Stomatologija. Baltic Dental and Maxillofacial Journal, 21: 99-106, 2019

The impact of the hyoid bone position on the pharyngeal airway characteristics among different facial skeletal patterns

Eglė Šadzevičiūtė, Julija Nazimova*, Giedrė Trakinienė**

SUMMARY

Objective. To identify the impact of the hyoid bone position on the pharyngeal airway characteristics among different facial skeletal patterns.

Materials and Methods. The orthodontic patients from the patients' data base of the Lithuanian University of Health Sciences base were examined. On each cephalogram 5 linear, 3 angular skeletal and 6 linear soft tissue landmarks were traced and measured using AudaxCeph program. The radiographs were divided into the three groups according to the ANB angle: control group, with skeletal class I (ANB angle 1-5°), study group 1 with skeletal Class II (ANB angle >5°), study group 2 with skeletal Class III (ANB angle <1°). All measurements and relations between dento-facial complex anatomical structures were statistically evaluated using IBM SPSS Statistics software.

Results. 261 patients (156 females, 105 males, aged between 7 and 35 years) were selected. The skeletal class II group consisted of 114, class III group – 59 and class I – 88 patients' cephalograms. Hyoid bone distance both to cervical third vertebrae and mandibular symphysis, maxilla and mandibular length, inferior airways space significantly differed between the Angle classes. Inferior airway space had a significantly positive correlation with all measurements, associated with hyoid bone.

Conclusion. Inferior airway space was significantly narrower and the hyoid bone localization was in more posterior superior position in the skeletal class II in comparison with other both groups. Decrease of the hyoid bone distance to the third cervical vertebrae, mandibular symphysis and mandibular plane led to the narrower inferior airways space.

Keywords: hyoid bone, pharyngeal airway, skeletal pattern, obstructive sleep apnea.

INTRODUCTION

Airways play an important role in the development of the dento-facial complex. The evaluation of the airways and their relation to the mandibular position and size is important in the orthodontic diagnosis because it could be linked to obstructive respiratory disorders, especially to the obstructive sleep apnea syndrome (OSAS). OSAS affects approximately 10% of all children and up to 20% of adults (1, 2). OSAS present recurrent events of the upper airway obstruction during sleep associated with clinical signs and symptoms. According to the American Association of Sleep Medicine, OSAS diagnosis requires the occurrence of at least five episodes of apnea hypopnea per hour of sleep combined with clinical symptoms, the most important of which are loud snoring and excessive daytime sleepiness. The apnea event is considered when the airflow is interrupted during sleep for a period of 10 seconds or more, and hypopnea when there is a reduction of at least 50 percent of the breathing capacity combined with the saturation decrease of the oxyhemoglobin in at least 3 percent (3). It has been shown that Obstructive Sleep Apnea patients have aberrated skeletal and soft tissue patterns that reduce airway space, short mandibular body length and backward/downward rotation (4). Also, the position of the mandible is often retruded in relation to the cranial base, and this can cause narrow-

*Department of Orthodontics, Lithuanian University of Health Sciences, Kaunas, Lithuania

Address correspondence to Eglė Šadzevičiūtė, Department of Orthodontics, Lithuanian University of Health Sciences, J. Lukšos-Daumanto g. 6, LT-3009 Kaunas, Lithuania.
E-mail address: egle.sadz@gmail.com

