Cephalometric evaluation of the main airway dimensions in subjects with different growth patterns and their relationship to patients’ ages and genders

Rabaa Mahmoud Aboubakr1, Nabeela Hassan Almalki2, Salah Awad Alanazi3*, Abdullah Ali Almulhim3, Osama Mesfer Alkhathami3, Saleh Hassan Alqhtani3

ABSTRACT

Background: Airway shape and dimensions have attracted attention during the past few decades; this can be attributed to the relationship between the upper airway configuration and sleep-disordered breathing and its relationship with craniofacial morphology in general. This study was conducted to 1. Compare the pharyngeal dimensions of subjects with different vertical growth patterns and 2. Assess the impact of modifying variables, like age and gender, on the airway dimensions.

Methods: Data collection was based on both cephalometric radiographs and patients’ files analysis. Radiographs were grouped according to patients’ ages, genders, and vertical growth patterns. Lateral cephalometric radiographs were taken using a standardized technique. The simple network management angle was used to divide the sample into hypodivergent, noromodivergent, hyperdivergent growth patterns with <26°, 26-38°, and >38°, respectively. The upper and lower pharyngeal airway widths were measured by using McNamara’s airway analysis.

Results: The widest upper and lower pharyngeal widths (LPWs) were found among hypodivergent subjects (20.1 ± 2.3 and 11.6 ± 4, respectively), and gender differences were found in the upper pharyngeal width (UPW) but in the lower (17.4 ± 3.4 and 18.1 ± 3.5, 10.1 ± 2.3 and 10.2 ± 3.1) for males and females in the upper and lower airways, respectively. Increasing the subject’s ages significantly increased the UPW but did not affect the LPW.

Conclusion: Hypodivergent patients had a higher UPW and LPW compared to the noromodivergent and hyperdivergent growth patterns. Also, the UPW and LPW were slightly higher in females than in males and increasing age had significantly increased UPW but did not affect LPW.

Keywords: Cephalometric radiographs, age, gender, vertical growth, airway dimensions.

Introduction

Upper airway space (UAS) structures play a significant role in developing the craniofacial complex and are critical parameters in orthodontic diagnosis and treatment planning [1]. The airway is an essential part of the craniofacial growth pattern, and any abnormality in the airway may lead to blockage of it wholly or partially that can cause mouth breathing [2].

The pharynx is composed of the nasopharynx, oropharynx, and laryngopharynx. The pharynx extension is started from the cranial base to the level of the sixth cervical vertebra. The nasopharynx is lined behind the nasal cavity; the oropharynx opens in the oral cavity; and laryngopharynx starts from the pharyngoepiglottic fold.
Cephalometric evaluation

until the sixth vertebra. Pharynx parts are essential in the functions of respiratory and digestive systems [3].

The width of pharyngeal structures can be determined by soft tissues’ growth of craniofacial skeletal structures. Subjects with vertical growth patterns have a narrower airway than issues with standard growth patterns that may increase airflow resistance [4].

Sometimes vertical growth patterns of condyles become greater than facial patterns that may affect the mandibular position and bite motion during the growth period; consequently, a discrepancy occurs between airway pattern and maxillary or mandibular patterns [5] orthodontic diagnosis and treatment planning impacts on the respiratory system. In addition, there is a relationship between nasopharynx and oropharynx growth with the skull growth. Therefore, proper early diagnosis of airway dimensions (primarily a vertical one) during orthodontic treatment helps prevent airway problems in growth periods [6]. Also, some patients with a sizeable soft palate may have airway problems like obstructive sleep apnea (OSA) [7].

Several studies demonstrated a relationship between airway dimensions and different sagittal and vertical facial growth patterns at various degrees. Skeletal structures abnormalities like; retrusion of the maxilla or mandible and vertical maxillary overgrowth in high angle patients may restrict anteroposterior dimensions of the airway [8].

Hereditary factors have a deleterious effect on the human face and pharyngeal airway. Also, treatment of breathing disorders may have an impact on airway size. Changing of the pharyngeal airway depth occurs during the transformation from the mixed dentition period to the adult dentition period [9]. Standard upper pharyngeal airway (UPA) space is 15-20 mm, while lower pharyngeal airway (LPA) space is 11-14 mm [9,10].

