Journal of
Babol University of Medical Sciences
JBUMS
e-ISSN: 2251-7170 p-ISSN: 1561-4107

Cephalometric Analysis of Airway Dimensions in Patients with Different Vertical Jaw Relations

Z. Kabiri (DDS)[1], M. Mirzaie (DDS, MS)[2], K. Hajian-Tilaki (PhD)[3], A. Hajian-Tilaki (DDS, MS)[*4]

1.Student Research Committee, Babol University of Medical Sciences, Babol, I.R.Iran.

2.Dental Materials Research Center, Health Research Institute, Babol University of Medical Sciences. Babol, I.R.Iran.

3.Department of Biostatistics and Epidemiology, School of Public Health, Babol University of Medical Sciences, Babol, I.R.Iran.

4.Oral Health Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, I.R.Iran.

[*]Corresponding Author: A. Hajian-Tilaki (DDS, MS)

Address: Department of Orthodontics, School of Dentistry, Babol University of Medical Sciences, Babol, I.R.Iran.

Tel: +98 (11) 32291408. **E-mail:** dr.arefehajian@yahoo.com

Article Type

Research Paper

Received: Nov 27th 2022

Revised: Mar 4th 2023

Accepted: May 31st 2023

ABSTRACT

Background and Objective: Knowledge of airway dimensions is important in the process of diagnosing and planning the treatment of orthodontic patients. Therefore, this study was conducted with the aim of performing cephalometric anlysis of airway dimensions in patients with different vertical jaw relations in the specialized clinic of Babol Dental School.

Methods: This cross-sectional study was conducted on 150 lateral cephalometric radiographs taken from patients aged 18 to 25 before orthodontic treatment. Based on the FMA angle and Jarabak index, the patients were divided into three groups of 50 according to the vertical skeletal pattern. The width of the upper (UP) and lower (LP) airways was measured in millimeters using McNamara's analysis. Moreover, the width of the nasopharynx (PNS-UPW), oropharynx (U-MPW) and hypopharynx (V-LPW) was recorded in millimeters and compared in three groups.

Findings: The studied population included 43 men and 107 women with a mean age of 20.39±2.50 years. The results showed a significant relationship in the dimensions of the upper airway, nasopharynx, and oropharynx between the vertical groups (p=0.001, p=0.001, and p=0.015, respectively). All these parameters in the Hyperdivergent group were significantly lower than the other two groups, and no significant relationship was found between the Hypodivergent and Normodivergent groups. The mean upper airway in Normodivergent group was 13.62±3.05. In addition, the dimensions of the lower airway and hypopharynx were not significantly different between the vertical groups.

Conclusion: The results of the study showed that hyperdivergent patients have a narrower upper airway. However, lower airway dimensions are not affected by vertical growth pattern factors.

Keywords: *Lateral Cephalometry, Airway, Vertical Dimensions of the Face.*

Cite this article: Kabiri Z, Mirzaie M, Hajian-Tilaki K, Hajian-Tilaki A. Cephalometric Analysis of Airway Dimensions in Patients with Different Vertical Jaw Relations. *Journal of Babol University of Medical Sciences*. 2024; 26: e38.

[DOI: 10.22088/jbums.26.1.38]

Introduction

In the last decade, studies have been conducted on the direct effect of respiratory function on craniofacial development (1). The structures of the upper airways play an important role in the volume of the airway, the growth and development of the craniofacial complex, sleep apnea and chewing pattern, and are key parameters in the diagnosis, planning and treatment of patients requiring orthodontic intervention (2). Adenoid, allergy, hypertrophy of tonsils, deformity of the nose, infections and polyps are among the predisposing factors of upper airway obstruction (1), which may lead to changes in the breathing pattern and overshadow the growth and development of the craniofacial structure (3).

The respiratory system can be divided into two parts (Upper Airway= UA) and (Lower Airway= LA). The lower part includes trachea, bronchus and lungs, and the upper part is usually divided into three parts: nasopharynx, oropharynx, and laryngopharynx (hypopharynx) (4, 5). However, there is no consensus among researchers on the terms used when describing the anatomical boundaries of UA (6).