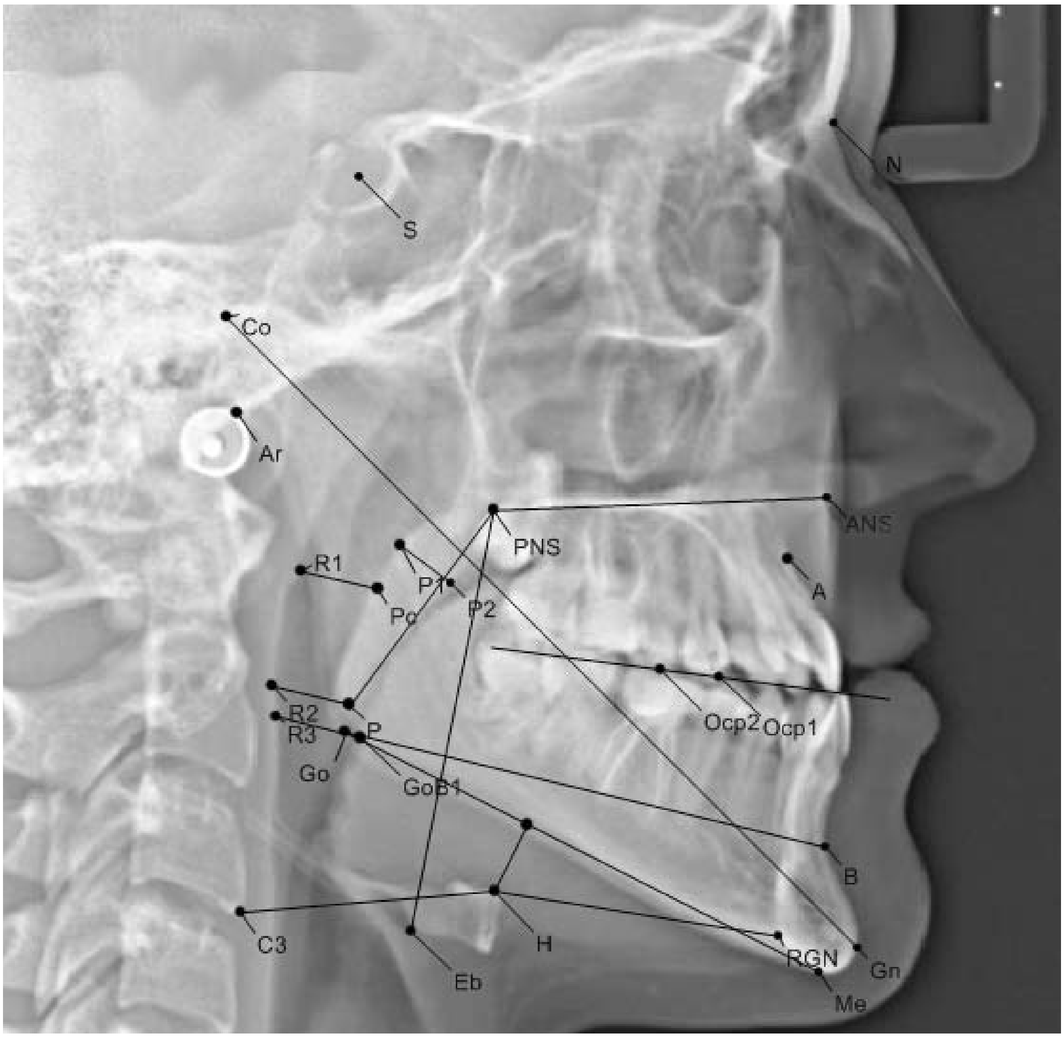

Fig 1. Cephalometric linear measurements used in cephalometric analysis: P1-P2 – width of soft palate, PNS-P – length of soft palate, PNS-Eb – vertical airway space, Go-B – traced to parallelize upper, middle and lower airway spaces measurements, Pc-R1 – upper airway space, P-R2– middle airway space, GoB1-R3 – lower airway space, ANS-PNS – length of maxilla, Co-Gn – length of mandible, C3-H – position of the hyoid bone to the third cervical vertebrae, H-RGN– position of the hyoid bone to the mandibular symphysis, H⊥Go-Me – position of the hyoid bone to the mandibular plane.

ing of the airway and changes in the soft palate parameter (5). These findings show that pharyngeal obstruction may be related to the changes in mandibular morphology. Decreased space between the cervical column and the mandibular body may lead to a posterior position of the soft palate, increasing the chances of the impaired respiration function during the day and possibly so causing Obstructive Sleep Apnea Syndrome. Studies have shown that changes in hyoid bone position tend to be related to changes in mandibular position (6-8). It was reported that in Class II subjects with a narrower upper airways the hyoid bone is positioned more posteriorly and it was shown that hyoid bone in Class III subjects lay more anteriorly. The effect of the change of the mandible in anteroposterior position on hyoid bone position and the pharyngeal airway space is well reported (9). This knowledge is definitive to the indication of the mandibular advancement, whether orthopedic or surgical, for treatment of these disorders. However, there is no consensus if the dimension of the pharyngeal airway and the position of the hyoid bone in the different skeletal patterns are interrelated. There are only few studies regarding the position of the pharyngeal airway and the hyoid bone to different skeletal patterns using the ANB angle. The present study aims to evaluate the pharyngeal airway dimension and hyoid bone position, soft and skeletal tissues dimensions with the use of lateral cephalograms in subjects having Angle I, II and III skeletal abnormalities.

