Pharyngeal airway characterization in adolescents related to facial skeletal pattern: A preliminary study

Lígia Vieira Claudino,a Claudia Trindade Mattos,b António Carlos de Oliveira Ruellas,c and Eduardo Franzoti Sant’ Anna*
Rio de Janeiro, Brazil

**Introduction:** The objective of this study was to characterize the volume and the morphology of the pharyngeal airway in adolescent subjects, relating them to their facial skeletal pattern. **Methods:** Fifty-four subjects who had cone-beam computed tomography were divided into 3 groups—skeletal Class I, Class II, and Class III—according to their ANB angles. The volumes of the upper pharyngeal portion and nasopharynx, and the volume and morphology of the lower pharyngeal portion and its subdivisions (velopharynx, oropharynx, and hypopharynx) were assessed with software (version 11.5; Dolphin Imaging & Management Solutions, Chatsworth, Calif). The results were compared with the Kruskal-Wallis and the Dunn multiple comparison tests to identify intergroup differences. Correlations between variables assessed were tested by the Spearman correlation coefficient. Correlations between the logarithms of airway volumes and the ANB angle values were tested as continuous variables with linear regression, considering the sexes as subgroups. **Results:** The minimum areas in the Class II group (112.9 ± 42.9, 126.9 ± 45.9, and 142.1 ± 83.5 mm²) were significantly smaller than in Class III group (186.62 ± 83.2, 234.5 ± 104.9, and 231.1 ± 111.4 mm²) for the lower pharyngeal portion, the velopharynx, and the oropharynx, respectively, and significantly smaller than the Class I group for the velopharynx (201.8 ± 94.7 mm²). The Class II group had a statistically significant different morphology than did the Class I and Class III groups in the velopharynx. There was a tendency to decreased airway volume with increased ANB angle in the lower pharyngeal portion, velopharynx, and oropharynx. In the upper pharyngeal portion, nasopharynx, and hypopharynx, there seemed to be no association between the airway volume and the skeletal pattern. **Conclusions:** The Class II subjects had smaller minimum and mean areas (lower pharyngeal portion, velopharynx, and oropharynx) than did the Class III group and significantly less uniform velopharynx morphology than did the Class I and Class III groups. A negative correlation was observed between the ANB value and airway volume in the lower pharyngeal portion and the velopharynx (both sexes) and in the oropharynx (just in male subjects). (Am J Orthod Dentofacial Orthop 2013;143:799-809)

The upper airway is a structure responsible for one of the main vital functions in the human organism—breathing. The interest in studying the upper airway has always been present in orthodontics, and 1 main objective is to clarify the relationship between pharynx structures and craniofacial complex growth and development.1-4

Obstructive processes of morphologic, physiologic, or pathologic nature, such as hypertrophy of adenoids and tonsils, chronic and allergic rhinitis, irritant environmental factors, infections, congenital nasal deformities, nasal traumas, polyps, and tumors, are predisposing factors to a blocked upper airway. When that happens, a functional imbalance results in an oral breathing pattern that can alter facial morphology and dental arch forms, generating a malocclusion.2,5,6

Considering the functional matrix theory proposed by Moss,7 the association of respiratory and masticatory functions and swallowing might act on craniofacial development.
The literature is controversial when it comes to the possible associations among respiratory function, facial morphology, and occlusion. The ways in which variation in the airflow can influence growth and development are not completely elucidated. These questions remain unanswered because of methodologic limitations related to, among other factors, the multifactorial etiology of malocclusion, the limitations in the cephalometric method, and the lack of longitudinal studies assessing the airway.\(^8,9\)

Many studies have assessed the relationship between craniofacial morphology and the pharyngeal airway in cephalometric radiographs.\(^10\)–\(^14\) However, lateral teleradiographs are limited because they reproduce a 3-dimensional structure in a 2-dimensional way that does not allow the assessment of cross-sectional areas and volumes of these structures.\(^15\),\(^16\)

