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Differences in Pharyngeal Characteristics According to Angle Class of Malocclusion

SUMMARY

Objectives*: To investigate potential differences in the pharynx, the soft palate, the pharyngeal tonsil, and the tongue between patients with different Angle Classes of malocclusion.*

Study Design*: Pre-treatment lateral cephalograms of 116 normal breathing individuals aged between 9 and 12 years were analyzed. 20 linear and 4 angular measurements, as well as 5 variables concerning the surface area of the pharynx and the soft palate were evaluated.*

Results*: The angle formed by the palatal plane and the base of the skull had lower values in Class II groups. The soft palate height was smaller in Class II, div. 1 group. The angle between the soft and hard palates was smaller in Class III, followed by Class I, Class II, div. 2, and Class II, div. 1, with increasing values. The distance of the tongue from the palatal plane was larger in Class I and Class III groups. The surface area of the oropharynx was larger in Class III than in Class II groups. The total surface area of the pharynx had higher values in Class III than in Class II/1.*

Conclusion*: Subjects with Class II malocclusion may be more prone to develop respiratory related disorders, such as obstructive sleep apnea, followed by Class I and Class III subjects.*

Keywords: Malocclusion; Pharynx; Airway

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Introduction

In recent years, the increased interest for Obstructive Sleep Apnoea (OSA) has turned the attention of numerous researchers to assessing pharyngeal dimensions. Various techniques have been implemented to image the pharynx, including optic fibres, ultrasonography, and cineradiography[1,2], while the most commonly used methods are CT/CBCT scanning and MRI[3,4]. CT offers the advantage of detailed 3D evaluation of hard-tissue pharyngeal structures, but it is an expensive, high radiation dose method. Also, through MRI, the volume, size, and shape of airways can be measured without ionizing radiation, but this is an even more expensive method, difficult to be performed[5].

On the other hand, lateral cephalometric radiography has been extensively used in craniofacial research, although its use to study anatomical structures such as the pharynx, the soft palate, and the tongue is limited. It is a routinely used radiographic technique in orthodontics, with low cost and low radiation dose. Thus, it can well point to the study of craniofacial features, which have been associated with OSA[2]. A recent study that evaluated MRI and cephalometric images confirmed that the lateral cephalogram is a valid method for measuring dimensions of the nasopharyngeal and retropalatal region[6].

Research based on cephalometry identified high correlation of a specific skeletal morphology, such as a small mandible in a retrognathic position, with OSA[7-9]. Further evidence supports that anteroposterior jaw relationships are associated with airway morphology, which directly affects the OSA[4,10,11]. However, such studies have focused on skeletal criteria for defining their study groups. This is an appropriate methodology for research hypothesis evaluation, but the use of this

information in everyday clinical practice needs special educational background by the dentist. On the other hand, the Angle Classes of malocclusion is a widespread and easy to use diagnostic tool, even for not specially trained clinicians. If a specific relation between the Angle Classes of malocclusion, which is an easy and convenient diagnostic element, and anatomical parameters that affect the airway is evident, this could be used to indicate increased predisposition to airway related disorders, such as the OSA syndrome.

Therefore, the purpose of this study was to evaluate the size and position of the pharynx, the soft palate, the pharyngeal tonsil, and the tongue through lateral cephalometric radiographs and investigate potential differences in these parameters in different Angle Classes of malocclusion in preadolescent individuals with normal breathing.

Subjects and Methods

The study sample consisted of lateral cephalometric radiographs selected from the archive of the Orthodontic Department, Aristotle University of Thessaloniki, based on the following criteria: a) Caucasian origin; b) age between 9 and 12 years; c) free medical history; d) no previous orthodontic treatment; e) no breathing problems detected by clinical examination or mentioned by the patient/parent; f) no surgical excision of the tonsils and/or adenoids; g) no clefts, syndromes or severe craniofacial malformations; h) high quality pre-treatment lateral cephalometric X-rays; and i) malocclusion pattern that could be assigned to 1 of the 4 groups described below:

- Class I: bilateral Class I molar and canine relationship with normal overbite and overjet;
- Class II, division 1: bilateral Class II molar and canine relationship with overjet > 4mm
- Class II, division 2: bilateral Class II molar and canine relationship with overbite > 4mm and overjet < 4mm
- Class III: bilateral Class III molar and canine relationship with overjet ≤ 0mm.

