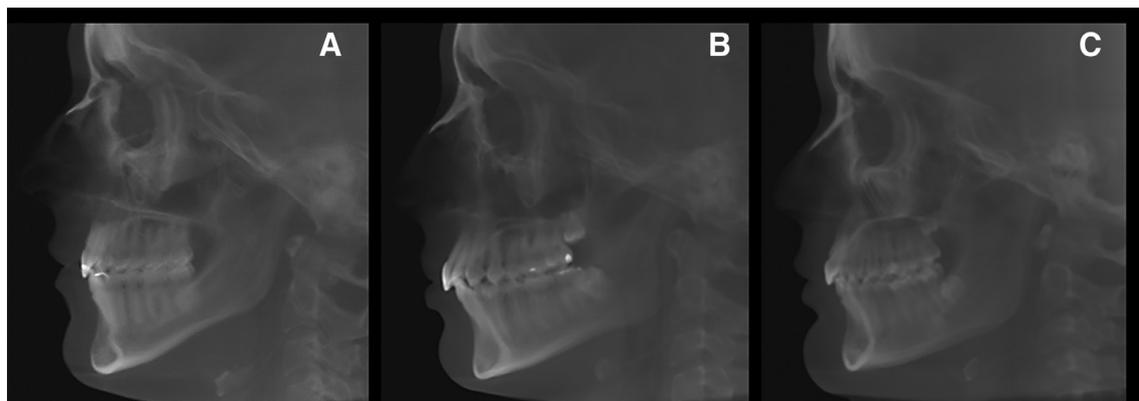


Fig. 2. Dolichocephalic (A), mesocephalic (B), and brachycephalic (C) profiles.

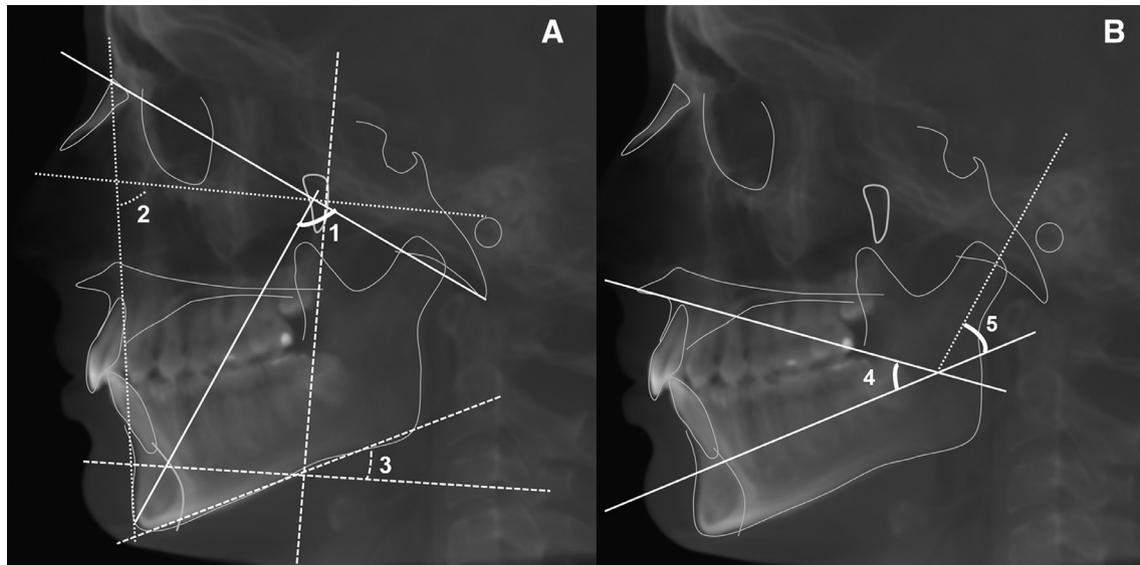


Fig. 3. Vert index. (A), Facial axis (1), facial depth (2), and mandibular plane (3). (B), Lower facial height (4) and mandibular arch (5).

hoc test was performed. To compare the measurements of the articular eminence and the mandibular fossa between the right and left sides, the Student *t* test was conducted. Significance level was established at  $\alpha = 0.05$ . Data were analyzed by using the SPSS software version 22.0 (SPSS Inc., Chicago, IL).

**RESULTS**

Intraclass correlation coefficients for intra- (0.889–0.921) and interexaminer (0.871–0.882) agreement showed excellent agreement for all the measures analyzed.<sup>23</sup>

Tables II and III present the mean and standard deviation values of the articular eminence and mandibular fossa measurements performed according to facial profile in male and female patients. No significant differences were observed between males and females ( $P > .05$ ); however, some differences in the measurements in patients with different facial profiles for each gender were observed. Males with brachycephaly had significantly greater values for angle  $\alpha$  compared with those with mesocephaly ( $P = .032$ ) and dolichocephaly ( $P = .001$ ) (see Table II), but no significant differences were identified for angle  $\alpha$  between facial profile

**Table II.** Mean and standard deviation of articular eminence and mandibular fossa measurements according to facial profile in male patients