Techniques that allow the precise diagnosis of changes in the upper airway considering their morphology and volume are fundamental to ensure normal development of the craniofacial complex in growing subjects and the choice of an adequate treatment plan.\(^17\),\(^18\)

Although it might expose patients to higher levels of radiation than isolated customary orthodontic digital radiography,\(^19\) cone-beam computed tomography (CBCT) uses a significantly reduced radiation dose compared with medical computed tomography machines and is equivalent to traditional dental imaging methods such as a full-mouth series.\(^20\),\(^21\) CBCT has the advantage of resulting images with good accuracy.\(^16\),\(^18\),\(^22\),\(^23\) Specific softwares and their tools make it possible to obtain highly reliable measurements of osseous structures and facial characteristics, as well as to assess soft tissues in 3 dimensions, including measurements of the oropharynx for volume, morphology, and minimum axial area. Many studies have been developed in this area.\(^24\)–\(^32\)

Guijarro-Martinez and Swennen\(^33\) published a systematic review concerning the CBCT analysis of the upper airway and included 46 clinically or technically relevant articles from 382 articles from 1968 to 2010 found in PubMed (National Library of Medicine, NCBI). The results indicate that the 3-dimensional analysis of the upper airway by using CBCT can be accurate and reliable, although important aspects still need to be elucidated.

The aim of this study was to characterize through CBCT and 3-dimensional image reconstruction software the volumes of the upper pharyngeal portion and nasopharynx, and the volume, minimum axial area, and morphology of the lower pharyngeal portion and its subdivisions—velopharynx, oropharynx, and hypopharynx—in adolescent subjects, relating them to their facial skeletal patterns.

**MATERIAL AND METHODS**

This project was approved by the research ethics committee of the Institute of Collective Health Studies from the Universidade Federal do Rio de Janeiro in Brazil. All patients signed a consent form allowing the use of their orthodontic records.

A sample calculation was performed based on the mean standard deviation from a previous study.\(^31\) A sample size of at least 17 patients would be necessary in each group to detect differences of 65 mm\(^2\) in the minimum axial area and of 2500 mm\(^3\) in the oropharynx volume, with a test power of 0.80 (\(\alpha = 0.05\)). The formula used was described by Pandis.\(^34\)

The sample was composed of 54 CBCT scans, requested as part of the initial records needed for diagnosis and planning of patients starting their orthodontic treatment in the orthodontic clinics of the postgraduate program in our school of dentistry. All CBCT scans used so far as orthodontic records in this university were performed on 1 device (i-CAT; Imaging Sciences International, Hatfield, Pa) according to a standard protocol (120 kV, 5 mA, 13 \(\times\) 17-cm field of view, 0.4-mm voxel, and 20-second scanning time). The CBCT scans were made with each subject sitting in a vertical position, and with the Frankfort horizontal plane parallel to the ground and in maximum intercuspation.

The CBCT scans of patients in the sample were selected from the sequential initial records from the clinics. The following inclusion criteria were used in sample selection: DICOM file, no previous orthodontic treatment or other treatment that might interfere with the natural course of maxillomandibular growth and development, good health conditions, no airway pathology, cranio-cervical inclination between 90° and 110° (since head posture might interfere with airway volume),\(^35\) CBCT image including the whole fourth cervical vertebra, no severe hyperdivergence (FMA angle, 19°–30°), and age from 13 to 20 years. The inclination between the palatal plane and the sella-nasion plane was measured to characterize the sample. To take the initial angular measurements necessary to confirm the inclusion criteria and distribute the subjects among the groups (ANB and FMA angles, and cranio-cervical inclination), 2-dimensional lateral cephalometric radiographs were created (ray-sum technique) from the CBCT scans in the software (version 11.5; Dolphin Imaging & Management Solutions, Chatsworth, Calif), and measurements were made by an experienced operator (L.V.C.). The subjects were then divided into 3 groups considering the relationship between the maxilla and the mandible...
(ANB angle): Class I (1° ≤ ANB ≤ 3°), Class II (ANB > 3°), and Class III (ANB < 1°).31 Fewer Class I and Class III subjects met all inclusion criteria than Class II patients. To maintain the sample size calculated and make the groups more even, random subjects were excluded from the Class II group using initials and sex. No numeric parameters were considered.

