Original Research

Correlation between the upper airway volume and Ricketts' facial biotypes: a cone-beam computed tomography study

Ana Rita Carvalho[1],* iD, *Maria Cristina Figueiredo Pollmann*[1] iD,
Eugénio Joaquim Pereira Martins[1] iD

[1] *Department of Orthodontics, Faculty of Dental Medicine, University of Porto, Porto, Portugal.*

A B S T R A C T

Objectives: This study aimed to determine if there are differences in the upper airway space between the three facial biotypes described by Ricketts. It also investigated if there are anatomical differences between males and females at the upper airway level.

Methods: Data was collected from a private orthodontic clinic. Orthodontic tracing was done using NemoFab Ortho software to obtain the dentoskeletal measurements: anterior facial height, posterior facial height, maxillary width, and palatal depth. The upper airway measurements were achieved using the same software by identifying landmarks for each upper airway compartment (nasopharynx and oropharynx). The Pearson correlation coefficient was used to determine the correlation between the variables α=0.05).

Results: The sample included eighty patients with a mean age of 30.4 years, predominantly females (67.5%). Statistical differences were found between brachyfacial and dolichofacial patients regarding the oropharynx volume (p=0.009) and total volume (p=0.027). Regarding the comparison by sex, male patients had significantly higher mean values for upper airway volumes and all the dentoskeletal features analyzed, except for maxillary width.

Conclusions: There are statistical differences in the upper airway space among different facial biotypes. Brachyfacial patients seem to have higher upper airway volumes than Dolichofacial patients. Moreover, males showed higher upper airway volumes than females. (Rev Port Estomatol Med Dent Cir Maxilofac. 2024;65(4):181-187)

* Corresponding author.
 E-mail address: ritacarv@gmail.com (Ana Rita Carvalho).

Correlação entre o volume das vias aéreas superiores e os biótipos faciais de Ricketts: um estudo de tomografia computadorizada de feixe cónico

RESUMO

Palavras-chave:
Vias aéreas
Cefalometria
Diagnóstico
Crescimento e desenvolvimento
Plano de tratamento
Imagens tridimensionais

Objetivos: O objetivo deste estudo foi avaliar se havia diferenças estatísticas em relação ao espaço das vias aéreas superiores entre os três biótipos faciais descritos por Ricketts. Avaliou-se ainda a existência de diferenças anatómicas entre homens e mulheres ao nível da via aérea superior.

Métodos: Os dados foram recolhidos de uma clínica ortodôntica privada. O traçado ortodôntico foi realizado utilizando o software NemoFab Ortho para obtenção das medidas dentoesqueléticas: altura facial anterior, altura facial posterior, largura maxilar e profundidade do palato. As medidas da via aérea superior foram obtidas utilizando o mesmo software através da identificação de pontos de referência para cada compartimento da via aérea superior (nasofaringe e orofaringe). O coeficiente de correlação de Pearson foi utilizado para determinar a correlação entre as variáveis (α=0.05).

Resultados: A amostra incluiu oitenta pacientes com idade média de 30,4 anos, predominantemente do sexo feminino (67,5%). Foram encontradas diferenças estatísticas entre pacientes braquifaciais e dolicofaciais quanto ao volume da orofaringe (p=0,009) e volume total (p=0,027). Em relação à comparação por sexo, os pacientes do sexo masculino apresentaram valores médios significativamente mais elevados para os volumes da via aérea superior e para todas as características dentoesqueléticas analisadas, com exceção da largura maxilar.