Many tools are used to measure the airway space, which are two types; two-dimensional and three-dimensional tools. Cephalometric radiographs have been used to evaluate facial growth and development [11,12]. Lateral cephalometric radiographs are accessible and suitable for the evaluation of craniofacial and soft tissues deformities and enables analysis of dental and skeletal anomalies [13].

Many studies have investigated the anatomic conformation of the upper airway with more sophisticated and expensive techniques, including cine-computed tomography (CT) [14], fluoroscopy [15], acoustic reflection [16], fiberoptic pharyngoscopy [17], and magnetic resonance imaging (MRI) [18]. CT has a vital role in measuring the upper airway in patients with OSA and patients with acromegaly. However, the significant disadvantages are high cost and high dose of addition [19]. MRI measures the maximum thickness and length of the soft palate [20]. A polysomnography setting (sleep laboratory) has been a reference standard for the diagnosis of OSA [21].

Materials and Methods

Materials

This retrospective study was conducted in Al-Riyadh city, using 200 cephalometric radiographs for subjects ranging from 16 to 45 years old of both genders. The radiographs were collected from Eastern Riyadh Specialist Dental Center.

A convenient nonrandomized sampling technique was used for patient allocation. Subjects having any history of a congenital disability, orthodontic treatment, surgery in the head and neck regions, joint disorder, cervical spine disorder, and any neuromuscular disease or history of nasal obstruction were excluded from the study group.

Methods

Data collection was based on both cephalometric radiographs and patients’ files analysis. First, the radiographs were divided into three groups according to patients’ ages: group I for ages 16-25, group II for ages 26-35, and group III for ages 36-45; then each age group was sorted into two subgroups according to the patients’ gender. Second, the collected radiographs were verified for their accuracy and reliability through two well-trained and calibrated examiners.

Standardization technique

Lateral cephalometric radiographs were taken using a standardized technique, with the jaw in centric relation, the teeth in occlusion, and the lips relaxed. The head in the natural head position [22] by the same operator with a cephalostat (Vatech- Pax-400C, Korea) was confirmed from the dental center from which the radiographs were collected.

Cephalometric analysis

Each subgroup was divided into three groups according to the vertical growth pattern of the mandible. The simple network management angle was used to separate the sample into hypodivergent, neurodivergent, and hyperdivergent growth patterns with <26°, 26-38°, and >38°, respectively, proposed by Isaacson et al. [23]. The UPA and LPA widths were measured by using McNamara’s airway analysis. Upper pharyngeal width (UPW) is taken as a point on the posterior outline of the soft palate to the closest end on the rear pharyngeal wall. Lower pharyngeal width (LPW) measured from the point of intersection of the posterior border of the tongue and the inferior border of the mandible to the closest end on the rear pharyngeal wall.

Statistical analysis

The statistical analysis was carried out using SPSS (version 20). The normal distribution of the data was carried out using Kolmogorov-Smirnov and Shapiro-Wilk tests; these tests indicated that the data displayed were not normally distributed. Hence, nonparametric
tests were applied. Descriptive statistics were used for data summarization and presentation. Mann-Whitney U test and Kruskal-Wallis test were applied to compare the difference between two and more than two variables, respectively. A two-sided \( p < 0.05 \) was considered statistically significant.

**Results**

The Kruskal-Wallis test was used to compare the pharyngeal width among cephalometric angulation groups. UPW expressed a statistically significant difference between the different cephalometric angulations (\( p = 0.001 \)), whereas LPW did not show a significant difference (\( p = 0.152 \)) (Table 1, Figure 1).

The Mann-Whitney U test is used to compare the pharyngeal width among separate cephalometric angulation groups. Statistics showed a statistically significantly (\( p = 0.001 \)) higher width among the hypodivergent angulation group compared to the hyperdivergent group among UPW. Similarly, the normodivergent angulation group displayed statistically significantly higher width compared to the hyperdivergent angulation group among UPW (Table 2).

The Mann-Whitney U test was used to compare the pharyngeal width among males and females. There is no significant difference between males and females concerning both UPW and LPW (Table 3, Figure 2).