Objective evaluation of airway patency is an important part of evaluating the airflow path (7). In various studies, complex and expensive methods of MRI, computed tomography, fluoroscopy and pharyngoscopy by fiber optics were used to examine the upper airway (8). CBCT imaging can also be used for special purposes in orthodontic patients, but the cost and radiation dose are high (8, 9). Although lateral cephalometric imaging provides two-dimensional information of craniofacial and soft tissue, it is a reliable, accurate and reproducible method for evaluating and estimating airways (10), and it is useful in identifying airway obstruction, adenoid hypertrophy and narrowing of the airway (11).

The growth pattern of the skull and face affects the width of the airway (12). In most people with a vertical growth pattern, symptoms of airway obstruction, snoring and mouth breathing are evident (13). Various studies have stated that the morphological structure of the airway varies among patients with different craniofacial characteristics (14, 15). Some authors (16, 17) have reported a relationship between the vertical growth pattern and airway obstruction and mouth breathing. However, there are contradictory findings in this area (18, 19). One of the reasons for these inconsistencies could be the different measurement criteria and methods used by researchers, including the patient's position (supine or upright), the matching of people's ages, and the variety of two-dimensional and three-dimensional landmarks used to define UA (20). Since various researches have provided contradictory results regarding the dimensions of the airway in patients with different jaw relations, the aim of this study is cephalometric analysis and determining the airways dimensions in patients with different jaw relations in the vertical dimension.

Methods

This cross-sectional study was approved by the Ethics Committee of Babol University of Medical Sciences with the code IR.MUBABOL.HRI.REC.1400.110, and was conducted on 150 lateral cephalometric radiographs of patients aged 18 to 25 years, whose permanent teeth (except the third molar) were fully developed and referred to the orthodontic department of Babol University of Medical Sciences for orthodontic treatment. Patients with a history of any previous orthodontic treatment, presence of facial asymmetry, history of maxillofacial surgery, cleft lip and palate syndrome or pathological conditions such as cysts and tumors were excluded from the study.

All cephalograms were manually traced. To reduce the error, tracings were done by a dental student under the supervision of an orthodontic specialist using a pencil with the same diameter (0.3 HB) on tracing paper. After performing the tracing, the patients were divided into three groups of 50 including Hypodivergent (with short face height), Normodivergent (with normal face height) and Hyperdivergent

[DOI: 10.22088/jbums.26.1.38]

(with long face height) based on vertical relationships. These 50 samples in each group can identify the effect size of 0.7 in airway dimensions with 80% test power and 95% confidence interval between vertical class groups (21). In this study, only lateral cephalometric radiographs prepared in the Natural Health Position (NHP), lips at rest and maximum intercuspation of the teeth were included in the study. In addition, the magnification of the device was considered in linear measurements on different lateral cephalometric radiographs. Patients with low quality of cephalometric images, as well as images that were not prepared in NHP condition, were excluded from the study.

After cephalometric measurements and based on the FMA angle, patients were divided into three skeletal groups based on vertical condition. Patients with an FMA angle of 22-28 degrees were placed in the Normodivergent group, those with an FMA angle of less than 22 degrees were placed in the Hypodivergent group, and those with an FMA angle greater than 28 degrees were placed in the Hyperdivergent group (20). In addition, for all patients of each group, Jarabak index was recorded as the second index of examining the patient's vertical condition, and the range of 63-65% was in the Normodivergent group, less than 63% in the Hyperdivergent group, and more than 65% in the Hypodivergent group. In case of inconsistency between FMA and Jarabak index, the sample was removed. Moreover, the sagittal relations of the patients were recorded based on their ANB angle; the angles 4≥ANB≥0 were considered as class I, 4<ANB as class II and ANB<0 as class III.

Reference points for measuring airway dimensions were marked on the traced radiographs and calculated according to the following definitions (22, 23):

Upper airway width (UP): the shortest distance between the posterior border of the soft palate and the posterior wall of the pharynx.

Lower airway width (LP): the distance between the intersection point of the posterior border of the tongue and the lower border of the lower jaw to the closest point on the posterior wall of the pharynx.

Nasopharyngeal width (PNS-UPW): the distance from the PNS point to the upper wall of the pharynx.

Oropharyngeal width (U-UPW): the distance between the uvula and the middle wall of the pharynx.

Hypopharynx width (V-LPW): the distance between the vallecula (the most posterior point of the base of the tongue) and the lower wall of the pharynx.