The archive from 2000 to 2004 was searched in a consecutive manner to identify the first 30 subjects that fulfilled the inclusion criteria. In order to obtain sex-balanced groups each gender was allowed to be predominant at most by 1 subject in each group. Regarding the Class III group, only 26 subjects fulfilled the inclusion criteria and were used for the study. A detailed description of the study sample is presented in table 1.

Table 1. Description of the sample used in the present study

Malocclusion group	Gender	Age (Mean ± SD
Class I	14 M, 16F	10.7 ± 0.9
Class II, division 1	14M, 16F	10.5 ± 0.6
Class II, division 2	15M, 15F	10.7 ± 0.7
Class III	13M, 13F	10.3 ± 0.9
Total	56M, 60F	10.6 ± 0.8
P-value	ns[1]	ns[2]

[1]Chi-spuare, [2]One-way ANOVA

All radiographs were obtained from the same radiographic unit that had a magnification of 7%, which was not corrected. Patients were standing with the Frankfurt Horizontal plane parallel to the floor and were asked to have teeth in maximum intercuspation with slight contact, lips in relaxed position, and not to swallow.

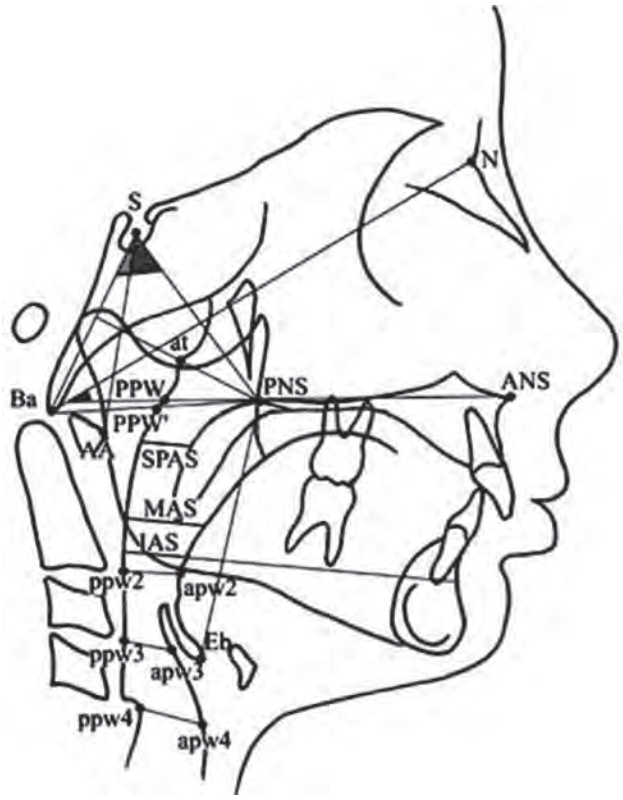

Figure 1. Parameters used to evaluate pharyngeal relationships: PNS-PPW, PNS-at, PNS-PPW', apw2-ppw2, apw3-ppw3, apw4-ppw4, SPAS, MAS, IAS, PNS-Eb, S-AA, NL-BaN, AA-Ŝ-PNS, Ba-Ŝ-PNS.

The X-rays were scanned and 41 points (21 to hard tissues, 19 to soft tissues) were digitized on screen by one investigator using the Viewbox 3 Software, which was appropriately modified for the needs of this study. 20 linear and 4 angular measurements that concerned the soft tissues of the pharynx (Fig. 1), the soft palate (Fig. 2), the pharyngeal tonsil (Fig. 3), and the tongue position (Fig. 4) were obtained. Moreover, 5 variables concerning the surface area of the pharynx and the soft palate[12] (Fig. 5) were calculated using Adobe Photoshop 6.0 software. A detailed description of the variables used in the present study along with the relevant references is provided in Appendix 1.