MATERIAL AND METHODS

This research project was approved by the Lithuanian University of Health Sciences Ethics Committee (process number BECOF-47). The orthodontic patients aged between 7 and 35 years were retrospectively obtained and examined from the patients' data base of the Lithuanian University of Health Sciences. The inclusion criteria were the following: no history of orthodontic or dento-facial orthopaedic treatment; no genetic syndromes; good quality digital lateral cephalometric radiographs done with the Care Stream CS 9000 using a standardized technique. Cephalometric radiographs were taken with the jaws in the cen-

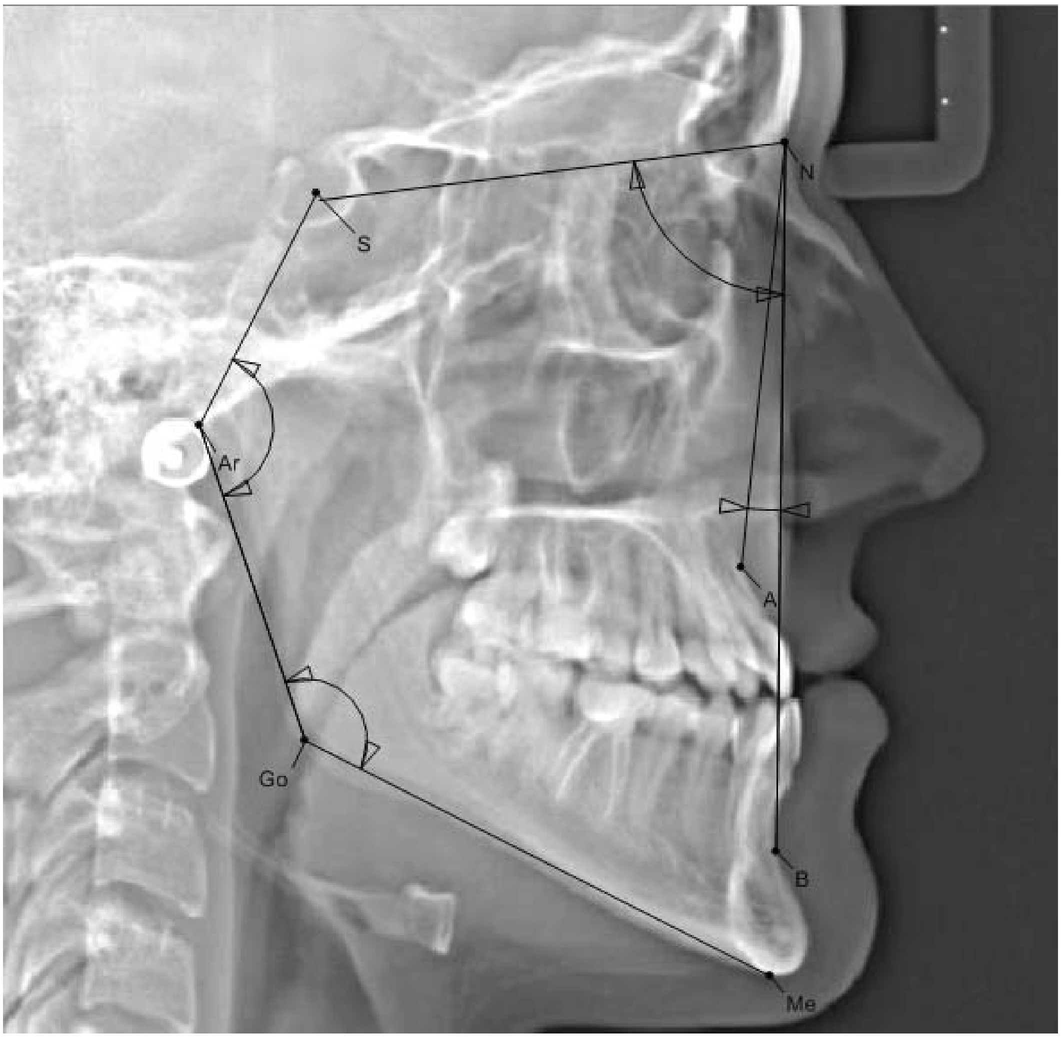

Fig 2. Cephalometric angular measurements used in cephalometric analysis: ANB- maxilla and mandible relation angle, SNB- mandible position referred to cranial base, Ar-Go-Me –gonial angle, S-Ar-Go – articular angle.