Conclusões: Existem diferenças estatísticas no espaço da via aérea superior entre os diferentes biótipos faciais. Pacientes braquifaciais parecem apresentar maiores volumes de via aérea superior do que os pacientes dolicofaciais. Além disso, os homens apresentaram maiores volumes de espaço de via aérea superior do que as mulheres. (Rev Port Estomatol Med Dent Cir Maxilofac. 2024;65(4):181-187)

Introduction

The link between respiratory function and craniofacial morphology has been a topic of great interest in recent years. Many studies have shown a relationship between those two variables,[1-3] while many other authors found no correlation.[4,5]

Upper airway obstruction can occur due to many factors and has been linked to a change in the respiratory pattern that may affect craniofacial growth and development.[6] Those airway constrictions lead to a shift from nasal to mouth breathing and, in many cases, culminate with the upper airway collapsing during sleep—the main symptom of obstructive sleep apnea.[7] The upper airway collapse mechanism is incompletely understood but is associated with several factors, including craniofacial changes. The most common among them are reduced mandibular body length, inferiorly positioned hyoid bone, posterior displacement of the maxilla, and narrowing of the pharyngeal space.[8] Within the pharyngeal space, the oropharynx is where most obstructive disorders occur.[9] Therefore, fully understanding this anatomic structure is extremely important.

Cone-beam computed tomography (CBCT) is a 3D radiological imaging technique widely used in upper airway volume assessment studies for several reasons, including its lower radiation dose compared to conventional computed tomography.[10] This technology, introduced in the late 1990s, allows visualizing anatomic structures in multiple planes, which was impossible using two-dimensional (2D) imaging techniques.

Although obstructive sleep apnea is a functional syndrome that must be evaluated and diagnosed with functional tests, CBCT can give information on obstruction sites within the upper airway. Therefore, besides supporting orthodontic diagnosis, it can help screen at-risk patients who must be referred to otorhinolaryngology.

According to Ricketts' analysis, facial biotypes can be classified into brachyfacial, mesofacial, and dolichofacial, depending on growth direction.[11] The dolichofacial, or vertical growth pattern, is characterized by a higher anterior facial height, a lower mandible position, and a narrowing of the hard palate on the transverse dimension. This type of facial growth is often associated with upper airway obstruction and mouth breathing.[12]

According to many authors, mouth breathing can predispose to a lowered position of the mandible and tongue, changing the direction of facial growth. It often determines a clockwise rotation of the mandible and a vertical growth of facial structures.[13,14]

Many studies have investigated correlations between the upper airway space and facial features or dental or skeletal classes. Although many studies have addressed this topic,

there is a lack of information on upper airway space differences among the three facial biotypes described by Ricketts. Therefore, this study aimed to assess if there are statistical differences among those three facial biotypes regarding the upper airway space and its most constricted site. Furthermore, we set out to investigate if there are correlations between dentoskeletal features and upper airway volume, as well as upper airway volumetric differences between males and females.

Material and Methods

In this retrospective epidemiological study, orthodontic treatment records of patients from a private clinic were examined and selected if they matched the inclusion criteria: Caucasian patients aged ≥16 years old with a CBCT scan available. Exclusion criteria were as follows: non-Caucasian patients, cranio-

facial anomalies, obstructive sleep apnea diagnosis, and previous orthodontic treatment or orthognathic surgery.

The methodology for CBCT acquisition was patients positioned upright, with the Frankfurt horizontal parallel to the ground, and in maximum intercuspation. The equipment used was the Planmeca2 ProMax 3D Mid instrument (Planmeca Oy, Helsinki, Finland). The images obtained were saved in DICOM (Digital Imaging and Communications in Medicine) format and imported to the NemoFab Ortho software for volume orientation. Orthodontic tracing was performed in the mid-sagittal plane slice using the same software. Cephalometric tracing assessed the following variables: anterior facial height (Na-Me), posterior facial height (S-Go), maxillary width, and palatal depth (Figure 1).