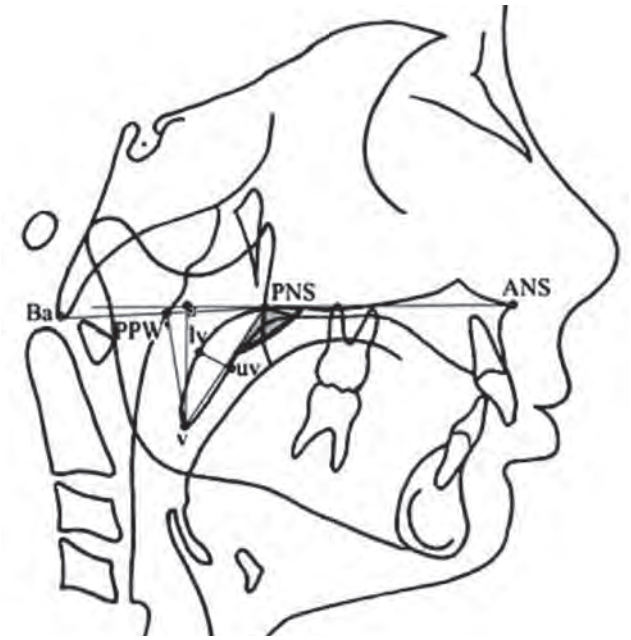

Figure 2. Parameters used to determine soft palate relationships: PNS-v, lv-uv, v- PPW´, v⊥NL, NL-v.

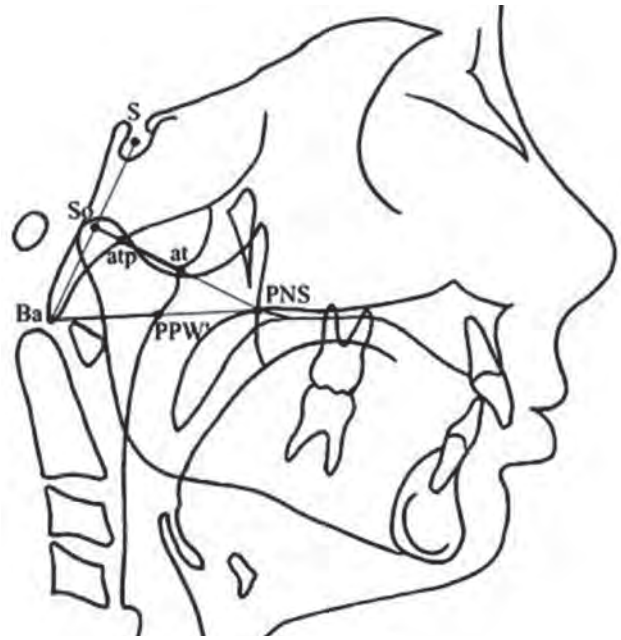

Figure 3. Parameters used to evaluate pharyngeal tonsil relationships: at-atp, PPW'- Ba, at-So.

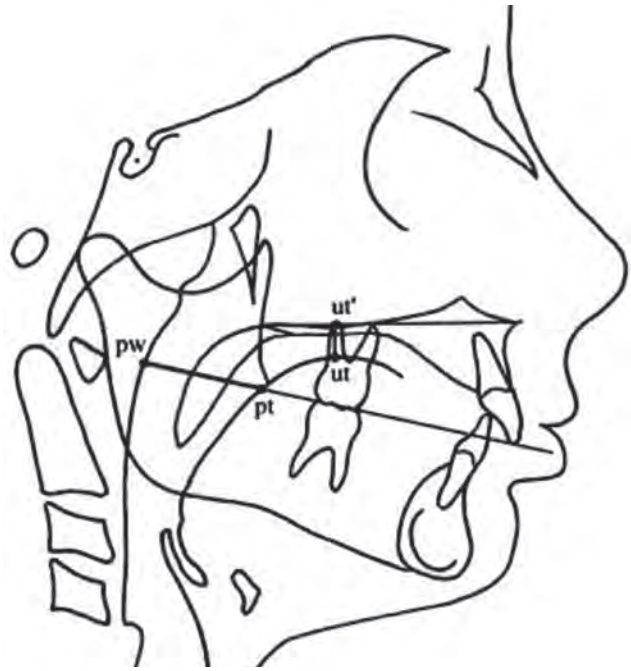

Figure 4. Parameters used to evaluate tongue position: pt-pw, ut-ut'.

