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GENDER-BASED VARIATIONS IN UPPER PHARYNGEAL AIRWAY VOLUME: A VOLUMETRIC STUDY OF A SAMPLE OF UPPER EGYPT POPULATION

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ABSTRACT

Background: The upper pharyngeal airway (UPA) is critical for respiratory function, and its size and volume significantly affect the craniofacial structure and occlusion. Gender differences play a key role in the variations in airway dimensions. Cone Beam Computed Tomography (CBCT) has become the preferred method for precise 3D analysis of airway morphology due to its accuracy and low radiation exposure compared to traditional computed Tomography (CT). However, limited research exists on UPA dimensions in the Upper Egypt population.

Purpose: This study investigates the effect of gender on upper pharyngeal airway dimensions in a sample of Upper Egypt population using 3D volumetric analysis.

Material and Methods: A total of 90 CBCT scans (38 males and 52 females, ages 18–60) were analyzed. The upper pharyngeal airway was segmented into the nasopharynx, oropharynx, and hypopharynx, with total volumes measured using Dolphin 3D software.

Results: Results revealed significant differences in gender, with males showing consistently larger nasopharyngeal, oropharyngeal, hypopharyngeal, and total airway volumes compared to females. These differences may be attributed to variations in the craniofacial structures .

Conclusions: Pharyngeal airway volume is significantly influenced by gender, highlighting the need for gender-specific considerations in the diagnosis and treatment.

KEYWORDS: Volumetric analysis; Cone beam computed tomography; Pharyngeal airway volume; Dolphin software.

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INTRODUCTION

The upper pharyngeal airway (UPA) is a key anatomical region of the respiratory system. It has a complex anatomical structure which is important to the harmonious growth and functioning of craniofacial regions. It consists of nasopharynx, oropharynx and hypopharynx, and it is involved in essential physiological functions, such as speech, breathing, and swallowing **(Tseng, Y. C. et al.2021 and Aboudara, C. et al 2009)**.

The upper pharyngeal airway significantly influences the development of optimal occlusion and facial morphology. Recent advancements in dentistry have heightened the focus on analyzing the pharyngeal airway and calculating its volume and dimensions. Deviations in the volume of the airway's structure can disrupt normal breathing patterns, which are critical for the development and stability of craniofacial structures and may contribute to malocclusion **(Alhammadi, M. S., et al 2021 and Rawdy, Ahmad & Elgemeeay, Walaa. 2018)**.

The assessment of the UPA's volume and size also is essential for understanding various health conditions.A reduced airway volume, particularly the upper pharyngeal airway, can lead to compromised airflow and contribute to conditions like obstructive sleep apnea (OSA), snoring, and difficulty in the breathing during sleep**.** Studies have consistently shown that smaller pharyngeal airways are linked to a higher risk of sleep-disordered breathing **(Thapa, A. et al., 2023 and Alves, M. et al 2012)** .

Radiographic techniques are essential for assessing the dimensions of the airway. Lateral cephalometry is a widely used two-dimensional (2D) imaging method in orthodontics and sleep medicine. It provides a cost-effective way to measure airway dimensions, but its limitation lies in its inability to capture the three-dimensional (3D) complexity of the upper airway .To overcome this CBCT offers 3D high-resolution imaging and allows for accurate volumetric and cross-sectional area analysis of the pharyngeal airway, making it particularly useful in volumetric studies. While it has a lower radiation dose compared to traditional CT scans. **(Carvalho, A. R. D. R. M. et al., 2024 and Diwakar, R. et al 2015)**.

Volumetric analysis measures the total volume of the airway, providing insights into its capacity and any potential constrictions or obstructions. Segmentation involves isolating specific regions of the pharyngeal airway, such as the nasopharynx (NP), oropharynx (OP) , or hypopharynx (HP), to evaluate their individual dimensions and contributions to the overall airway structure. Specialized software programs are used for this purpose, enabling precise identification of anatomical landmarks and delineation of airway boundaries. **(Malhotra, A. et al 2022 and Feng, X. et al.2015)**

Little research is concerning the gender variation so the this study is aiming to fill this gap by performing a volumetric analysis of the UPA in the Upper Egypt population to examine gender-based differences.

MATERIALS AND METHODS

Ethical clearance for this research was provided by the Research Ethics Committee (REC) of the Faculty of Dentistry at Minia University, referenced under the approval number 582-5/6/2022.