The facial biotype was assessed using the VERT index proposed by Ricketts, which entails five cephalometric measurements (facial axis, facial depth, mandibular plane, anteroinfe-
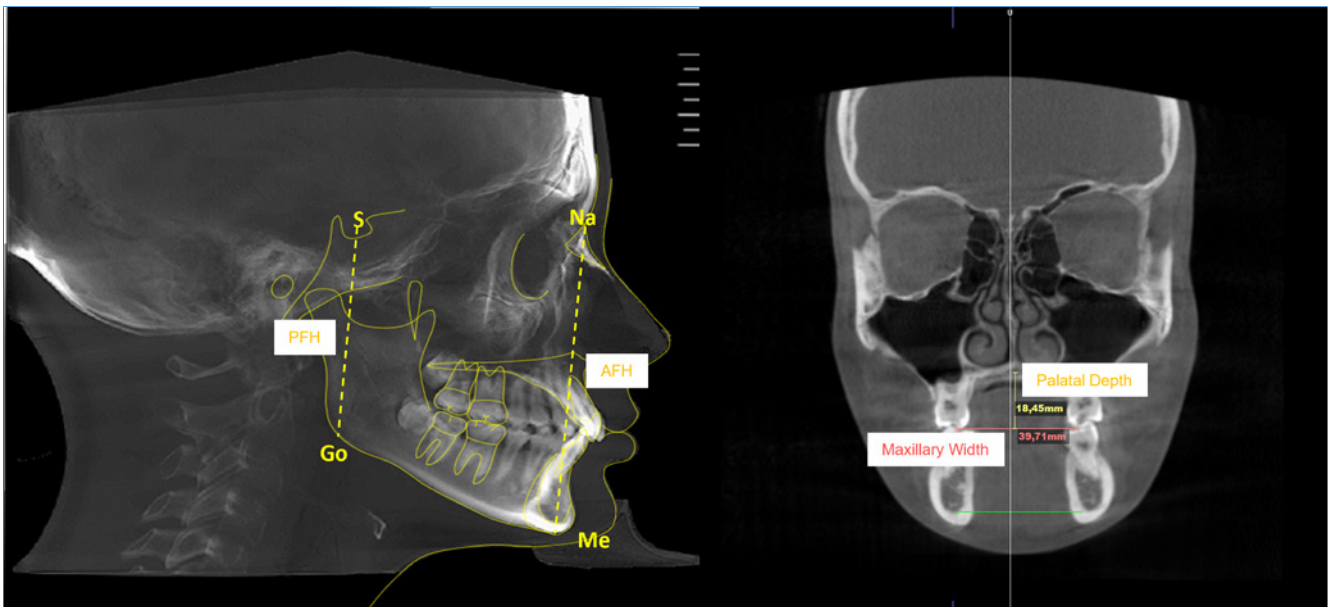

Figure 1. Assessment of dentoskeletal variables using NemoFab Ortho software.
AFH – anterior facial height; PFH – posterior facial height; PD – palatal depth; MW – maxillary width.
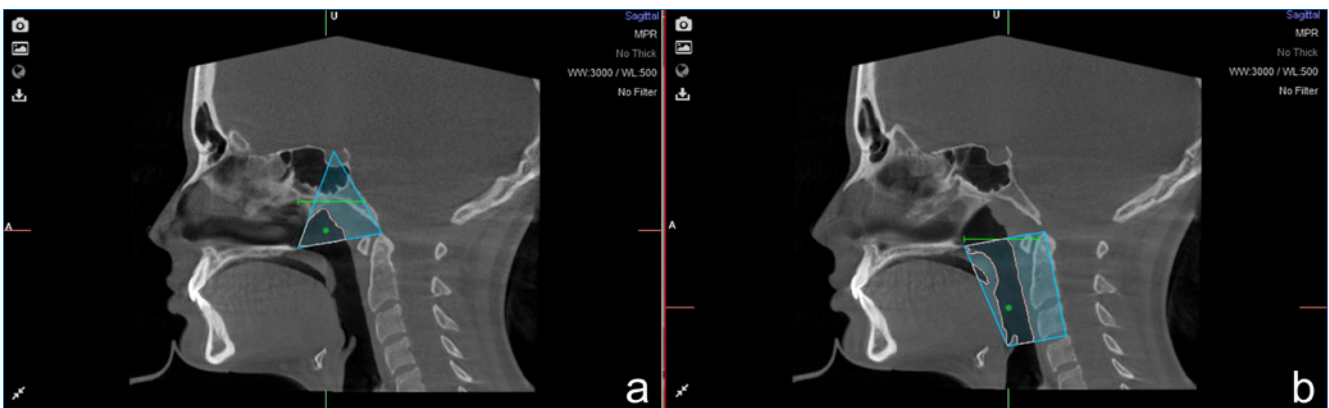