The groups were divided in the following way: Class I (17 patients, 12 female and 5 male), Class II (20 patients, 10 female and 10 male), and Class III (17 patients, 11 female and 6 male). The mean age of the sample was 16.28 years (SD, 2.30 years) and the mean FMA angle was 24.51° (SD, 4.37°). The mean inclination between the palatal plane and the sella-nasion plane was 8.40° (SD, 3.60°). The lower pharyngeal portion—velopharynx, oropharynx, and hypopharynx—were delimited by 4 cross-sectional planes, constructed with previously determined points. The upper limit of the velopharynx was the palatal plane, and the lower limit was a plane parallel to the palatal plane that intersected the uvula (Fig 4, A). The upper limit of the oropharynx segment was the lower limit of velopharynx, and its lower limit was a plane parallel to the palatal plane intersecting the upper point of the epiglottis (Fig 4, B). The upper limit of the hypopharynx was the lower limit of the oropharynx, and its lower limit was a plane parallel to the palatal plane intersecting the lower and most anterior point of the fourth cervical vertebra (Fig 4, C).

Once volume, minimum axial area, and total length of the lower pharyngeal portion, velopharynx, oropharynx, and hypopharynx were obtained, the mean area of each segment was calculated using the following ratio: mean area = volume/total airway length.

The morphologic characterizations of the lower pharyngeal portion, velopharynx, oropharynx, and hypopharynx were possible by calculation of the following ratio for each segment: morphology = minimum area/mean area.36 This ratio shows whether the area distribution along the upper airway was uniform or irregular.

### Statistical analysis

All measurements were repeated in 40% of the CBCT scans after a 2-week interval. Calibration of the operator was tested with the intraclass correlation coefficient.

A descriptive analysis, including means and standard deviations, was performed for all quantitative variables. The Kolmogorov-Smirnov test was applied to assess the

### Table I. Descriptive statistics of age and cephalometric characteristics of patients in all groups, classified according to ANB angles

<table>
<thead>
<tr>
<th></th>
<th>Class I (n = 17)</th>
<th>Class II (n = 20)</th>
<th>Class III (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>15.62 (2.17)</td>
<td>16.83 (2.74)</td>
<td>16.28 (1.74)</td>
</tr>
<tr>
<td>FMA (°)</td>
<td>24.51 (2.37)</td>
<td>25.73 (4.07)</td>
<td>24.05 (3.52)</td>
</tr>
<tr>
<td>ANB (°)</td>
<td>2.18 (0.76)</td>
<td>5.55 (2.00)</td>
<td>−2.05 (2.52)</td>
</tr>
<tr>
<td>PP-SN (°)</td>
<td>6.64 (3.89)</td>
<td>8.7 (3.21)</td>
<td>9.83 (3.18)</td>
</tr>
</tbody>
</table>

Different superscript letters mean statistically significant difference (same line).

PP-SN, Angle between the palatal plane and the sella-nasion line.
normality of the data. No significant sex-related differences were found; therefore, the data were combined. The Kruskal-Wallis test was used to verify whether there were statistically significant differences ($P < 0.05$) among the groups. The Dunn multiple comparison test was then used to identify where these differences were. Correlations among the variables were tested by the Spearman correlation coefficient. The $P$ values were adjusted for multiple comparisons. Correlations between the logarithms of airway volumes and the ANB angle values were tested as continuous variables using linear regression, with the sexes as subgroups.

**RESULTS**

The intraclass correlation coefficient results were higher than 0.95 for all variables assessed; this confirmed the operator’s calibration.