Sex	Facial profile	Mean ( $\pm$ SD)			
		$\alpha$ ( $^\circ$ )	$\beta$ ( $^\circ$ )	AEh (mm)	$\delta$ ( $^\circ$ )
Male	Dolichocephalic	51.28 (2.80) <sup>a</sup>	33.92 (1.68) <sup>a</sup>	6.86 (0.38) <sup>a</sup>	140.07 (2.89) <sup>a</sup>
	Mesocephalic	56.69 (2.05) <sup>a</sup>	37.42 (1.23) <sup>ab</sup>	7.64 (0.28) <sup>ab</sup>	146.38 (2.12) <sup>ab</sup>
	Brachycephalic	62.76 (1.91) <sup>b</sup>	40.56 (1.15) <sup>b</sup>	8.22 (0.26) <sup>b</sup>	149.27 (1.97) <sup>b</sup>

The letters *a* and *b* in the columns indicate significant difference for each measurement between the different facial profiles ( $P \leq .05$ ).

**Table III.** Mean and standard deviation of articular eminence and mandibular fossa measurements according to facial profile in female patients

Sex	Facial profile	Mean ( $\pm$ SD)			
		$\alpha$ ( $^\circ$ )	$\beta$ ( $^\circ$ )	AEh (mm)	$\delta$ ( $^\circ$ )
Female	Dolichocephalic	54.21 (1.85) <sup>a</sup>	35.03 (1.11) <sup>a</sup>	6.85 (0.25) <sup>a</sup>	145.63 (1.91) <sup>a</sup>
	Mesocephalic	55.61 (2.05) <sup>a</sup>	36.61 (1.23) <sup>a</sup>	6.94 (0.28) <sup>a</sup>	146.46 (2.12) <sup>a</sup>
	Brachycephalic	58.45 (2.14) <sup>a</sup>	40.75 (1.28) <sup>b</sup>	8.07 (0.29) <sup>b</sup>	147.04 (2.21) <sup>a</sup>

The letters *a* and *b* in the columns indicate significant difference for each measurement between the different facial profiles ( $P \leq .05$ ).

groups in females (see Table III). For angle  $\beta$  and articular eminence height, males with brachycephaly presented significantly greater values compared with those with dolichocephaly ( $P = .001$  for angle  $\beta$  and  $.005$  for AEh), as shown in Table II. Among females with brachycephaly, angle  $\beta$  and AEh were significantly greater compared with those with mesocephaly ( $P = .022$  and  $.007$ , respectively) and dolichocephaly ( $P = .001$  and  $.002$ , respectively) (see Table III). For angle  $\delta$ , only males with brachycephaly showed significantly higher values compared with those with dolichocephaly ( $P = .010$ ); no significant differences were observed in angle  $\delta$  between women in any of the facial profile groups.

When comparing the articular eminence and mandibular fossa measurements between the right and left sides, no significant differences were found for any of the measurements ( $P = .438$  for  $\alpha$ ;  $P = .331$  for  $\beta$ ;  $P = .110$  for AEh;  $P = .276$  for  $\delta$ ).

## DISCUSSION

The articular eminence and the mandibular fossa are of clinical importance because these structures are involved in the dynamic function of the TMJ. It can be observed that the articular eminence presents a strong functional dependence in response to masticatory loads, varying from a flat structure at birth to an inclined posterior wall as a result of its progressive development.<sup>1,3,8,10</sup> Thus, the objective of this study was to evaluate the morphology of the articular eminence and the mandibular fossa according to facial profile because there are differences in muscle activity among different facial profiles.

For the evaluation of eminence inclination, the 2 methods most recommended in the literature were used<sup>1,8,9,17</sup>; additionally, for most measurements, the corrected sagittal reconstruction of the eminence was selected because this is the area that best represents eminence inclination.<sup>3-5,17</sup>

In the first method, measurements were made through the angle formed by the inclination of the posterior wall of the articular eminence with the Frankfort plane (angle  $\alpha$ ),<sup>8,9,17</sup> which corresponds to the movement of the condylar head in reality.<sup>1,3</sup> The results showed that males with a brachycephalic facial profile presented a significantly steeper angle  $\alpha$  (62.76 degrees) compared with those with a dolichocephalic facial profile (51.28 degrees) and those with a mesocephalic facial profile (56.69 degrees). It has been shown that normal inclination values are estimated to be between 30 degrees and 60 degrees, with values below 30 degrees being classified as flat eminences, whereas values higher than 60 degrees are classified as steep eminences.<sup>8</sup> Overly flat eminences can be associated with degenerative diseases, such as osteoarthritis,<sup>4</sup>

whereas overly inclined eminences may be related to dislocation of the articular disk.<sup>8,24</sup> Thus, our results indicate that patients with a brachycephalic profile may be more prone to disk displacement. However, this is something that still needs to be proven in future studies.