The obtained data were entered into SPSS version 25 and compared by non-parametric analysis of variance using the Kruskal-Wallis test. In addition, post hoc multiple comparisons were performed using Tukey's method between different vertical groups. In a sample of 20, the reliability of the measurements was evaluated using the Pearson correlation coefficient. The findings show that there is a correlation of over 90% between the first and second measurements and the mean of pretest and posttest measurements was not statistically significant. The p-value in all parameters was reported to be less than 0.001 and p<0.05 was considered significant.

Results

The study population included 43 (28.7%) men and 107 (71.3%) women with a mean age of 20.39±2.50 years. Descriptive characteristics including sex, age and other characteristics of patients as well as the distribution of people according to sagittal relations in each of the vertical groups are shown in Table 1. The mean SNA, SNB, ANB, FMA and Jarabak index in all patients of this study were 80.80±3.97, 77.54±4.42, 3.20±3.38, 26.48±7.01, and 64.01±5.34, respectively.

In relation to the dimensions of the lower airway and hypopharynx, no significant difference was observed between the groups. However, this difference was significant in the dimensions of the upper airway, nasopharynx, and oropharynx (p=0.001, p=0.001, p=0.03, p=0.015, respectively) (Table 2).

[DOI: 10.22088/jbums.26.1.38]

Table 1. Descriptive findings of the study samples based on the patient's vertical pattern (n=50)

Vertical pattern / Variables	Hypodivergent Number(%) or Mean±SD	Normodivergent Number(%) or Mean±SD	Hyperdivergent Number(%) or Mean±SD
Gender			
Male	16(37.2)	11(25.6)	16(37.2)
Female	34(31.8)	39(36.4)	34(31.8)
Sagittal relations			
Class I	18(36)	23(46)	25(50)
Class II	22(44)	20(40)	15(30)
Class III	10(20)	7(14)	10(20)
Age (years)	2.87±20.54	2.06±19.62	2.35±21
SNA (degree)	3.61±81.80	3.40±82.14	3.85±78.46
SNB (degree)	4.61±78.34	3.93±78.70	4.09±75.58
ANB (degree)	3.52±3.34	3.01±3.40	3.60±2.84
FMA (degree)	2.73±18.96	1.62±25.98	3.98±34.50
Jarabak index (%) (S-Go/N-Me)	2.85±69.59	0.60±64.15	3.63±58.30

Table 2. Average measurements of airway parameters based on patient's vertical pattern

Vertical pattern / Airway parameters	Hypodivergent Mean±SD	Normodivergent Mean±SD	Hyperdivergent Mean±SD	p-value*
Up (mm)	14.47±2.70	13.62±3.05	10.50±3.32	0.001
Lp (mm)	10.70±3.11	10.88±3.38	9.75±2.99	0.11
PNS-UPW (mm)	20.47±4.24	20.85±3.38	16.22±4.48	0.001
U-UPW (mm)	9.95±3.08	10.37±3.58	8.47±2.68	0.015
V-LPW (mm)	12.93±3.93	12.47±4.26	11.50±3.90	0.13

***Kruskal Wallis test**

Tukey's post hoc test was used to compare two groups. According to the table, as inferred in the Kruskal-Wallis test, the dimensions of the upper airway, nasopharynx and oropharynx between Normodivergent and Hyperdivergent groups, and the dimensions of the upper airway and nasopharynx between Hypodivergent and Hyperdivergent groups showed a significant relationship ($p<0.05$). In addition, no significant difference was observed in the dimensions of the lower airway and hypopharynx between the groups. Also, a two-by-two comparison showed that none of the parameters had significant differences between the Hypodivergent and Normodivergent groups (Table 3).

Since airway dimensions may be affected by sagittal relations, in order to reduce the error of analysis and conclusions, the variables measured in each of the sagittal groups of class I and II were examined. The results showed that among people with class I sagittal relations in different vertical groups, there is a significant relationship with the dimensions of the upper airway and the dimensions of the nasopharynx. In people with class II sagittal relations, in addition to upper airway dimensions and nasopharynx dimensions, hypopharynx dimensions also showed a significant correlation between the three vertical groups (Tables 4 and 5).

Based on the comparison of airway parameters among gender groups, it was concluded that gender has no effect on mean airway dimensions (Table 6).