The Kruskal-Wallis nonparametric test was applied for all variables, since the distribution of some variables was not normal. Comparisons among mean values of all groups for all dimensional variables (except for volumes) assessed for each airway segment are given in Tables II through V.

In the lower pharyngeal portion, the Class II group had a significantly smaller ($P < 0.007$) upper length than did the Class I group. The most constricted area was in the middle portion (50% of the total length) in the Class II group. The Class II group also showed significantly smaller ($P < 0.007$) minimum airway area and mean area than did the Class III group (Table II).

All groups showed variations in lower pharyngeal portion morphology, characterized by a less uniform distribution of the airway area along the length of this structure. However, no statistically significant difference was found (Table II).

The Class II group had significantly smaller ($P < 0.01$) velopharynx minimum axial area and mean area, and a greater morphologic variation than did the Class I and Class III groups (Table III).

In the oropharynx segment, the Class II group showed significantly smaller minimum axial area and mean area than did the Class III group (Table IV).

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Fig 1. Limits of the upper pharyngeal portion: A, determination of the last axial slice before the nasal septum fuses with the pharyngeal posterior wall; B, the reflection of that slice in the sagittal plane defines the upper limit, and the palatal plane determines the lower limit.

Fig 2. Nasopharynx limits: the lower limit is the palatal plane ($pp$) extended to the posterior pharyngeal wall, and the upper limit is the line uniting PNS and So (middle point in the $Ba-S$ line).
No statistically significant differences were observed in the hypopharynx segment in any assessed measurements (Table V).

The correlation analysis between airway volumes and the variables FMA, age, and sex, and the correlation analysis between the palatal plane to sella-nasion and ANB angles are shown in Table VI. No variable had a correlation with airway volumes.

The plots of the correlations between airway volumes and ANB angle (Fig 5) showed a tendency in male
subjects toward greater volumes than in females, except for the nasopharynx, where there was no difference. In the lower pharyngeal portion, velopharynx, and oropharynx, the linear regression coefficient (R²) was more consistent; the greater the ANB angle, the smaller the airway volume. In the oropharynx, this was significant only in male subjects. In the upper pharyngeal portion, nasopharynx, and hypopharynx, there seemed to be no association between airway volume and skeletal pattern.

DISCUSSION

The main objective of this study was to assess the volumes of the upper pharyngeal portion and nasopharynx and the volumes, the minimum axial areas, and the morphology of the lower pharyngeal portion and its segments (velopharynx, oropharynx, and hypopharynx) using CBCT scans of 13- to 20-year-old subjects divided into Class I, Class II, and Class III groups according to their ANB angles.

The Dolphin Imaging software we used is user friendly and provides quick upper airway segmentation—good segmentation sensitivity that can be checked in 2-dimensional slices (axial, coronal, and sagittal)—and minimum cross-sectional area analysis. It is considerably more accurate than or similar to other softwares in upper airway assessments.27,37 Its disadvantages include cost, lack of tools to adjust or correct the segmentation in 2-dimensional slices, and threshold interval units that are not comparable with other imaging softwares.37 Many studies have been performed to assess the relationship between upper airway and dentomaxillofacial morphology using CBCT.25,26,30,31,38 Nevertheless, most of these studies assessed only airway segments that do not necessarily represent the complete upper portion of this complex structure. The assessment of the entire upper airway is necessary to establish a correct diagnosis.28 We were concerned with determination of the anatomic limits of the upper airway and its measurements.