Study design

This retrospective study utilized existing CBCT scans from the archives of outpatient clinics in the Oral and Maxillofacial Radiology Departments at the Faculty of Dentistry of Minia Universities. CBCT data from 90 patients (male, n=38; mean age; women, n=52, mean age, 33.46 ± 13.4) met the eligibility criteria and were included in the analysis.

Inclusion criteria required participants to have complete clinical records, CBCT images that fully displayed the upper pharyngeal airway space, high-quality radiographic images, and no history of craniofacial abnormalities. Exclusion criteria involved patients with craniofacial disorders, a history of orthodontic treatment or orthognathic surgery, detectable upper airway pathologies, or a diagnosis of obstructive sleep apnea

Image acquisition

CBCT scans were obtained using SCANORA® 3Dx CBCT unit under standardized parameters (90kV, 10 mAs, 6 seconds exposure, scan time 34s, focal spot 0.5 mm). The scans were acquired with patients in an upright position, ensuring natural head orientation and proper occlusion.

Segmentation and volume analysis

The DICOM files were imported into the Dolphin 3D® software (version 11.5) for segmentation and volumetric analysis. The software first reoriented the scans across axial, sagittal, and frontal planes. After reorienting the scans, the upper pharyngeal airway was segmented into three subregions: nasopharynx, oropharynx, and hypopharynx. The segmentation followed guidelines by **Guijarro-Martínez and Swennen 2013** and was defined by the pharyngeal walls with manually applied clipping boundaries. The anterior limit was marked by a coronal plane passing by the posterior nasal spine, and the posterior limit by a plane passing through the superior margin of the second cervical vertebra (C2) odontoid process. Lateral boundaries were defined by sagittal planes tangential to the lateral pterygoid plates.

The pharyngeal subregions are outlined based on the Frankfort horizontal (FH) plane. The nasopharynx is defined by an upper boundary at the roof of the clivus and a lower boundary at the posterior nasal spine (PNS). For the oropharynx, the upper boundary is at the PNS, while the lower boundary is at the anterior inferior body of the third cervical vertebra (C3ai). The hypopharynx's upper boundary is set at the anterior inferior body of third cervical vertebra (C3ai), and its lower boundary is at the anterior-inferior point of forth cervical vertebra (C4ai). These established limits facilitate accurate segmentation and measurement of airway volume.

The nasopharyngeal airway was segmented using Dolphin 3D software through a semi-automatic approach. After determining the limits in the sagittal and transverse views, a seed point was placed, and the threshold value was manually adjusted . The operator also manually corrected any missed areas. The airway volume was calculated in cubic millimeters (Figure 1).

Using the same method as for the nasopharyngeal airway, the oropharyngeal and hypopharyngeal airway volumes. (Figure 2) Seed points were placed to identify the boundaries in the sagittal view.

Total airway volume was determined by summing the volumes of the NPV, OPV, and HPV. This combined measurement provided a comprehensive representation of the overall airway dimensions. To evaluate the consistency and reliability of the measurements, 10 scans were analyzed by the principal investigator and a co-investigator and re-measured two weeks later by the principal investigator.

Statistical Analysis

The normative quantitative data was assessed by examining data distribution and conducting normality tests, including the Kolmogorov-Smirnov and Shapiro-Wilk tests. All data were found to follow a normal (parametric) distribution. Descriptive statistics, such as mean and standard deviation (SD), were used to present the data. For comparisons between the two groups, the Student's t-test was employed, as it is appropriate for analyzing parametric data. This approach ensured robust statistical analysis and reliable interpretation of the results. Inter- and intra-observer agreement were assessed using Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (ICC). Closer values of the coefficients to one indicate better agreement.