[DOI: 10.22088/jbums.26.1.38]

Table 3. Two-by-two comparisons between vertical groups by Tukey Post hoc test

Airway parameters / Comparison	UP p-value	LP p-value	PNS-UPW p-value	U-UPW p-value	V-LPW p-value
Hypodivergent & Normodivergent	0.35	0.95	0.89	0.78	0.83
Hypodivergent & Hyperdivergent	0.001	0.30	0.001	0.51	0.18
Normodivergent & Hyperdivergent	0.001	0.18	0.001	0.008	0.45

Table 4. Average measurements of airway parameters in patients with class I sagittal relations

Vertical pattern / Airway parameters	Hypodivergent (n=18) Mean±SD	Normodivergent (n=23) Mean±SD	Hyperdivergent (n=25) Mean±SD	p-value*
Up (mm)	14.86±2.86	12.60±2.74	11.53±3.38	0.007
Lp (mm)	10.26±2.98	10.18±2.72	9.82±2.95	0.81
PNS-UPW (mm)	20.97±3.70	20.37±4.54	17.30±4.05	0.009
U-UPW (mm)	9.96±3.23	9.91±3.66	8.14±2.83	0.15
V-LPW (mm)	13.29±4.75	12.06±4.27	12.22±3.97	0.74

*Kruskal Wallis test

Table 5. Average measurements of airway parameters in patients with class II sagittal relations

Vertical pattern / Airway parameters	Hypodivergent (n=22) Mean±SD	Normodivergent (n=20) Mean±SD	Hyperdivergent (n=15) Mean±SD	p-value*
Up (mm)	14.23±2.79	13.62±2.80	9.08±2.70	<0.001
Lp (mm)	11.63±3.44	10.72±3.86	9.99±3.60	0.16
PNS-UPW (mm)	20.39±4.70	20.84±3.30	15.89±5.17	0.006
U-UPW (mm)	10.49±3.19	10.06±3.60	8.28±2.56	0.08
V-LPW (mm)	13.66±3.23	12.38±4.11	10.22±3.60	0.013

*Kruskal Wallis test

Table 6. Comparison of airway parameters between the two genders

Gender / Airway parameters	Male (n=50) Mean±SD	Female (n=107) Mean±SD	p-value*
Up (mm)	12.35±3.78	13.07±3.33	0.44
Lp (mm)	10.01±2.69	10.62±3.35	0.22
PNS-UPW (mm)	18.17±5.17	19.59±4.41	0.29
U-UPW (mm)	9.38±2.94	9.68±3.33	0.58
V-LPW (mm)	11.37±3.94	12.68±4.06	0.93

*Independent sample T-test

Discussion

In the present study, the dimensions of the upper airway, nasopharynx and oropharynx in hyperdivergent patients were narrower compared to the other two groups, and gender had no effect on the dimensions of the airway in different vertical groups. Also, the results showed that the average measurement of the

[DOI: 10.22088/jbums.26.1.38]

dimensions of the upper airway using McNamara analysis in the Hyperdivergent group was significantly lower than the other two groups, and no significant relationship was found between the Normodivergent and Hypodivergent groups. This finding is similar to the results of several studies (16, 20, 22, 24-29). However, in a study by Ansar et al. (20), the SN-Man plane angle was used, and in a study by Memon et al. (24), the SN-GoGn criterion was used to divide patients into three vertical groups. But in this study, we used two vertical criteria of FMA and Jarabak index, and in case of inconsistency between the two relevant variables, we removed the data from the studied samples. Also, in the study of Ucar et al. (16), sagittal relations were the same in all subjects and all were class I. In the present study, the results of the non-parametric Kruskal Wallis test in each of the sagittal groups of class I and II also showed a significant relationship between the three vertical groups, although the distribution of people in the groups was not the same. However, Grauer et al. (30) stated in another study that there is no significant difference in relation to upper airway volume in vertical groups. The results of this study are in conflict with the results of the present study. Although CBCT imaging was used in their study, but the much smaller volume of samples and the use of patients with an age range of 17-46 years are the main differences between their study and ours.

Regarding nasopharyngeal dimensions, our study showed that nasopharyngeal dimensions in Hyperdivergent patients are significantly lower than the other two groups, and no significant relationship was found between Normodivergent and Hypodivergent groups. The results of the present study are similar to the results of studies by Ponnada et al. (31), Ucar et al. (16), and Joseph et al. (27). Of course, in the first two studies, the sagittal relations were the same in all groups, although the analysis of our study data based on class I and II sagittal relations also showed similar results.