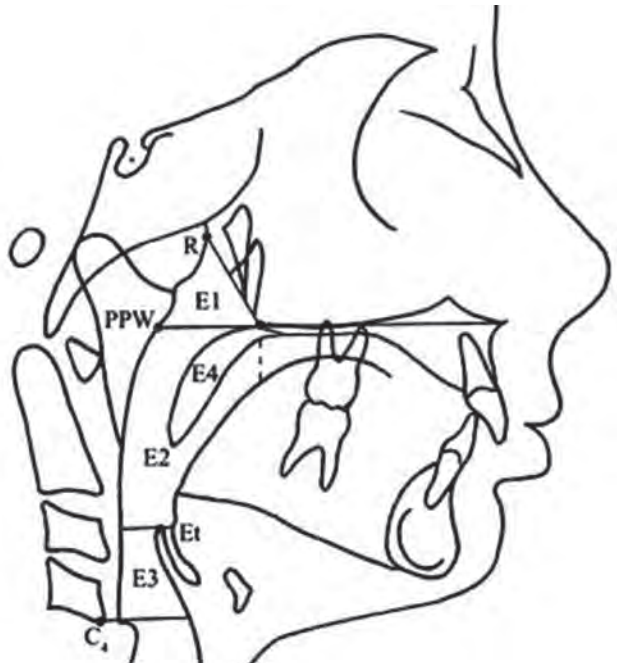

Figure 5. Parameters used to evaluate the surface area of the pharynx and the soft palate: E1, E2, E3, E4, E5.

APPENDIX 1.

Detailed description of the cephalometric variables used in the study along with the relevant references.

Description of the parameters used to evaluate pharyngeal relationships (Figure 1).

PNS-PPW: The width of the rhinopharynx, measured as the distance between the posterior nasal spine and the posterior pharyngeal wall.[1]

PNS-at: The distance between the posterior nasal spine and point *at* on the pharyngeal tonsil.[2,3]

PNS-PPW': the distance between the posterior nasal spine and point PPW' on the posterior pharyngeal wall.[2,3]

apw2-ppw2: the distance between points apw2 and ppw2, which corresponds to the pharyngeal width at the lowest axis border.[4]

apw3-ppw3: the distance between points apw3 and ppw3, which corresponds to the pharyngeal width at the lowest edge of the 3rd cervical vertebra.[1]

apw4-ppw4: the distance between points apw4 and ppw4, which corresponds to the pharyngeal width at the lowest edge of the 4th cervical vertebra.[4]

SPAS (upper airway space): the distance from the posterior wall of the soft palate to the posterior pharyngeal wall at the level of the mid soft palate, along a line parallel to the Go-B plane.[5]

MAS (middle airway space): the distance from the base of the tongue to the posterior pharyngeal wall at the level of the uvula along a line parallel to the Go-B plane.[5]

IAS (lower airway space): the distance from the base of the tongue to the posterior pharyngeal wall, along Go-B plane.[5]

PNS-Eb: the vertical dimension of the upper airway, measured as the distance between points PNS and Eb.[5]

S-AA (posterior craniocervical height): the distance between points S and AA.[6]

NL-BaN: the angle formed by the palatal plane and the base of the skull.[7]

AA-Ŝ-PNS: anterior craniocervical depth.[6]

Ba-Ŝ-PNS: posterior craniocervical depth.[6]

Description of the parameters used to evaluate soft palate relationships (Figure 2).

PNS-v: the length of the soft palate, measured as the distance between the posterior nasal spine and the uvula.[8]

lv-uv: the thickness of the soft palate, measured as the distance between points lv and uv.[8]

v-PPW´: the height of the soft palate, measured as the distance between the uvula and point PPW´ on the posterior pharyngeal wall.[9]

v⊥NL: the height of the soft palate, measured as the projection of point v on the palatal plane.[9]

NL-v: the angle formed between the soft and hard palates.[9]

Description of the parameters used to evaluate pharyngeal tonsil relationships (Figure 3).

at-atp: the width of the pharyngeal tonsil between points at and atp.[1]

PPW'-Ba: the width of the pharyngeal tonsil between PPW' and Ba.[1]

at-So: the width of the pharyngeal tonsil between at and So.[10]

Description of the parameters used to evaluate tongue position (Figure 4).

pt-pw: the distance of the tongue from the posterior pharyngeal wall, measured between points pt and pw.[11]

ut-ut': the distance of the tongue from the palate, measured between the highest point on the tongue dorsal surface (ut) and point ut'.[11]

Description of the parameters used to evaluate the surface area of the pharynx and the soft palate (Figure 5).