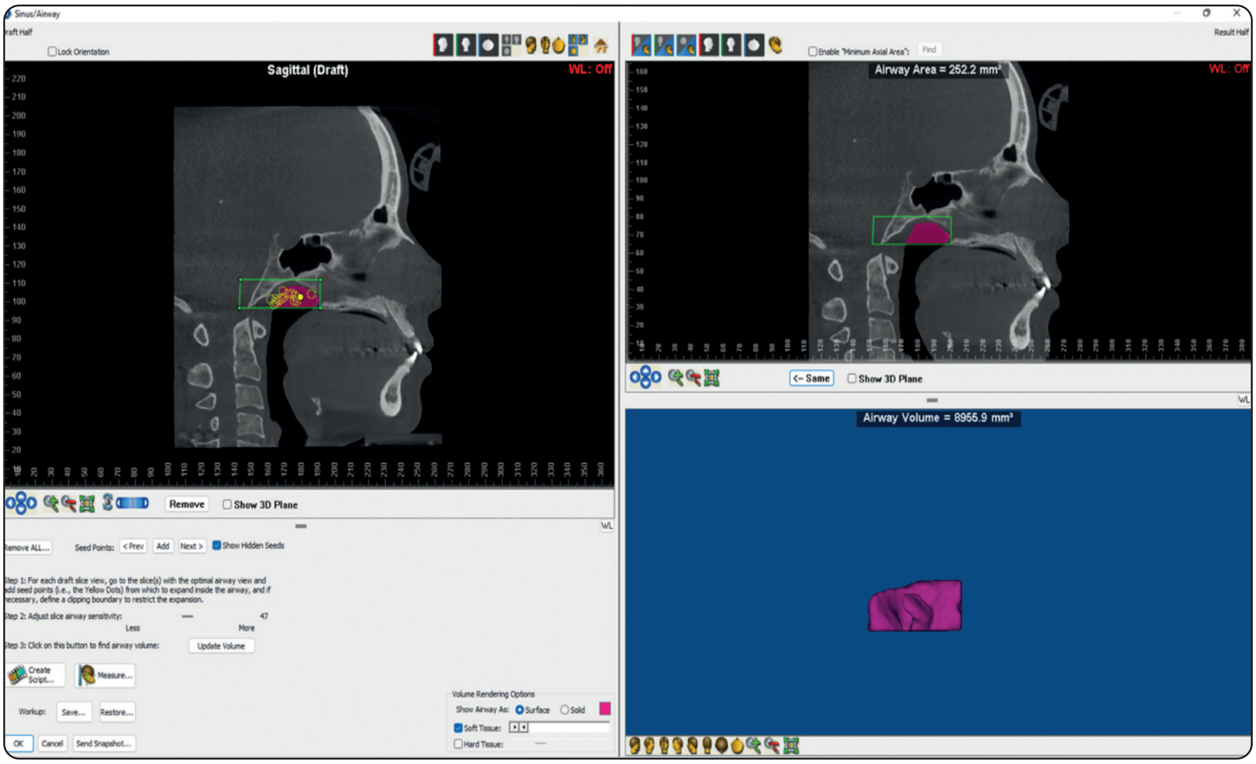

Fig. (1) Showing nasopharyngeal limits and volume in mm^3

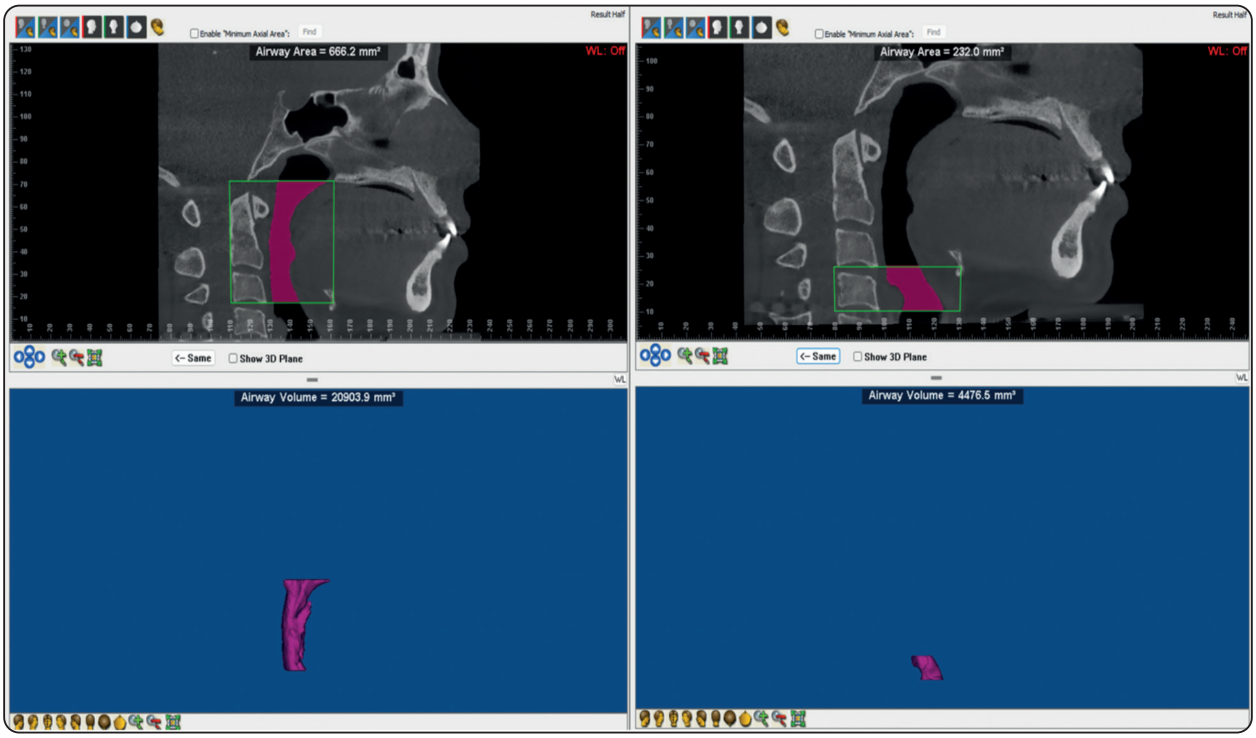

Fig. (2) Showing oropharyngeal and hypopharyngeal limits and volumes in mm^3

RESULTS

Baseline Characteristics of the studied Cohort

The baseline characteristics of the studied sample, mean age was 33.4 ± 13.4 years with a median of 34 (18 – 60 years). Regarding Sex, about 42.2% (n = 38) of cases were male and about 57.8% (n = 52) of cases were female.

Upper Pharyngeal Airway Evaluation of the studied Cohort

The mean value of nasopharynx volume was 7579.3± 1839.7 mm^3 , the mean value of oropharynx volume was 21235.6 ± 7464 mm^3, the mean value of hypopharynx volume was 5551.5 ± 1932.6 mm^3, the mean value of total volume was 34375.5 ± 9935.2 mm^3)**.**

Sex Difference in the Upper Pharyngeal Airway Evaluation

Table 1. showed the sex difference in the upper pharyngeal airway parameters.

Males had significantly (p 0.001*) higher mean nasopharynx volume (8326.9 ± 2043.4mm^3) than females (7007.6 ± 1442.8 mm^3). Likely, males had significantly ($p < 0.001$) higher mean oropharynx volume (25908.9 ± 7671.4 mm^3) than females (17661.8 ±4937.4 mm^3). Likewise, males had significantly ($p < 0.001$) higher mean hypopharynx volume (6936.2 ± 1813.1 mm^3) than females (4492.6 ± 1229.2 mm^3). Similarly, males had significantly ($p < 0.001$) higher mean total volume (41192.9 ± 9959.4 mm^3) than females (29162.1 ± 6028.4mm^3).