In the second method of measuring the inclination of the articular eminence, the angle formed between the Frankfort plane and a line connecting the roof of the mandibular fossa to the lowest point of the articular eminence (angle  $\beta$ ) was evaluated. This method is related to variations arising from articular eminence height.<sup>8,9,17</sup> Both male and female patients with brachycephaly had higher values, confirming these patients' tendency to present structures that may cause greater interference in the displacement of the disk during the normal excursion of the condyle.

It may be suggested that the differences in angles  $\alpha$  and  $\beta$  are caused by the greater muscle tone and stronger bite of individuals with brachycephaly.<sup>13-16</sup> Compared to patients with dolichocephaly, these individuals have mechanical advantages, such as a smaller gonial angle and reduced facial height, which make bite force more effective.<sup>13,14</sup> In addition, individuals with brachycephaly present greater muscle strength in the mandibular elevating muscles (masseter and temporal).<sup>14</sup> In contrast, individuals with dolichocephaly have lower muscle tone and, consequently, lower masticatory efficiency, requiring more masticatory cycles to promote food breakage.<sup>13</sup>

Additionally, it is suggested that in males with brachycephaly, the presence of male hormones tends to increase muscle strength even further.<sup>17</sup> This may possibly be transmitted to the articular disk—condylar head complex in the anteroposterior plane, resulting in a greater level of bone remodeling in the inclination of the articular eminence. This may be the reason for the higher inclination of the eminence in males with brachycephaly compared with those with other facial profiles. With regard to females with a brachycephalic profile, we believe that the bite forces are not so excessive as to promote remodeling of the inclination of the articular eminence, but these forces do provide an increase in the AEh in females with a brachycephalic profile compared with females with dolichocephalic and mesocephalic profiles.

Angle  $\delta$ , which refers to the measurement of the lateral wall of the mandibular fossa, was also evaluated.<sup>9</sup> In addition to the rotational—translational movement (anteroposterior movement), the articular disk—condylar head complex also moves laterally. In the present study, males with brachycephaly presented significantly higher values for the inclination of the lateral wall of the mandibular fossa compared with individuals with dolichocephaly. According to Verner et al.<sup>9</sup> higher

values of this angle indicate more muscular forces exerted on the articular disk–condylar head complex, which consequently generates remodeling of the lateral wall of the mandibular fossa. Therefore, these results confirm that in males with a brachycephalic profile, it is possible that more force is generated in the articular disk–condylar head complex. This is the case both in the anteroposterior movement (leading to a larger inclination of the eminence) and in the lateral direction of the mandibular fossa.

Some studies<sup>25,26</sup> suggested an association between the articular eminence and facial structures, whereas other studies<sup>1,4,5,11</sup> indicated association with bite forces. However, because both facial structures and muscular function are active in the facial profile, we suggest that the articular eminence and the mandibular fossa may be affected by both factors.

According to Bavia et al.,<sup>16</sup> the difference in muscle fiber composition of the brachyfacial masseter, which is characterized by rapid contraction and less resistance to fatigue, may be associated with the presence of muscular pain in individuals with brachycephaly presenting temporomandibular disorders. In addition, on the basis of the results of the present study, we suggest that the greater inclination and AEh in these individuals can also be considered causal factors in painful symptoms. The more inclined the eminence, the more the condylar head is forced into an inferior movement, causing an increase in the amplitude of condylar excursion.<sup>8,10</sup> In addition, a greater inclination of the articular eminence causes an increase in the posterior rotation of the articular disk. This can cause loosening of the ligaments that connect the articular disk to the condylar head,<sup>7</sup> leading to disk displacement.<sup>24,27</sup> However, because of the multifactorial nature of temporomandibular disorders,<sup>28</sup> further studies should be performed to clarify whether individuals with a brachycephalic profile are, indeed, more predisposed to this dysfunction.

Although these results may be attributed to the muscular physiologic action of individuals with a brachycephalic profile, it is suggested that during the restorative/prosthetic or orthodontic treatment, the facial profile should also be analyzed. This analysis should be performed to avoid an imbalance in the breakage and shear forces during the masticatory function and, consequently, in the TMJ structures.

Finally, this study aimed to understand potential association between the patient's facial profile and the morphology of the articular eminence and the mandibular fossa classified by gender. The results indicated no significant difference in measurements between males and females, suggesting that the factors at work in the association of facial profile and measurements of the articular eminence and mandibular fossa are unaffected by sex.

## CONCLUSIONS

Articular eminence morphology is associated with the facial profile, specifically with increased height values for both males and females with a brachycephalic profile. The inclination of the articular eminence and the lateral wall of the mandibular fossa exhibited the greatest values for male patients with a brachycephalic profile. Consequently, it is recommended that dental professionals be aware of the differences between facial profiles and take these into account when planning treatment.

## PRESENTATION

This study was presented as a poster in the XXV Odontological Congress at the Piracicaba Dental School, University of Campinas (XXV Jornada Odontológica de Piracicaba – FOP/UNICAMP) on May 25, 2018, and in the 35th Annual Meeting of the Brazilian Division of the International Association for Dental Research (SBPqO-IADR), on September 4, 2018.

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