### Table II. Intergroup comparison of LPP dimensional measurements and morphology

<table>
<thead>
<tr>
<th>Class</th>
<th>Mean (SD)</th>
<th>Class</th>
<th>Mean (SD)</th>
<th>Class</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I (n = 17)</td>
<td></td>
<td>Class II (n = 20)</td>
<td></td>
<td>Class III (n = 17)</td>
<td></td>
</tr>
<tr>
<td>LPP total length (mm)</td>
<td>66.7 (7.9)</td>
<td>67.0 (7.8)</td>
<td>70.22 (5.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPP upper length (mm)</td>
<td>50.8 (14.5)</td>
<td>31.20 (15.2)</td>
<td>46.81 (17.65)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPP minimum area (mm²)</td>
<td>132.45 (48.5)</td>
<td>112.9 (42.9)</td>
<td>186.62 (83.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPP mean area (mm²)</td>
<td>205.38 (68.7)</td>
<td>211.8 (52.9)</td>
<td>299.93 (93.16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum area location (Ul/Tl)</td>
<td>0.7 (0.2)</td>
<td>0.5 (0.2)</td>
<td>0.6 (0.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPP morphology (Amin/Amean)</td>
<td>0.5 (0.1)</td>
<td>0.5 (0.1)</td>
<td>0.6 (0.1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Different superscript letters mean statistically significant difference (same line).

LPP, Lower pharyngeal portion; Ul, upper airway length; Tl, total airway length; Amin/Amean, minimum area/mean area.

### Table III. Intergroup comparison of VP dimensional measurements and morphology

<table>
<thead>
<tr>
<th>Class</th>
<th>Mean (SD)</th>
<th>Class</th>
<th>Mean (SD)</th>
<th>Class</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I (n = 17)</td>
<td></td>
<td>Class II (n = 20)</td>
<td></td>
<td>Class III (n = 17)</td>
<td></td>
</tr>
<tr>
<td>VP length (mm)</td>
<td>29.5 (4.9)</td>
<td>28.7 (4.1)</td>
<td>21.5 (2.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VP minimum area (mm²)</td>
<td>201.8 (94.7)</td>
<td>126.9 (45.9)</td>
<td>234.5 (104.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VP mean area (mm²)</td>
<td>291.0 (93.6)</td>
<td>218.8 (87.8)</td>
<td>327.9 (112.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VP morphology (Amin/Amean)</td>
<td>0.7 (0.1)</td>
<td>0.6 (0.1)</td>
<td>0.7 (0.2)</td>
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</table>

Different superscript letters mean statistically significant difference (same line).

VP, Velopharynx; Amin/Amean, minimum area/mean area.

### Table IV. Intergroup comparison of OP dimensional measurements and morphology

<table>
<thead>
<tr>
<th>Class</th>
<th>Mean (SD)</th>
<th>Class</th>
<th>Mean (SD)</th>
<th>Class</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I (n = 17)</td>
<td></td>
<td>Class II (n = 20)</td>
<td></td>
<td>Class III (n = 17)</td>
<td></td>
</tr>
<tr>
<td>OP length (mm)</td>
<td>18.56 (3.9)</td>
<td>14.73 (5.4)</td>
<td>16.0 (5.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP minimum area (mm²)</td>
<td>160.2 (62.6)</td>
<td>142.1 (83.5)</td>
<td>231.1 (111.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP mean area (mm²)</td>
<td>210.9 (86.9)</td>
<td>195.1 (85.3)</td>
<td>283.4 (124.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP morphology (Amin/Amean)</td>
<td>0.76 (0.1)</td>
<td>0.7 (0.1)</td>
<td>0.8 (0.1)</td>
<td></td>
<td></td>
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</tbody>
</table>

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OP, Oropharynx; Amin/Amean, minimum area/mean area.
and the ANB angle. Our study showed that the use of 2 criteria to eliminate such limitations is not always coincident. Many studies have demonstrated that the parameters used and described in the literature.

The sample division into Class I, Class II, and Class III skeletal patterns according to the ANB angle (Table VI). This angle might be influenced by the anteroposterior position of nasion relative to Points A and B, among other factors, and some authors have suggested that the diagnosis of such discrepancies must be based on more than 1 anteroposterior appraisal. Despite its limitation, the ANB angle was used alone because the use of 2 criteria to eliminate such limitations is not always coincident. Many studies have demonstrated negative correlations between the oropharynx volume and the ANB angle. Our study showed significant negative correlations between the lower pharyngeal portion and the velopharynx volumes and the ANB angle (Fig 5).