### Table 1. Comparison of different cephalometric angulations among UPW and LPW.

| Group | Angulation     | N  | Mean ± SD | Mean rank | \( p \)-value |
|-------|----------------|----|-----------|-----------|---------------|
| UP    | Hypodivergent  | 14 | 20.1 ± 2.3| 142.14    | 0.001*       |
|       | Normodivergent | 107| 19.2 ± 3.01| 122.98    |               |
|       | Hyperdivergent | 79 | 15.7 ± 3.1| 62.68     |               |
| LPW   | Hypodivergent  | 14 | 11.6 ± 4  | 123.64    | 0.152        |
|       | Normodivergent | 107| 10.4 ± 2.7| 102.93    |               |
|       | Hyperdivergent | 79 | 9.8 ± 2.8 | 93.1      |               |

*Statistical significance set at 0.05.

![Figure 1](image1.png)

**Figure 1.** Mean distribution of UPW and LPW among different cephalometric angulations.

### Table 2. Multiple comparisons of different cephalometric angulations among UPW and LPW.

| Group | Angulation     | N  | Mean rank | \( p \)-value |
|-------|----------------|----|-----------|---------------|
| UP    | Hypodivergent  | 14 | 72.57     | 0.186        |
|       | Normodivergent | 107| 59.49     |               |
|       | Hypodivergent  | 14 | 77.07     | 0.001*       |
|       | Hyperdivergent | 79 | 41.67     |               |
|       | Normodivergent | 107| 117.49    | 0.001*       |
|       | Hyperdivergent | 79 | 61.01     |               |

*Statistical significance set at 0.05.
The Kruskal-Wallis test is used to compare the pharyngeal width among different age groups. UPW expressed a statistically significant difference between the other age groups ($p = 0.005$), whereas LPW did not show a significant difference ($p = 0.777$) (Table 4, Figure 3).

The Mann-Whitney U test was used to compare the pharyngeal width among individual age groups. Statistics showed a statistically significantly higher width among the 26-35 age group than the 16-25 age group for UPW. Similarly, the 36-45 age group displayed statistically significantly higher width than the 16-25 age group for UPW (Table 5).

**Discussion**

In the present study, the assessment tool of pharyngeal airway dimensions was cephalometric radiographs. Controversy exists as the cephalogram measures two-dimensional views of three-dimensional structures. Also, Aboudara et al. [24] compared CT and cephalometric radiographs and found a significant positive relationship between nasopharyngeal airway size on lateral cephalogram and its actual volumetric size as determined from CT scan. In addition, cephalometry has several advantages compared to other radiographic techniques, like low cost and minimal radiation exposure.
Our results revealed that the mean upper airway width (UAW) was higher for hypodivergent subjects, followed by noromodivergent subjects and then hyperdivergent subjects, which were the least. Furthermore, the comparison between angulation groups in UAW found that the hyperdivergent group showed statistically significant differences comparing to the hypodivergent and noromodivergent groups. On the other hand, the mean lower airway width showed the same sequence as in UAW without statistically significant differences between different angulations.

This finding matched Ucar et al.’s [25] study, which reported a larger UPA space in low-angle subjects than in high-angle subjects. Furthermore, Memon et al. [26] revealed that hyperdivergent facial pattern subjects had a narrow UPA than noromodivergent and hypodivergent.

On the other hand, Ansar et al. [2] reported that hyperdivergent growth pattern subjects showed a statistically significantly narrow upper and LPA width compared to noromodivergent and hypodivergent facial patterns. They explained their results that the small pharyngeal width in hyperdivergent subjects could be attributed to the downward and backward rotation of the mandible that might lead to a posterior tongue position and increasing the chances of impaired respiratory function. However, they also showed that the “reduction” of the pharyngeal airway in hyperdivergent patients cannot be attributed only to the larger adenoids or soft tissue in the posterior nasopharyngeal region, and there may be another factor that is not fully understood.

Concerning gender, females showed higher mean UPA and UPW in comparison to males. However, the mean LPW was nearly equal for both genders. There were no significant differences between both genders regarding UPW and LPW. Our finding can be explained by sexual dimorphism, which is a usual finding in investigations evaluating pharyngeal morphometry in healthy young adults [27].

Our results matched with Daraze et al. [28], who reported larger UPWs in females than males. However, our finding is not consistent with the findings of young adult European Spanish and Chinese [29] populations, where there were no gender-related differences in the minimum depth of the airway. Also, in Mislik et al.’s [30] study on forage effect, it was found that UPW increased by increasing age, but LPW did not affect by age. Our finding disagreed with Mislik et al. [30], who showed no radical change in the upper airway dimensions between 6 and 17 years of age and explained this by forming and developing upper airway dimensions in early periods.