E1: the rhinopharyngeal surface area, which is encompassed by points R, PNS and PPW.[5]

E2: the oropharyngeal surface area, which is encompassed by the lowest edge of the rhinopharynx, the posterior surface of the soft palate, the posterior undersurface of the tongue, a line parallel to the palatal plane that goes through point Et, and the posterior pharyngeal wall.[5]

E3: the hypopharyngeal surface area, which is encompassed by the lowest edge of the oropharynx, the posterior surface of the uvula, a line parallel to the palatal plane that goes through point C4, and the posterior pharyngeal wall.5

E4: the surface area of the soft palate, which is encompassed by the perimeter of the soft palate, starting and ending at point PNS having gone through point v.[5]

E5: the total pharyngeal surface area (E1+E2+E3).

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Descriptive and conclusive statistics were used for the study. The normality of data and homogeneity of variances were tested and confirmed by the Kolmogorov- Smirnov test and Levene's test, respectively. One-way ANOVA analysis was used to check if there was a statistically significant difference among the mean values of the 4 groups. Further *post hoc* analysis with pair-wise comparisons was performed with Waller-Duncan test. The level of significance was set at $p < 0.05$.

To estimate the method error, 35 randomly selected X-rays were re-digitized by the same investigator, after a time period of 3 weeks. Dahlberg's formula was used to calculate consistency between the 2 measurements.

For most variables the method error was under 10% of biological variability. 2 variables, the rhinopharyngeal surface area (E1) and the rhinopharyngeal width at the lowest edge of the 4th cervical vertebra (apw4-ppw4) were highly inconsistent and were not included in the results.

Results

Descriptive statistics of each variable for the 4 groups, as well as group comparisons are presented in table 2. Significant group differences were identified for the following 6 variables: NL-BaN angle, vlNL distance, NL-v angle, ut-ut' distance, E2 surface area, E5 surface area. Further statistical analysis for detecting between-group differences resulted in the following findings:

Table 2. Descriptive statistics and group comparisons for each variable tested (mean ± SC)

	PNS-PPW	PNS-at	PNS-PPW'	apw2-ppw2	apw3-ppw3	apw4- ppw4
Class I	20,0 ± 5,8	13,5 ± 2,8	17,7 ± 4,8	10,6 ± 3,8	12,7 ± 5,4	16,2 ± 4,6
Class II/1	22,2 ± 6,1	14,9 ± 4,2	19,7 ± 5,9	9,4 ± 4,1	12,1 ± 5,5	14,1 ± 4,8
Class II/2	23,1 ± 4,3	18,6 ± 15,4	21,1 ± 4,2	8,9 ± 3,0	12,7 ± 4,7	14,2 ± 2,5
Class III	20,6 ± 5,1	14,7 ± 3,0	20,0 ± 5,1	10,6 ± 4,2	14,1 ± 5,4	13,5 ± 2,7
p	ns	ns	ns	ns	ns	ns

	PNS-Eb	S-AA	NL-BaN	AA-Ŝ-PNS	Ba-S-PNS	PNS-v
Class I	61,9 ± 6,0	49,3 ± 4,9	27,6 ± 2,7^{a}	42,4 ± 4,9	59,3 ± 4,7	32,3 ± 2,6
Class II/1	60,6 ± 6,2	50,6 ± 4,1	25,3 ± 3,0^{b}	42,2 ± 5,1	59,4 ± 5,3	32,4 ± 4,3
Class II/2	59,8 ± 4,2	49,1 ± 4,6	26,6 ± 2,5$^{a'}$	42,2 ± 4,0	59,8 ± 4,4	32,9 ± 3,6
Class III	60,8 ± 4,9	49,3 ± 4,9	28,1 ± 2,5$^{a,b'}$	41,1 ± 5,0	58,7 ± 5,3	32,4 ± 3,1
p	ns	ns	0.001*	ns	ns	ns