tral occlusion,competitive lips and the head in the natural position. The patients were asked not to move while the radiographs were being exposed. An evaluation of the cephalograms was performed by two different researchers using AudaxCeph program (error of measures 0.01 mm, 0.01°). 21 anatomical landmarks were marked (Table 1), 9 linear (Figure 1) and 4 angular (Figure 2) craniofacial measurements in each cephalogram were done. The study sample was divided into three groups accordingto the ANB angle: control group with skeletal Class I (ANB angle 1–5°), study group 1 with skeletal Class II (ANB angle >5°), study group 2 with skeletal Class III (ANB angle <1°)

Statistical analysis

The Statistical Package for Social Sciences program (SPSS 22.0, Chicago III, USA) was used for the data analysis. Statistical significance of difference in proportion was tested by Chi- square test. Mean (M) and standard deviation (SD) were used to describe quantitative characteristics of the research. Every quantitative characteristic set was tested for normality with Kolmogorov-Smirnov test. Analysis of variance ANOVA was used to compare quantitative variables of more than two samples (Bonferroni Post Hoc). Statistical testing between the groups for differences of quantitative data was performed using Student's t test. For the data that were not normally distributed, Kruskall-Wallis and Mann-Whitney U test was applied. Pearson's correlation was also used in order to identify the correlation between all radiographic measurements. Selected level of significance p<0.05. The interauthor agreement of the measurements was analyzed using Pearson correlation coefficient. The power of analysis was 0.8.

RESULTS

261 out of 3200 orthodontic patients with a mean age (SD) 14 (4.1) were analyzed. Patients' gender didn't differ statistically significant among the groups, while male were older (14.7 (4.9)) than female (13.5 (3.4)), p=0.112. The skeletal class II group consisted of 114 patients' cephalograms. The skeletal class III group – 59 cephalograms, whereas the control group consisted of 88 rentgenograms of patients with Class I malocclusion (Table 2).

6 measured parameters were significantly different between the groups. The longest distance from hyoid bone to the cervical third vertebrae was in Class III and the shortest was in Class II (p<0.05). The longest distance from the hyoid bone

to the mandibular symphysis was in Class III and the shortest was in Class II (p<0.05). The longest maxilla was in Class II and the shortest was in Class III (p<0.05). The longest mandible was in Class III and the shortest was in Class II (p<0.05). All these differences were statistically significant among the groups.

No significant difference was found between the groups in superior, middle airway space and vertical airway length (p>0.05). Inferior airway space showed a tendency to decrease in Angle II. The widest inferior airways space was in Class III and the narrowest was in Class II (p<0.05) (Table 3).

Superior airways space showed weak positive correlation only with middle airway space (r=0.378, p=0.000). If the superior airway space increased, the middle airway space would increase as well.

Middle airway space showed a positive moderate correlation with inferior airways space (r=0.435, p=0,000), positive weak correlation with mandible (r=0.327, p=0.000) and maxilla lengths (r=0.218, p=0,000), distance between hyoid bone and cervical third vertebrae (r=0.265, p=0.000), distance between hyoid bone and mandibular symphysis (r=0.323, p=0.000). The increase in the inferior airway space, mandible and maxilla length, distance between hyoid bone and mandibular symphysis was associated with the increase of the middle airway space.

Inferior airway space showed positive weak correlation associated with all hyoid bone measurements: the distance from hyoid bone to the third cervical vertebrae (r=0.192, p=0.002), distance from the hyoid bone to the mandibular symphysis (r=0.286, p=0.000), perpendicular distance from hyoid bone to mandibular plane (r=0.199, p=0.001). With the increase of these hyoid bone measurements, the inferior airway space increased proportionally.