### Conclusion

Our results show that hypodivergent patients had higher UPW and LPW when compared to noromodivergent and hyperdivergent growth patterns. Also, the UPW and LPW were slightly higher in females than in males. Increasing age had significantly increased UPW but did not affect LPW.
Cephalometric evaluation

Recommendations
The following recommendations are proposed:
1. To obtain more valid data, similar studies should be conducted on a larger sample size.
2. Three-dimensional assessment techniques may be more accurate in recording three-dimensional structure than two-dimensional techniques.

List of Abbreviations
LPW: Lower pharyngeal width.
MRI: Magnetic resonance imaging.
OSA: Obstructive sleep apnea.
UPA: Upper pharyngeal airway.
UPW: Upper pharyngeal width.

Conflict of interest
The authors declare that there is no conflict of interest regarding the publication of this article.

Funding
None.

Consent to participate
Written informed consent was obtained from all the participants.

Ethical approval
Ethical approval was obtained from the ethical committee of scientific research at Al-Farabi College of Dentistry and Nursing in Al-Riyadh city and then from the Saudi Ministry of Health.

Author details
Rabaa Mahmoud Aboubakr, Nabeela Hassan Almalki, Salah Awad Alanazi, Abdullah Ali Almulhim, Osama Mesfer Alkhathami, Saleh Hassan Alyqtani
1. Dental Public Health and Preventive Dentistry, Alfarabi College of Dentistry and Nursing, Riyadh, Saudi Arabia
2. Ministry of Health, Riyadh, Saudi Arabia
3. Intern, Alfarabi College of Dentistry and Nursing, Riyadh, Saudi Arabia

References
1. Lowe AA, Ono T, Ferguson KA, Pae EK, Ryan CF, Fleetham JA. Cephalometric comparisons of craniofacial and upper airway structure by skeletal subtype and gender in patients with obstructive sleep apnea. Am J Orthod Dentofacial Orthop. 1996;110(6):653–64. https://doi.org/10.1016/0002-8177(96)90043-6
2. Ansar J, Singh RK, Bhattacharya P, Agarwal DK, Verma SK, Maheshwari S. Cephalometric evaluation of the airway dimensions in subjects with different growth patterns. J Orthop Res. 2015;3:108–12. https://doi.org/10.4103/0975-7406.163532
3. Ceylan I, Oktay H. A study on the pharyngeal size in different skeletal patterns. Am J Orthod Dentofacial Orthop. 1995;108(1):69–75. https://doi.org/10.1016/0002-8177(95)70068-4
4. Flores-Blancas AP, Carruitero MJ, Flores-Mir C. Comparison of airway dimensions in skeletal Class I malocclusion subjects with different vertical facial patterns. Dental Press J Orthod. 2017;22(6):35–42. https://doi.org/10.1590/2177-6709.22.6.035-042.oar
5. Iqbal N, Rasool G, Alam T, Hussain U, Shah SS. Comparison of different craniofacial patterns with pharyngeal widths. JKDC. 2015;6:20–4.
6. Lakshmi KB, Yelchuru SH, Chandrika V, Lakshmiyar OG, Sagar VL, Reddy GV. Comparison between growth patterns and pharyngeal widths in different skeletal malocclusions in south Indian population. J Int Soc Prev Community Dent. 2018;8(3):224–8. https://doi.org/10.4103/jispcd.JISPCD_77_18
7. Gungor AV, Turkkrahman H. Effects of airway problems on maxillary growth: a review. Eur J Dent. 2009;3(3):250–4. https://doi.org/10.1055/s-0039-1697440
8. Memon S, Fida M, Shaikh A. Comparison of different craniofacial patterns with pharyngeal widths. J Coll Physicians Surg Pak. 2012;22(5):302–6.
9. Sheng CM, Lin LH, Su Y, Tsai HH. Developmental changes in pharyngeal airway depth and hyoid bone position from childhood to young adulthood. Angle Orthod. 2009;79(3):484–90. https://doi.org/10.2319/062308-328.1
10. Mani P, Muthukumar K, Krishnan P, Senthil Kumar KP. Upper and lower pharyngeal airway space in West-Tamil Nadu population. J Pharm Bioalied Sci. 2015;7(6 Suppl 2):5539–42. https://doi.org/10.4103/0975-7406.163532
11. Steiner CC. Cephalometric in clinical practice. Angle Orthod. 1959;29(1):8–29.
12. Khouw FE, Proffit WR, White RP. Cephalometric evaluation of patients with dentofacial disharmonies requiring surgical correction. Oral Surg Oral Med Oral Pathol. 1970;29(6):789–98. https://doi.org/10.1016/0030-4220(70)90425-1
13. Mukaihara K, Hassewaga-Moriyama M, Iwasaki T, Yamasaki Y, Kamnura Y. Evaluation of the pharyngeal airway using computational fluid dynamics in patients with acromegaly. Laryngoscope Invest Otolaryngol. 2018;3(2):133–8. https://doi.org/10.1002/lor.2151
14. Haponik EF, Smith PL, Bohiman ME, Allen RP, Goldman SM, Bleecker ER. Computerized tomography in obstructive sleep apnea. Correlation of airway size with physiology during sleep and wakefulness. Am Rev Respir Dis. 1983;127(2):221–6.
15. Suratt PM, Dee P, Atkinson RL, Armstrong P, Wilhoit SC. Fluoroscopic and computed tomographic features of the pharyngeal airway in obstructive sleep apnea. Am Rev Respir Dis. 1983;127(4):487–92. https://doi.org/10.1164.1983.127.4.487
16. Bradley TD, Brown IG, Grossman RF, Zamel N, Martinez DC, Culée C, et al. Pharyngeal shape and dimensions in healthy subjects, snorers, and patients with obstructive sleep apnoea. Thorax. 1990;45(10):722–7. https://doi.org/10.1136/thx.45.10.722
17. Rodenstein DO, Dooms G, Thomas Y, Liistro G, Stanescu K, Maheshwari S. Cephalometric evaluation of the craniofacial and pharyngeal airway dimensions in subjects with different growth patterns. J Orthop Res. 2015;3(2):108–12. https://doi.org/10.1002/lio2.151
18. Remmers JE, De Groot WJ, Sauerland EK, Anch AM. Fluoroscopic and computed tomographic features of the pharyngeal airway in obstructive sleep apnea. Am Rev Respir Dis. 1983;127(4):487–92. https://doi.org/10.1164.1983.127.4.487
19. Ryu HH, Kim CH, Cheon SM, Bae WY, Kim SH, Koo SK, et al. The usefulness of cephalometric measurement as a diagnostic tool for obstructive sleep apnea syndrome: a
Cephalometric evaluation