Reliability analysis (Inter- and intra-observer agreement)

Table 2 .There was a very good inter-observer agreement regarding all measurements with *Cronbach's alpha* reliability coefficients ranging from 0.980 to 0.999.

There was a very good intra-observer agreement regarding all measurements with *Cronbach's alpha* reliability coefficients ranging from 0.978 to 0.999.

TABLE (1) Sex Difference in Upper Pharyngeal Airway Evaluation : Student's t-test for comparison between Nasopharynx volume , oropharynx volume , hypopharynx volume and total volume (mm3) in males and females

Mean (Range)	Male (n = 38)	Female (n = 51)	P-value*
	Mean ± SD	Mean ± SD	
Nasopharynx Volume (mm^3)	8326.9 ± 2043.4	7007.6 ± 1442.8	0.001*
Oropharynx Volume (mm^3)	25908.9 ± 7671.4	17661.8 ±4937.4	<0.001*
Hypopharynx Volume (mm^3)	6936.2 ± 1813.1	4492.6 ± 1229.2	<0.001*
Total Volume (mm^3)	41192.9 ± 9959.4	29162.1 ± 6028.4	<0.001*

: Significant at $P \le 0.05$

TABLE (2) Results of Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (ICC) for inter- and intra-observer agreement regarding airway space measurements

Measurement	Inter-observer		Intra-observer	
	Cronbach's alpha	ICC	Cronbach's alpha	ICC
Nasopharynx volume	0.980	0.960	0978	0.957
Oropharynx volume	0.996	0.992	0.996	0.992
Hypopharynx volume	0.997	0.994	0.997	0.995
Total volume	0.999	0.998	0.999	0.998