Vertical airway length positively moderately correlated with the mandible length (r=0.437, p=0.000), distance between the hyoid bone and the third cervical vertebrae (r=0.400, p=0.000), distance between the hyoid bone and the mandibular symphysis (r=0.430, p=0.000) and positively weakly with the maxilla length (r=0.298, p=0.000), soft palate length (r=0.343, p=0.000) and thickness (r=0.209, p=0.001). Vertical airway length showed positive strong correlation with perpendicular distance from the hyoid bone to the mandibular

Table 1. Definition of skeletal, pharyngeal and soft tissue landmarks, used in cephalometric analysis

Landmark	Definition
S	the center of the hypophyseal fossa
N	the junction of the nasal and frontal bones
A	the most concave point on the curvature from the maxillary anterior nasal spine to the crest of the maxillary alveolar process
B	most concave point on the anterior mandibular surface
ANS	the most anterior point on the maxilla at the nasal base
PNS	the tip of the posterior nasal spine of the palatal bone, at the junction of the soft and hard palate
Gn	the most outward and everted point on the profile curvature of the symphysis of the mandible, located midway between Pogonion and Menton
P	the most inferior point of the soft palate
Pc	the middle of the soft palate
P1	the most posterior point of the soft palate posterior wall
P2	the most anterior point of thesoft palate anterior wall
Go	midway between the most inferior posterior point of the right and left angles of the mandible, which was on the intersection of the mandibular plane and ramus of mandibular
Me	the lowest point on the symphysis of the mandible
Co	the most superior posterior point of the mandibular condylar
RGN	The posterior point of the mandibular symphysis
C3	the most anterior inferior point of the body of the third cervical vertebra
H	the most superior anterior point of hyoid bone
Ar	the junction between inferior surface of the cranial base and the posterior border of the ascending ramus of the mandible
Eb	the basis of epiglottis
GoB1	the point on a Go-B line, which indicated the anterior wall of the inferior pharyngeal airway space
R1	the point of the posterior pharyngeal airway wall (PPAW), which was marked parallel to Go-B on a line, going through Pc
R2	the point of PPAW, which was marked parallel to Go-B on a line, going through P
R3	the point of PPAW, marked directly on Go-B line

Table 2. Subjects' distribution among sex and Angle classes

	Subjects	Angle I	Angle II	Angle III
Female	156 (59.8%)	51 (32.7%)	71 (45.5%)	34 (21.8%)
Male	105 (40.2%)	37 (35.2)	43 (41.0%)	25 (23.8%)
Total	261	88	114	59

plane (r=0.625, p=0.000). With the increase of the mandible, maxilla length, soft palate length, thickness, distance between the hyoid bone and the third cervical vertebrae, distance between the hyoid bone and the mandibular symphysis and perpendicular distance from the hyoid bone to the mandibular plane increased, vertical airway length increased as well (Table 4).

Table 3. Hard and soft tissue cephalometric dimensions in different skeletal patterns

Variable	Angle class	Mean	Std. Deviation	Minimum	Maximum	P value between groups
SNB	I	78.3	3.9	67.4	88.2	0.000
	II	76.2	3.7	62.2	84.4	
	III	80.5	4.7	68.2	96.8	
P-PNS	I	30.8	4.0	19.2	40.2	0.909
	II	30.9	3.7	20.6	42.4	
	III	30.6	4.2	20.4	44.5	
C3-H	I	32.3	4.8	21.6	45.6	0.001
	II	30.7	3.6	23.6	43.6	
	III	33.1	5.0	22.4	46.8	
H-RGN	I	34.6	6.2	18.4	48.1	0.001
	II	33.4	5.9	20.3	48.1	
	III	37.0	6.2	23.2	53.4	
H⊥MeGo	I	15.0	4.4	5.3	28.3	0.378
	II	16.0	6.2	4.4	33.8	
	III	16.1	6.8	3.5	36.5	
P1-P2	I	8.1	1.5	5.0	12.7	0.332
	II	8.2	1.2	4.9	11.2	
	III	8.5	1.9	4.8	14.5	
S-Ar-Go	I	138.4	9.1	115.8	156.5	0.357
	II	137.1	9.3	114.0	157.0	
	III	136.3	8.6	115.0	156.0	
ANS-PNS	I	49.3	5.0	36.0	65.0	0.005
	II	50.0	4.0	40.0	61.3	
	III	47.4	5.2	32.0	58.4	
Ar-Go-Me	I	129.3	6.0	115.0	148.2	0.223
	II	129.3	6.3	112.7	146.8	
	III	131.0	6.1	112.3	141.0	
Co-Gn	I	109.5	9.8	70.2	129.6	0.000
	II	107.0	7.3	87.0	136.0	
	III	113.0	9.2	88.3	136.0	