In the present study, a significant relationship was found between the groups in relation to the dimensions of the oropharynx, and its value was lower in the Hyperdivergent group compared to the other two groups, while a two-by-two comparison showed that there was a significant relationship only between the Hyperdivergent and Normodivergent groups. Furthermore, Joseph et al. (27) showed that the dimensions of the oropharynx in Hyperdivergent individuals are significantly lower than the Normodivergent group. They stated that in the hyperdivergent group, the tongue is lower and more posterior. The results of the present study are in conflict with the study of Ponnada et al. (31). They stated that there is no significant relationship between the groups in relation to oropharynx dimensions, which could be due to the similar distribution of people based on sagittal relations and gender in vertical groups or different measurement methods in the study of Ponnada.

In relation to hypopharynx dimensions, significant relationship was found between vertical groups without considering sagittal relations in our study. This relationship was significant only in people with class II sagittal relations, that is, the dimensions of the hypopharynx in hyperdivergent and class II people were significantly smaller than the other two vertical groups. The reason for the difference in the results of these two analyses can be due to the unequal number of Hyperdivergent, Normodivergent and Hypodivergent individuals in each of the sagittal groups. Eslamian et al. (17) also stated that the hypopharynx dimensions in Hypodivergent patients are significantly higher than the other two groups, and the average hypopharynx dimensions in the Normodivergent group were the lowest. Of course, in their study, the inclusion criteria were different, and unlike our study, no range was selected to determine the age of patients entering the study. Also, the number of studied samples was much less than our study and it was performed on 50 cephalometric lateral radiographs with normal sagittal relations.

In this study, similar to the results of Memon et al. (24), de Freitas et al. (25) and Ponnada et al. (31), no significant correlation was found between the dimensions of the lower airway between the three vertical patterns. However, the findings of Ansar et al. (20) in a two-by-two comparison showed that the lower

[DOI: 10.22088/jbums.26.1.38]

airway in the Hyperdivergent group was significantly lower than the Hypodivergent group. However, no significant difference has been found between Hypodivergent and Normodivergent groups, nor between Hyperdivergent and Normodivergent groups. In addition, Alfawzan (22) stated that the dimensions of the lower airway in the Hyperdivergent group are significantly narrower than the Normodivergent and Hypodivergent groups, and there is no statistically significant difference between the Normodivergent and Hypodivergent groups. Of course, in this study, unlike our study, all subjects were the same and class I in terms of sagittal relations, while the data analysis of our study in the class I sagittal group did not show such a relation. Considering the conflicting results, it can be assumed that the lower airway, unlike the upper airway, is not affected by growth patterns. However, more studies with more population and considering all confounding variables are needed in this field.

In the present study, no significant difference was found between male and female groups in relation to upper and lower airway dimensions. These findings are similar to the results of a group of studies (26, 31-33). However, our findings contradict the findings of Samman et al. (34) who stated that there is a significant difference between gender groups in relation to nasopharyngeal dimensions. This contradiction can be caused by the difference in the inclusion and exclusion criteria of the studies, because in the study by Samman et al., all subjects had normal facial profiles.

Due to the lower dimensions of the upper airway in the Hyperdivergent group, these patients may be more prone to mouth breathing and obstructive sleep apnea, which can be due to the downward and backward rotation of the mandible, which causes the tongue to be placed posteriorly and increase the possibility of respiratory disorders. Of course, the reduction of airway dimensions in these patients is influenced by various other factors that are not yet known to us (20). Early diagnosis of hyperdivergent patients can help prevent complications such as breathing disorders and sleep apnea. Therefore, during the diagnosis and treatment of patients with malocclusion, the orthodontist must recognize airway morphologies that can make a person prone to craniofacial abnormalities (35).

According to the findings of the present study, the upper airway, nasopharynx and oropharynx are narrower in hyperdivergent patients. However, lower airway dimensions are probably not influenced by growth pattern factors. Finally, considering the effect of the lack of pharyngeal space in oral breathing and respiratory obstruction, and considering the possible effects of orthognathic surgical interventions on airway dimensions, it should be noted that orthodontic, orthopedic and orthognathic treatments prevent the reduction of airway dimensions, especially in hyperdivergent people, as much as possible. In addition, orthodontists should consider the morphology of the airway, which can be one of the predisposing factors for adverse craniofacial development, in order to stabilize the treatment results, when diagnosing and treating patients with different malocclusions. Sleeping in the supine position can affect the size and patency of the airway and contribute to the collapse of all structures. In the present study, the graph of all patients was examined in the sitting position, and it is suggested that in future studies, airway parameters be examined in the supine position as well.