20. Barrera JE, Pau CY, Forest VI, Holbrook AB, Popelka GR, Medical Advisory Secretariat. Polysomnography in patients with obstructive sleep apnea: an evidence-based analysis. Ont Health Technol Assess Ser. 2006;6(13):1–38.

22. Solow B, Tallgren A. Natural head position in standing subjects. Acta Odontol Scand. 1971;29(5):591–607. https://doi.org/10.3109/00016357109026337

23. Isaacson JR, Isaacson RJ, Speidel TM, Worms FW. Extreme variation in vertical facial growth and associated variation in skeletal and dental relations. Angle Orthod. 1971;41(3):219–29.

24. Aboudara C, Nielsen I, Huang JC, Maki K, Miller AJ, Hatcher D. Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2009;135(4):468–79. https://doi.org/10.1016/j.ajodo.2007.04.043

25. Ucar FI, Uysal T. Orofacial airway dimensions in subjects with Class I malocclusion and different growth patterns. Angle Orthod. 2011;81(3):460–8. https://doi.org/10.2319/091910-545.1

26. Memon S, Fida M, Shaikh A. Comparison of different craniofacial patterns with pharyngeal widths. J Coll Physicians Surg Pak. 2012;22(5):302–6.

27. Martin O, Muelas L, Viñas MJ. Comparative study of nasopharyngeal soft-tissue characteristics in patients with Class III malocclusion. Am J Orthod Dentofacial Orthop. 2011;139(2):242–51. https://doi.org/10.1016/j.ajodo.2009.07.016

28. Daraze A, Delatte M, Liistro G, Majzoub Z. Cephalometrics of pharyngeal airway space in Lebanese adults. Int J Dent. 2017;2017:e3959456. https://doi.org/10.1155/2017/3959456

29. 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.

30. 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. https://doi.org/10.1093/ejo/cjt068