DISCUSSION

Cephalometric analysis is an important tool in the orthodontic diagnosis and treatment. Since radiograph was discovered in 1895 by Wilhelm Conrad Roentgen, it's being widely used for diagnosis in various medical fields. It has given the orthodontist an ability to see beneath soft tissue. Pharyngeal airway dimensionsare an area of interest of many authors. Many articles exploring the relationship between nasopharyngeal airway and craniofacial growth were published since. More often radiological examinations in orthodontics are done not only for the diagnosing patient`s malocclusion, but are also used to evaluate soft tissue and skeletal characteristics of the patients with such disorders as OSAS (10, 11). In order to prevent OSAS, it seems reasonable to create the same skeletal characteristics for all orthodontic patients. It is necessary to comprehend that the position and movements of craniofacial bones

Table 4. Airway space measurements among different skeletal patterns

Variable	Angle class	Mean	Std. Deviation	Minimum	Maximum	P value between groups	Angle class (I&II)	Angle class (I&III)	Angle class (II&III)
Superior airway space Pc-R1	I	12.7	3.1	2.6	20,6	0.071			
	II	13.7	3.0	6.2	23,1				
	III	13.4	2.9	7.1	20,2				
Middle airway spase P-R2	I	10.6	2.8	4.4	17.7	0.087			
	II	10.0	2.3	4.2	17.9				
	III	11.0	2.9	4.0	17.0				
Inferior airway space GoB1-R3	I	11.9	3.0	5.4	19.0	0.041	0.027	0.979	0.052
	II	11.0	3.2	4.5	19.2				
	III	12.0	3.4	6.0	21.2				
Vertical airway space PNS-Eb	IIIIII	58.660.060.2	8.28.48.8	21.119.841.0	80.079.582.8	0.548			

and soft tissues make an impact on the airways measurements which are essential in obstruction development. The purpose of this study was to evaluate possible connections between hard and soft tissue dimensions in the craniofacial anatomy, which could be useful in the clinical practice predicting pathological changes in the morphology of anatomical structures in the growing patient. One of the main point of this investigation was the relation between the distal position of the mandible, position of the hyoid bone and the lower pharyngeal airway space. In this study, a statistically significant connection between distal position of the mandible and narrow lower air pharyngeal space was found, which was in agreement with that reported by Elham (12). Alhmet stated, that patients with OSAS have no changes in the position of the teeth and the only middle air pharyngeal space was significantly different among OSAS and healthy patients. In the recent study both middle and inferior airway volume were lower in the patients, with retrognathic mandible, but only changes in the inferior airway space volume was considered to be statistically meaningful. The differences in these findings could be due different ages of study groups used in studies (13). The treatment of OSAS is based on the severity of the disease. According to the American Academy of Pediatricians adenotonsillectomy should be the first line treatment for children with OSAS to consider. Despite the high postoperative success and improvements of respiratory function in majority of clinical cases, 20 to 30% patients may exhibit residual symptoms. The postoperative symptoms of OSAS may occur during the pubertal growth or after it, when dento-facial development reached 90% of its final growth. It was reported that due to the insufficient success of adenotosillectomy in ceasing OSAS symptoms, the individual patient craniofacial morphology and other factors should be analyzed and auxiliary/additional treatment should be applied to manage OSAS, where by mean of surgery absolute treatment could not be accomplished (14).