	NL-v	at-atp	PPW'-Ba	at-So	pt-pw	ut-ut'
Class I	131,1 ± 6,4^{a}	18,0 ± 3,2	27,7 ± 4,8	26,5 ± 3,0	22,1 ± 4,1	9,6 ± 3,5^{a}
Class II/1	136,2 ± 8,1^{b}	17,6 ± 3,2	26,4 ± 6,1	25,5 ± 3,4	20,4 ± 4,0	7,8 ± 3,0^{b}
Class II/2	132,7 ± 8,3^{a}	19,5 ± 16,0	25,4 ± 5,7	25,7 ± 5,4	20,9 ± 3,9	6,7 ± 2,4^{b}
Class III	126,6 ± 4,9^{c}	17,5 ± 3,0	25,3 ± 4,5	25,3 ± 3,0	22,1 ± 4,2	9,6 ± 3,0^{a}
p	0.000*	ns	ns	ns	ns	0.000*

	E4	E5
Class I	2,1 ± 0,3	11,3 ± 1,9
Class II/1	2,0 ± 0,6	10,5 ± 2,4^{a}
Class II/2	2,0 ± 0,4	10,8 ± 1,7
Class III	2,1 ± 0,5	12,0 ± 2,4^{b}
p	ns	0.048*

For each variable tested values with different letters as superscripts differ significantly ($a \neq b \neq c$ and $a' \neq b'$) (Waller-Duncan test)
ns - not significant
* - p<0

The angle formed by the palatal plane (NL) and the base of the skull plane (BaN) presented significantly lower values in Class II/1 than in Classes I and III and it also showed statistically significantly lower values in Class II/2 than in Class III cases;

The soft palate height, measured as the distance of the uvula from the palatal plane (v⊥NL) presented significantly lower values in Class II/1 group than in the other groups;

The angle between the soft and hard palates (NL-v) presented significantly lower values in Class III cases, followed by Class I and Class II/2 with higher values, and, finally, Class II/1 which presented even higher values;

The distance of the tongue from the palatal plane (ut-ut') presented significantly higher values in the Class I and Class III than in Class II/1 and II/2 groups. The surface area of the oropharynx (E2) presented marginally statistically significant higher values in the Class III than in Class II/1 and II/2 groups;

The total surface area of the pharynx (E5) presented significantly higher values in the Class III than in the Class II/1 patients group.

Discussion

In the present study we examined lateral cephalograms of untreated young individuals with normal breathing and concluded that the anatomy of the pharynx, the soft palate, and the tongue differs at specific features among the various Angle Classes of malocclusion. Mild overbite and overjet criteria were also applied for inclusion of a subject in the study to account for misleading molar relationships attributed to molar rotations, mesialization due to space loss, or similar reasons. No cephalometric inclusion criteria were applied in sample selection because this could insert bias on the results. Our aim was to assess the measured variables in groups defined by a simple and easy to use criterion, such as the Angle Class of malocclusion and not by more specific criteria that can be used only by specialists. The sample was representative of a regular orthodontic population, since it was selected in a consecutive manner (restricted just regarding gender) from the archives of an orthodontic clinic. Groups were also similar regarding distribution of chronological age, which is strongly correlated to skeletal age[13].

Longitudinal studies regarding growth of the pharynx concluded that changes in the complex pharyngeal soft tissues are accelerated between 6 and 9 years of age, while significantly less change occurs between 9 and 12 years of age[14]. Thus, by limiting the sample within this period (range: 9 to 12 years, mean: 10.6 ± 0.8 years), we minimized growth effect on the results. This is 1 reason for selecting subjects of this age. Another reason is that this is the age where people usually seek orthodontic treatment. Thus, our sample represented the major part of the untreated orthodontic population, where proper diagnosis and information to the patient and his/her parent should be provided. The balanced sex distribution allowed as not forming sub-groups depending on patients' gender and thus reducing the power of the study. In any case, previous studies did not show statistically significant differences between genders at this age[14,15].