DISCUSSION

The Measuring of airway volume and comparing it to normative data is vital for treatment planning. Reliable 3-D airway analysis, considering gender, is key for accurate evaluation. CBCT is a powerful tool in medicine and dentistry, offering precise airway measurements and detailed craniofacial analysis through various radiographs. It provides accurate three-dimensional reconstructions with low radiation exposure compared to conventional CT, enabling the assessment of both anatomical and pathological changes in airway morphology **(Abramson, Z. et al., 2009).**

This study showed that males had significantly larger nasopharyngeal volume, oropharyngeal volume, hypopharyngeal volume as well as the total volume than females which is compatible with **(Guijarro-Martínez, R., & Swennen, G. 2013)** who analyzed CBCT images of Caucasian adults (aged 23–35 years) using Dolphin software and found significantly larger oropharyngeal and hypopharyngeal volumes in males. **In addition,** these results are compatible with **Pop, S. I et al., 2024** analyzed 90 CBCT scans from the Romanian population (mean age 45 years), while **Inamoto, Y. et al., 2015** studied 3D CT images of 54 Japanese participants (ages 23–77), both reporting larger airway dimensions in males. Research on younger populations, such as **Diwakar, R. et al., 2021** in India (mean age 15.38 years), **Chan, L. et al., 2020** in Detroit (ages 9–15), further confirmed these findings, revealing significantly larger nasopharyngeal, oropharyngeal, and total pharyngeal airway volumes in males.

This result are likely due to males typically having larger craniofacial structures, such as wider jaws, longer palates, and broader nasal passages, all of which contribute to greater upper airway volumes. **(Chan, L. et al., 2020)**

Several studies contrast the findings of this research, revealing no significant gender differences in airway dimensions. **Tanikawa, C. et al., 2023** examined CBCT scans of young Japanese adults and found no significant sex differences in oropharyngeal or hypopharyngeal volumes . Also in contrast to the current study **Grauer, D. et al., 2009** found that there is no relationship between total airway volume and sex. **Carvalho, A. R. D. R. M. et al., 2024** reported also no significant differences in total upper airway .Similarly, in contrast to this study **Abramson, Z. et al., 2009,** using 3-D Slicer software, reported no significant gender differences in airway dimensions despite males having larger craniofacial structures. The observed discrepancies in gender effects across studies may be attributed to several factors, including variations in age distribution, differences in population characteristics, and the positioning of the trunk, head, and the neck during the scanning process **(Inamoto, Y. et al., 2015).** These variables highlight the importance of considering demographic and methodological differences when interpreting findings related to airway dimensions and gender-based variations.

CONCLUSION

The study concludes that significant differences in gender exist in the volumetric dimensions of the upper pharyngeal airway within the Upper Egypt population, with males having notably larger airway volumes than females.

REFERENCES

1. Aboudara, C., Nielsen, I., Huang, J. C., Maki, K., Miller, A. J., & Hatcher, D. (2009). Comparison of airway space with conventional lateral head films and 3-dimensional reconstruction from cone-beam computed tomography. American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics, 135(4), 468–479. https://doi.org/10.1016/j.ajodo.2007.04.043

2. Abramson, Z., Susarla, S., Troulis, M., & Kaban, L. (2009). Age-related changes of the upper airway assessed by 3-dimensional computed tomography. The Journal of craniofacial surgery, 20 Suppl 1, 657–663. https://doi.org/10.1097/SCS.0b013e318193d521

3. Alhammadi, M. S., Almashraqi, A. A., Halboub, E., Almahdi, S., Jali, T., Atafi, A., & Alomar, F. (2021). Pharyngeal airway spaces in different skeletal malocclusions: a CBCT 3D assessment. Cranio : the journal of craniomandibular practice, 39(2), 97–106. https://doi.org/10.1080/08869634.2019.1583301

4. Alves, M., Jr, Franzotti, E. S., Baratieri, C., Nunes, L. K., Nojima, L. I., & Ruellas, A. C. (2012). Evaluation of pharyngeal airway space amongst different skeletal patterns. International journal of oral and maxillofacial surgery, 41(7), 814–819. https://doi.org/10.1016/j.ijom.2012.01.015

5. Carvalho, A. R. D. R. M., Pollmann, M. C. F., & Martins, E. J. P. (2024). Upper airway dimensions and craniofacial morphology: A correlation study using cone beam computed tomography. Korean journal of orthodontics, 54(5), 274–283. https://doi.org/10.4041/kjod23.206