Acknowledgment

We hereby acknowledge the research and technology department of Babol University of Medical Sciences for supporting the research, as well as the staff of the orthodontic department of Babol Dental School.

[DOI: 10.22088/jbums.26.1.38]

References

1.Mughal MA, Baloch AJ, Riar N, Kumar D, Lal R. Cephalometric Assessment of Pharyngeal Airway Dimensions in Sagittal and Vertical Growth Patterns. Pak J Med Health Sci. 2022;16(9):39-41.

2.Martin O, Muelas L, Viñas MJ. Nasopharyngeal cephalometric study of ideal occlusions. Am J Orthod Dentofacial Orthop. 2006;130(4):436.e1-9.

3.Paul P, Thakur A, Mathur AK, Chitra P. Airway dimensions and mandibular position in adults with different growth patterns: a cone-beam computed tomography study. J Stoma. 2022;75(2):87-92.

4.Rojas E, Corvalán R, Messen E, Sandoval P. Upper airway assessment in orthodontics: A review. Odontoestomatología. 2017;19(30):40-51. Available from: http://www.scielo.edu.uy/pdf/ode/v19n30/1688-9339-ode-19-30-00040.pdf

5.Chokotiya H, Banthia A, Rao SK, Choudhary K, Sharma P, Awasthi N. A Study on the Evaluation of Pharyngeal Size in Different Skeletal Patterns: A Radiographic Study. J Contemp Dent Pract. 2018;19(10):1278-83.

6.Rama AN, Tekwani SH, Kushida CA. Sites of obstruction in obstructive sleep apnea. Chest. 2002;122(4):1139-47.

7.Welch KC, Foster GD, Ritter CT, Wadden TA, Arens R, Maislin G, et al. A novel volumetric magnetic resonance imaging paradigm to study upper airway anatomy. Sleep. 2002;25(5):532-42.

8.Ludlow JB, Gubler M, Cevidanes L, Mol A. Precision of cephalometric landmark identification: cone-beam computed tomography vs conventional cephalometric views. Am J Orthod Dentofacial Orthop. 2009;136(3):312.e1-10.

9.Patel A, Bhavra GS, O'Neill JR. MRI scanning and orthodontics. J Orthod. 2006;33(4):246-9.

10.Pirilä-Parkkinen K, Löppönen H, Nieminen P, Tolonen U, Pääkkö E, Pirttiniemi P. Validity of upper airway assessment in children: a clinical, cephalometric, and MRI study. Angle Orthod. 2011;81(3):433-9.

11.Filho DI, Raveli DB, Raveli RB, de Castro Monteiro Loffredo L, Gandin LG Jr. A comparison of nasopharyngeal endoscopy and lateral cephalometric radiography in the diagnosis of nasopharyngeal airway obstruction. Am J Orthod Dentofacial Orthop. 2001;120(4):348-52.

12.Shaikh SY, Malik AM, Khalid O, Mahnoor M. Comparison of upper pharyngeal airway space in ClassII and Class III malocclusion cases. Pak Orthod J. 2014;6(1):2-6.

13.Shavakhi M, Mohamadian F, Zarif Najafi H. The effects of the headgear therapy on the airway dimensions in patients with class II malocclusion: A systematic review. Dent Med Probl. 2019;56(2):191-6.

14.El H, Palomo JM. Airway volume for different dentofacial skeletal patterns. Am J Orthod Dentofacial Orthop. 2011;139(6):e511-21.

15.Alves Jr M, Franzotti ES, Baratieri C, Nunes LK, Nojima LI, Ruellas AC. Evaluation of pharyngeal airway space amongst different skeletal patterns. Int J Oral Maxillofac Surg. 2012;41(7):814-9.

16.Ucar FI, Uysal T. Orofacial airway dimensions in subjects with Class I malocclusion and different growth patterns. Angle Orthod. 2011;81(3):460-8.

17.Eslamian L, Badiee MR, Yousefinia S, Kharazifard MJ. Radiographic Assessment of Upper Airway Size in Skeletal Sagittal and Vertical Jaw Discrepancies. J Islam Dent Assoc Iran. 2014;26(2):96-101.