Mandible retrognathism could be treated conservatively by using Forsus, Herbst or other appliances. Mandible retrognathic position treatment with Forsus appliance in children aged 10-17 showed significant increase in the upper and lower pharyngeal airways volume, using a three-dimensional cone-beam computed tomography to assess (15). It was reported that after 12-month treatment with Herbst appliance, both the length of the mandible and the posteror airway space increased and the hyoid bone moved to a more anterior position by 2mm. All those recorded cephalometric changes improved patients' respiration and eliminated symptoms, indicating OSAS: mouth breathing and persistent snoring, which were primarily reported by parents and then verified by means of clinical and polysomnographic evaluations (16). Ulusoyet al. also reported that functional appliance treatment of adolescents with mandibular deficiency led to increase of the nasopharyngeal and oropharyngeal dimensions and it was being stable throughout the 29.75 ± 5.17 months followed retention period (17). It was also reported that Class II correction with twin block ceased the symptoms of OSA and results remained stable for a long period of time (18). Contrary to above discussed findings, Carvalho in his review stated, that there is not enough evidences to prove the fact that oral and functional orthopaedic appliances are effective in obstructive sleep apnea treatment in children and adeno-tonsillectomy remained the most common treatment of OSAS in children (19).

Distally positioned mandible could be managed by orthognathic surgery. Long-term studies revealed, that mandibular surgery didn't achieve stable increase of the airway volume. Contrary, after 12-year follow-up of the surgery, it was noticed, that both upper and middle pharyngeal airway spaces were narrower than preoperatively, whereas lower airway space decreased to the same volume, as before surgery (20).

Hyoid bone position is an area of interest because it plays an important role in maintaining the upper airway dimensions (21). In this study, the hyoid bone position varied among the different Angle skeletal classes. In Class II subjects, hyoid bone was located in an upward and backward position, whereas in Class III subjects it was located in downward and forward position. These findings were in agreement with those reported by others (22-24). The more mandible was positioned distally, the more hyoid bone was localized posteriorly and possibly narrowed the lower pharyngeal airway space. Maxilla length was significantly larger whereas mandibular length tended to be shorter in class II patients than in other groups, which matched with the findings of Ahmet's study. However, authors have also stated that patients with OSA have no changes in the position of teeth and only middle airpharyngeal space was significantly different among OSA and healthy patients (10). In this study, both middle and inferior dimensions were significantly different in patients, with retrognathic mandible.

It is very important to notice and recognize Angle II malocclusion in the early childhood, to observe the child and to explain the parents that severe Angle II malocclusion is not only poor esthetics and function, it also could induce alterations in the pharyngeal space morphology and cause sleep apnea disease, which is usually hardly diagnosed. Dentist should be the first who notices the changes in the pharyngeal airway space and refers symptomatic patients to sleep medicine specialist to the detailed assessment and achieve treatment before the growing process ends (12, 14). If the growing process ended, treatment would become more complicated, long-termed and unstable.

CONCLUSIONS

1. Inferior airway space was significantly narrower in Angle II compared to Angle l and III.
2. Decrease of the hyoid bone distance to the third cervical vertebrae, mandibular symphysis and mandibular plane led to the narrower inferior airway space.
3. Angle II skeletal pattern showed significantly shorter mandible and longer maxilla.
4. Mandibular posterior position in the relation to the cranial base, expressed in SNB angle, influenced the position the hyoid bone. The decrease of SNB angle, matched with the reduction of the distance between the hyoid bone and the mandibular plane.

STATEMENT OF CONFLICTS OF INTEREST

The authors state no conflict of interest.