6. Chan, L., Kaczynski, R., & Kang, H. K. (2020). A cross-sectional retrospective study of normal changes in the pharyngeal airway volume in white children with 3 different skeletal patterns from age 9 to 15 years: Part 1. American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics, 158(5), 710–721. https://doi.org/10.1016/j.ajodo.2019.10.019

7. Da Rocha Martins De Carvalho, A. R., Pollmann, M. C. F., & Martins, E. J. P. (2024). Upper airway dimensions and craniofacial morphology: A correlation study using cone beam computed tomography. The Korean Journal of Orthodontics, 54(5), 274–283. https://doi.org/10.4041/kjod23.206

8. Diwakar, R., Kochhar, A. S., Gupta, H., Kaur, H., Sidhu, M. S., Skountrianos, H., Singh, G., & Tepedino, M. (2021). Effect of Craniofacial Morphology on Pharyngeal Airway Volume Measured Using Cone-Beam Computed Tomography (CBCT)-A Retrospective Pilot Study.International journal of environmental research and public health,18(9), 5040. https://doi.org/10.3390/ijerph18095040

9. Feng, X., Li, G., Qu, Z., Liu, L., Näsström, K., & Shi, X. Q. (2015). Comparative analysis of upper airway volume with lateral cephalograms and cone-beam computed tomography. American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics, 147(2), 197–204. https://doi.org/10.1016/j.ajodo.2014.10.025

10. Grauer, D., Cevidanes, L. S., Styner, M. A., Ackerman, J. L., & Proffit, W. R. (2009). Pharyngeal airway volume and shape from cone-beam computed tomography: relationship to facial morphology.American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics, 136, 805–814. https://doi.org/10.1016/j.ajodo.2008.0

11. Guijarro-Martínez, R., & Swennen, G. (2013). Three-dimensional cone beam computed tomography definition of the anatomical subregions of the upper airway: a validation study. International Journal of Oral and Maxillofacial Surgery, 42(9), 1140–1149. https://doi.org/10.1016/j.ijom.2013.03.007

12. Inamoto, Y., Saitoh, E., Okada, S., Kagaya, H., Shibata, S., Baba, M., Onogi, K., Hashimoto, S., Katada, K., Wattanapan, P., & Palmer, J. B. (2015). Anatomy of the larynx and pharynx: effects of age, gender and height revealed by multidetector computed tomography. Journal of oral rehabilitation, 42, 670–677. https://doi.org/10.1111/joor.12298

13. Malhotra, A., Huang, Y., Fogel, R., Lazic, S., Pillar, G., Jakab, M., Kikinis, R., & White, D. P. (2006). Aging influences on pharyngeal anatomy and physiology: the predisposition to pharyngeal collapse.The American journal of medicine,119(1),72.e972.e7.2E14.https://doi.org/10.1016/j.amjmed.2005.01.07

14. Pop, S. I., Procopciuc, A., Arsintescu, B., Mițariu, M., Mițariu, L., Pop, R. V., Cerghizan, D., & Jánosi, K. M. (2024). Three-Dimensional Assessment of Upper Airway Volume and Morphology in Patients with Different Sagittal Skeletal Patterns. Diagnostics (Basel, Switzerland), 14(9), 903. https://doi.org/10.3390/diagnostics14090903

15. Rawdy, Ahmad & Elgemeeay, Walaa. (2018). Volumetric analysis of total pharyngeal airway space using cone beam computed tomography among adult egyptians. Egyptian Dental Journal. 64. 2183-2189. 10.21608/edj.2018.76783.

16. Tanikawa, C., Oka, A., Shiraishi, Y., & Yamashiro, T. (2023). Sex differences in airway volume and 3-dimensional shape in Japanese adults. Scientific Reports, 13(1). https://doi.org/10.1038/s41598-023-41263-6

17. Thapa, A., Roy, I. D., Jayan, B., Ray, S., Kumar, A. N., & Antil, A. (2023). Volumetric analysis of pharyngeal airway dimensions and hyoid bone position following orthognathic surgery in skeletal class III patients: a cross sectional cephalometric study. International Journal of Otorhinolaryngology and Head and Neck Surgery, 9(12), 921–927. https://doi.org/10.18203/issn.2454-5929.ijohns20233536

18. Tseng, Y. C., Tsai, F. C., Chou, S. T., Hsu, C. Y., Cheng, J. H., & Chen, C. M. (2021). Evaluation of pharyngeal airway volume for different dentofacial skeletal patterns using cone-beam computed tomography. Journal of dental sciences, 16(1), 51–57. https://doi.org/10.1016/j.jds.2020.07.015