Our sample included subjects with an FMA angle from 19° to 30°. Therefore, no subject with severe mandibular hypodivergency or hyperdivergency was included in the sample, because this aspect can influence airway dimensions, as described by Joseph et al. These authors observed greater pharyngeal anteroposterior narrowing in hyperdivergent subjects at the levels of the hard palate and the oropharynx, the soft-palate tip, and the mandible. Ucar and Uysal reached similar conclusions when comparing craniofacial dimensions and airway and tongue width in healthy Class I subjects with different vertical growth patterns. They observed smaller nasopharynx airway dimensions in hyperdivergent subjects compared with hypodivergent and normodivergent subjects. In our study, no correlation was found between airway volume and FMA angle (Table VI); this is probably because subjects with a severe divergence were eliminated from the sample. These findings agree with the results of El and Palomo in normodivergent subjects (FMA angle, 19°–31°). No correlation was observed between the inclination of the palatal plane and the ANB angle (Table VI).

The age range in this study was selected to observe airway differences in growing adolescents with different skeletal patterns. According to Schendel et al, airway dimensions increase until age 20 years; after this, moderate stability is observed. No statistically significant differences were observed in the upper pharyngeal portion and the nasopharynx volume among our groups. Nevertheless, a slight tendency of increase was observed with an increase of ANB angles (Fig 5, A and B). These results might be explained by the difficulty in the assessment of the upper pharyngeal portion volume in areas where nasal conchae presented a more complex anatomy. This difficulty was also reported by El and Palomo. However, they did not find a statistically significant smaller volume in this region in their Class II subjects.

Some studies have demonstrated that the parameters used to determine pharyngeal airway dimensions, such as the ANB angle, are important in the assessment of craniofacial and airway differences in growing adolescents with different skeletal patterns. According to Schendel et al, airway dimensions increase until age 20 years; after this, moderate stability is observed. No statistically significant differences were observed in the upper pharyngeal portion and the nasopharynx volume among our groups. Nevertheless, a slight tendency of increase was observed with an increase of ANB angles (Fig 5, A and B). These results might be explained by the difficulty in the assessment of the upper pharyngeal portion volume in areas where nasal conchae presented a more complex anatomy. This difficulty was also reported by El and Palomo. However, they did not find a statistically significant smaller volume in this region in their Class II subjects.

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Fig 5. Plots showing the linear regression analyses between the logarithms of airway volume and the ANB angle values tested as continuous variables, with the sexes as subgroups. The blue circles represent males, and the green circles represent females. The black line represents the mean correlation of the entire sample. The blue and green lines represent the mean correlations for male and female subjects, respectively. Segments analyzed: A, upper pharyngeal portion; B, nasopharynx; C, lower pharyngeal portion; D, velopharynx; E, oropharynx; F, hypopharynx. *P < 0.05; **P < 0.01; ***P < 0.001.
as volume, minimum cross-sectional area, length, and form, are correlated with obstructive sleep apnea syndrome and its gravity.46-49 The probability of its development increases with minimum cross-sectional area narrowing, which is considered severe when it is smaller than 52 mm², intermediate when it is between 52 and 110 mm², and less severe if it is above 110 mm².50 Our Class II subjects had significantly smaller lower pharyngeal portions, velopharynx and oropharynx minimum axial areas and mean areas than did the Class III group, and a mean lower pharyngeal portion minimum axial area of 112.9 mm². One subject in the Class II group even had a minimum axial area smaller than 52 mm², which is considered severe. This finding led to the conclusion that Class II subjects are more susceptible to the development of obstructive sleep apnea syndrome than are patients with different skeletal patterns.

Additionally, studies show that most obstructive sleep apnea subjects’ airway constriction occurs at the level of the oropharynx, near the occlusal plane.36,51 In this study, the Class II group had smaller minimum axial areas, which were located in the oropharynx segment.