Although most parameters evaluated did not differ significantly among the 4 groups, there were certain important findings. Of the angular measurements estimating the relationships of the pharynx, the angle formed by the palatal plane and the base of the skull (NL-BaN) was significantly smaller in Class II/1 and Class II/2 compared to Class III subjects. This parameter estimates the width of underlying skeletal elements of the nasopharynx and is considered important for detecting patients with nasal obstruction[16]. The lowest values reported for this measurement, in Classes II/1 and II/2, were probably caused by the more horizontally oriented posterior midline cranial base of the skull in Class II as compared to Class III group[17].

As for the tongue position, a statistically significant difference was found in the distance of the dorsal tongue surface from the palatal plane (ut-ut') in the 4 groups. Specifically, in Classes I and III the dorsal tongue surface (ut) lay at a lower position, while in Class II/1 and Class II/2 it lays at a shorter distance from the palatal plane (ut'). Moreover, the pt-pw measurement, which estimates the anteroposterior position of the tongue base, tended to present higher values in Classes I and III and lower values in Classes II/1 and II/2; however, this difference was not statistically significant. A likely explanation for these findings is that, in Class II, the tongue is restricted within a smaller space and pushed upward and backward, while in Class I and Class III the tongue spreads forward and downward.

Findings concerning the inclination of the soft palate are of particular interest. In Class III subjects, the angle between soft and hard palates (NL-v) was significantly smaller, while Class II/1 patients presented the highest values. Furthermore, in Class II/1, the distance of the uvula from the palatal plane (v⊥NL) was significantly shorter than in the other groups. On the other hand, the length of the soft palate (PNS-v) remained stable in the 4 groups. These may be caused by the position the tongue assumes in different Angle Classes, which may affect the corresponding activity of the palatoglossal muscles. For example, in Class III, the most anterior position of the tongue may activate the palatoglossal muscles more intensely and this can result in the soft palate being pulled further forward and downward than in the other groups. The measurements of the pharyngeal surface area presented statistically significant differences both in regards to

the oropharyngeal part and the total pharyngeal area. Specifically, in Class III, higher values were found for the oropharyngeal surface area compared to Classes II/1 and II/2, while the total pharyngeal surface area was significantly different only between Class III and Class II/1. These findings are in agreement with research studies based on skeletal criteria. It has been found that the smaller the ANB angle, the larger the oropharyngeal surface area[18]. In another study, no statistically significant differences were found for the surface area of the rhinopharynx between Class I and Class II/1[19]. In a study of normodivergent facial patterns, there was a significant tendency towards reduced dimensions of the upper airway in the lower palatopharyngeal and hypopharyngeal parts, in the following order: Class III, Class I and Class II[20]. The oropharyngeal height (PNS-Eb) has been correlated with the OSA syndrome[21].

The present study showed no statistically significant difference in this measurement in the 4 groups or any tendency for variation. The same is true for the posterior cranio-cervical height (S-AA). Besides, sagittal measurements of the oropharynx and the tongue position (SPAS, MAS, IAS, apw2-ppw2) showed a tendency to present higher values in Classes I and III and lower values in Classes II/1 and II/2 cases, however without any statistical significance. This fact, combined with the lower tongue position in Class III explains why the oropharyngeal surface area in the specific group was found to be larger when compared with Classes I/1 and II/2. This is in agreement with previous findings suggesting that the longer the mandible, the more increased the sagittal dimension at the lowest part of the oropharynx[22,23].

Future studies could investigate in greater detail possible correlations between pharyngeal relationships, occlusal relationships and particular craniofacial features, such as the vertical facial types, and their association with OSA. The 3D evaluation of nasopharyngeal and oropharyngeal structures and potential relationships with respiratory function or OSA symptoms could offer a better insight in the understanding of these issues. Moreover, a study similar to ours conducted in an untreated adult sample would also be of particular interest, although this sample is difficult to collect.

In conclusion, the present study revealed a certain relationship between Angle malocclusion classes and pharyngeal structures. This could indicate that Class II subjects may be more prone to develop respiratory related disorders, such as the OSA syndrome, followed by Class I and Class III subjects. Thus, clinicians should be more aware for this in certain Angle Classes of malocclusion. This is a simple, definite and well known diagnostic classification that can be easily performed during clinical examination, not only by specialists, but also by general dentists.

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