18.Alves PV, Zhao L, O'Gara M, Patel PK, Bolognese AM. Three-dimensional cephalometric study of upper airway space in skeletal class II and III healthy patients. J Craniofac Surg. 2008;19(6):1497-507.

19.De Felice F, Di Carlo G, Saccucci M, Tombolini V, Polimeni A. Dental Cone Beam Computed Tomography in Children: Clinical Effectiveness and Cancer Risk due to Radiation Exposure. Oncology. 2019;96(4):173-8.

20.Ansar J, Singh R, Bhattacharya P, Agarwal D, Verma S, Maheshwari S. Cephalometric evaluation of the airway dimensions in subjects with different growth patterns. J Orthod Res. 2015;3(2):108-12.

[DOI: 10.22088/jbums.26.1.38]

21.Hajian-Tilaki K. Sample size estimation in epidemiologic studies. Caspian J Intern Med. 2011;2(4):289-98.
22.Alfawzan AA. Assessment of airway dimensions in skeletal Class I malocclusion patients with various vertical facial patterns: A cephalometric study in a sample of the Saudi population. J Orthod Sci. 2020;9:12.
23.McNamara Jr JA. A method of cephalometric evaluation. Am J Orthod. 1984;86(6):449-69.
24.Memon S, Fida M, Shaikh A. Comparison of different craniofacial patterns with pharyngeal widths. J Coll Physicians Surg Pak. 2012;22(5):302-6.
25.de Freitas MR, Alcazar NM, Janson G, de Freitas KM, Henriques JF. Upper and lower pharyngeal airways in subjects with Class I and Class II malocclusions and different growth patterns. Am J Orthod Dentofacial Orthop. 2006;130(6):742-5.
26.Aboubakr RM, Almalki NH, Alanazi SA, Almulhim AA, Alkhathami OM, Alqhtani SH. Cephalometric evaluation of the main airway dimensions in subjects with different growth patterns and their relationship to patients' ages and genders. Int J Med Dev Countries. 2022;6(1):28-34. Available from: https://www.bibliomed.org/mnsfulltext/51/51-1631380481.pdf?1698743660
27.Joseph AA, Elbaum J, Cisneros GJ, Eisig SB. A cephalometric comparative study of the soft tissue airway dimensions in persons with hyperdivergent and normodivergent facial patterns. J Oral Maxillofac Surg. 1998;56(2):135-9.
28.Akcam MO, Toygar TU, Wada T. Longitudinal investigation of soft palate and nasopharyngeal airway relations in different rotation types. Angle Orthod. 2002;72(6):521-6.
29.Batool I, Shaheed M, Rizvi SA, Abbas A. Comparison of upper and lower pharyngeal airway space in class ii high and low angle cases. Pak Oral Dent J. 2010;30(1):81-4.
30.Grauer D, Cevidanes LS, Styner MA, Ackerman JL, Proffit WR. Pharyngeal airway volume and shape from cone-beam computed tomography: relationship to facial morphology. Am J Orthod Dentofacial Orthop. 2009;136(6):805-14.
31.Ponnada SR, Ganugapanta VR, Perumalla KK, Naqeed MA, Harini T, Mandaloju SP. Airway Analysis in Skeletal Class I and Class II Subjects with Different Growth Patterns: A 2D Cephalometric Study. J Pharm Bioallied Sci. 2020;12(Suppl 1):S161-S7.
32.Mislik B, Hänggi MP, Signorelli L, Peltomäki TA, Patcas R. Pharyngeal airway dimensions: a cephalometric, growth-study-based analysis of physiological variations in children aged 6-17. Eur J Orthod. 2014;36(3):331-9.
33.Abramson Z, Susarla S, Troulis M, Kaban L. Age-related changes of the upper airway assessed by 3-dimensional computed tomography. J Craniofac Surg. 2009;20 (Suppl 1):657-63.
34.Samman N, Mohammadi H, Xia J. Cephalometric norms for the upper airway in a healthy Hong Kong Chinese population. Hong Kong Med J. 2003;9(1):25-30.
35.Gholinia F, Habibi L, Amrollahi Boyouki M. Cephalometric Evaluation of the Upper Airway in Different Skeletal Classifications of Jaws. J Craniofac Surg. 2019;30(5):e469-e74.

[DOI: 10.22088/jbums.26.1.38]