The upper airway morphology is also described in the literature as a parameter that can predict the chance of obstructions developing in these structures.36,46 In our study, the morphology was characterized by the ratio between the minimum axial area and the mean axial area, and it was considered more irregular if the value obtained from the ratio was lower. When this ratio in the lower pharyngeal portion was compared among the groups, all groups had irregularities in airway morphology as shown by the morphology values (Table II), and no statistically significant difference was found among the groups. Nevertheless, the velopharynx segment was more sensitive to morphologic changes, and the Class II group had a less uniform area distribution compared with the Class I and Class III groups (Table III).

Another fact from this study was that subjects with higher ANB values had smaller lower pharyngeal portions and velopharynx volumes and velopharynx minimum axial areas compared with the other groups. Alves et al19 reached similar conclusions when evaluating the dimensions of the pharyngeal airway space in 50 awake, upright children with different anteroposterior skeletal patterns using CBTC. The patients were divided into 2 groups according to their ANB angles (group I, 2° ≤ ANB ≤ 5°; group II, ANB > 5°). Those authors concluded that the pharyngeal airway space was statistically larger in group I than in group II, indicating that the dimensions of the pharyngeal airway space are affected by different anteroposterior skeletal patterns.

Additionally, our results show that when a negative correlation was found between airway volume and ANB angle (lower pharyngeal portion and velopharynx), a difference between the sexes was notable, although this difference was not enough to trigger a significant correlation between airway volume and sex. Male subjects had greater airway volumes than did females; this is similar to the results of Shigeta et al,24 who found larger airway volumes in men than in women. When we considered the whole lower pharyngeal portion, this difference seemed to decrease with higher ANB values, which meant that men and women with severe skeletal Class II problems have no great differences in lower pharyngeal portion volumes. Specifically in the velopharynx segment, the difference between the sexes persisted no matter what the ANB value.

Therefore, orthodontists must be aware that specific dimensional characteristics such as a greater constriction might be associated with the skeletal pattern. Dimensional airway assessments of the upper airway that include 3- and 2-dimensional measurements such as those we used in this study are relevant information for the orthodontic diagnosis and treatment plan. Considering this information, an orthodontist must define the best treatment for each patient, avoiding treatments that could compromise airway dimensions in those who are already prone to have smaller dimensions in this structure.

These findings should be considered with caution, since this was a preliminary study. The small sample size did not allow an adequate statistical appreciation of the differences between the sexes. Based on these results, we intend to evaluate a larger sample and to adopt the lower limit of the oropharynx, since the hypopharynx showed no differences between the groups for any variable. That will simplify sample selection, since many patients were excluded from this study because they did not have the lower limit adopted (fourth cervical vertebra) in the tomographic image.

The comparison between Class I and Class III subjects showed similar airway dimensions, confirmed by the fact that no statistically significant difference was found in any measurement between these groups. The Class II group, however, had statistically significant smaller dimensions in many segments compared with the other 2 groups, especially the Class III group; this was similar to the findings of El and Palomo.31

Longitudinal studies of airway changes in subjects with different skeletal patterns in specific craniofacial growth and development periods should be performed to elucidate detailed knowledge on the relationship between upper airway morphology and function and craniofacial characteristics.
CONCLUSIONS

Based on the results from this study, the following conclusions can be inferred.

1. Class II subjects have smaller minimum and mean areas in the lower pharyngeal portion, and the velopharynx and oropharynx segments than do Class III subjects.
2. No dimensional differences were observed among the groups in the hypopharynx segment.
3. The velopharynx segment was more sensitive to airway morphologic changes, and the Class II group had the greatest irregularity in this region.
4. No statistically significant difference in airway dimensions was observed between the Class I and Class III groups.
5. A negative correlation was observed between ANB value and airway volume in the lower pharyngeal portion and the velopharynx (both sexes) and in the oropharynx only in male subjects.

REFERENCES