REFERENCES

1. Capdevila OS, Kheirandish-Gozal L, Dayyat E, Gozal D. Pediatric Obstructive Sleep Apnea: Complications, Management, and Long-term Outcomes. Proceedings of the American Thoracic Society 2008;5(2):274-282.
2. Jordan AS, McSharry DG, Malhotra A. Adult obstructive sleep apnea. Lancet 2014;383(9918):736-747.
3. Epstein LJ, Kristo D, Strollo PJ Jr, Friedman N, Malhotra A, Patil SP et al. Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. Adult obstructive sleep apnea task force of the American Academy of Sleep Medicine. J Clin Sleep Med 2009;5:263–76.
4. Lyberg T, Krogstad O, Djupesland G. Cephalometric analysis in patients with obstructive sleep apnea syndrome. J Laryngol Otol 1989;103:293–297.
5. Jena AK, Singh SP, Utreja AK. Sagittal mandibular development effects on the dimensions of the awake pharyngeal airway passage. Angle Orthod 2010;80:1061-7.
6. Battagel JM, Johal A, L'Estrange PR, Croft CB, Kotecha B. Changes in airway and hyoid position in response to mandibular protrusion in subjects with obstructive sleep apnea (OSA). Eur J Orthod 1999;21:363–375.
7. Winnberg A, Pancherz H, Westesson PL. Head posture and hyomandibular function in man: a synchronized electromyographic and videofluorographic study of the open closeclench cycle. Am J Orthod Dentofacial Orthop 1988;94: 393–404.
8. Adamitis PI, Spyropoulos NM. The effects of lymphadenoid hypertrophy on the position of the tongue, the mandible and the hyoid bone. Eur J Orthod 1983;5:287–294.
9. Adamidis IP, Spyropoulos MN. Hyoid bone position and orientation in Class I and Class III malocclusions. Am J Orthod Dentofacial Orthop 1992;101:308–312.
10. Abramson Z, Susarla S, August M, Troulis M, Kaban L. Three-dimensional computed tomographic analysis of airway anatomy in patients with obstructive sleep apnea. J Oral Maxillofac Surg 2010;68: 354-362.
11. Armalaite J., Lopatiene K. Lateral teleradiography of the head as a diagnostic tool used to predict obstructive sleep apnea. Dentomaxillofacial Radiology 2016; 45:20150085.
12. Allhaija ESA, Al-Khateeb SN. Uvulo-Glosso-Pharyngeal Dimensions in Different Anteroposterior Skeletal Patterns. Angle Orthod 2005; 75(6): 1012-1018.
13. Masoud AI, Jackson GW, Carley DW. Sleep and airway assessment: A review for dentists. Cranio - Journal of Craniomandibular Practice 2016; 18:1-17.
14. Bozzini MFR, Di Francesco RC. Managing obstructive sleep apnoea in children: the role of craniofacial morphology. Clinics 2016;71(11):664-666.
15. Temani P, Jain P, Rathee P, Temani R. Volumetric changes in pharyngeal airway in Class II division 1 patients treated with Forsus-fixed functional appliance: A three-dimensional cone-beam computed tomography study. Contemporary Clinical Dentistry 2016; 7(1):31-35.
16. Schütz TC, Dominguez GC, Hallinan MP, Cunha TC, Tufik S. Class II correction improves nocturnal breathing in adolescents. Angle Orthod 2011; 81(2):222-8.
17. Ulusoy C, Canigur Bavbek N, Tuncer BB, Tuncer C, Turkoz C, Gencturk Z. Evaluation of airway dimensions and changes in hyoid bone position following class II functional therapy with activator. Acta Odontologica Scandinavica 2014; 72(8): 917-925.
18. Ghodke, S, Utreja, AK, Singh SP, Jena AK. Effects of twin-block appliance on the anatomy of pharyngeal airway passage (PAP) in class II malocclusion subjects. Progress in Orthodontics 2014; 15(1): 68.
19. Carvalho FR, Lentini-Oliveira DA, Prado LBF, Prado GF, Carvalho LBC. Oral appliances and functional orthopaedic appliances for obstructive sleep apnoea in children. Cochrane Database of Systematic Reviews 2016; 10.Art. No.: CD005520
20. Eggensperger N, Smolka K, Johner A, Rahal A, Thuer U, Iizuka T. Long-term changes of hyoid bone and pharyngeal airway size following advancement of the mandible. Oral Surg Oral Med Oral Pathol Oral RadiolEndod 2005; 99(4):404-10.
21. Bibby RE, Preston CB. The hyoid triangle. Am J Orthod 1981;80:92–97.
22. Yamaoka M, Furusawa K, Uematsu T, Okafuji N, Kayamoto D, Kurihara S. Relationship of the hyoid bone and posterior surface of the tongue in prognathism and micrognathia. J Oral Rehabil 2003;30:914–920.
23. Issa FG, Edwards P, Szeto E, Lauff D, Sullivan C. Genioglossus and breathing responses to airway occlusion:

effect of sleep and route of occlusion. J ApplPhysiol 1988;64: 543.
24. Battagel JM, Johal A, L'Estrange PR, Croft CB, Kotecha B. Changes in airway and hyoid position in response to mandibular protrusion in subjects with obstructive sleep apnoea (OSA). Eur J Orthod 1999; 21(4):363-376.

Received: 19 04 2017
Accepted for publishing: 24 12 2019