Figure 2. Assessment of (a) nasopharynx and (b) oropharynx volumes using NemoFab Ortho software.

rior facial height, and mandibular arch) and classifies the face into six types: severe brachyfacial, brachyfacial, mesofacial, light dolichofacial, dolichofacial, and severe dolichofacial.[15]

The limits of the nasopharynx and the oropharynx were determined for the upper airway assessment. The following landmarks were identified as the nasopharynx boundaries: (1) posterior nasal spine, (2) sella, and (3) the odontoid process tip, forming a triangle (Figure 2a). For the oropharynx, four anatomic points were identified: (1) posterior nasal spine, (2) epiglottis tip, (3) odontoid process tip, and (4) posterior superior border of the fourth cervical vertebra (Figure 2b). Afterward, the software calculated the corresponding volume in cubic centimeters (cm^3) and the minimal sectional area in square millimeters (mm^2). The sum of both nasopharynx and oropharynx volumes represented the total upper airway volume.

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) software for Windows, version 29 (IBM Corp. Released, 2022). Student's t-test and the intraclass correlation coefficient were used in the error evaluation of the continuous measurements. The intra-observer error for the linear and volumetric measurements was assessed on 30 randomly repeated measurements selected from the total sample, with the method proposed by Walter et al..[16] The Pearson correlation coefficient was used to determine the correlation between dentoskeletal variables and upper airway volume. A 5% significance level was set for the statistical tests' results; i.e., differences and correlations were considered statistically significant when the significance value was lower than 0.50 (α=0.05).

Results

The results of the Student's t-tests for paired samples showed no statistically significant differences (p>0.05) between the means of the first measurement and the means of the second measurement. The intraclass correlation coefficient (ICC) values were greater than 0.97 in all variables, indicating excellent consistency between the results of the first and second measurements. Together, these results guarantee excellent reliability of the measurements and confirm the absence of measurement errors.

Our sample included 80 patients aged between 16 and 56 years, with a mean age of 30.4 years (SD=11.4) and a median age of 28.0 years (Table 1). Regarding gender, 54 (67.5%) were female and 26 (32.5%) male. Of the 80 patients, 28 (35.0%) had the brachyfacial type, 26 (32.5%) the mesofacial type, and 26

Table 1. Sample characterization.

Age	Minimum	16
	Maximum	56
	Mean	30.4
	Median	28.0
Sex	Female	54 (67.5%)
	Male	26 (32.5%)
Facial biotype	Brachyfacial	28 (35.0%)
	Mesofacial	26 (32.5%)
	Dolichofacial	26 (32.5%)

Table 2. Characterization of dentoskeletal, nasopharyngeal, and oropharyngeal variables.

Variables	Mean	SD
Nasopharinx – volume	6.87	2.40
Nasopharinx – minimal sectional area	13.22	9.72
Oropharynx – volume	17.24	6.76
Oropharynx – minimal sectional area	200.74	101.16
Total volume	24.12	7.99
Posterior facial height	77.38	7.84
Anterior facial height	115.65	7.78
Palatal depth	21.06	2.90
Maxillary width	47.93	6.38

SD – standard deviation

(32.5%) the dolichofacial type (Table 1). Table 2 presents the characterization of dentoskeletal, nasopharynx, and oropharynx variables.

The results of the correlations between the dentoskeletal variables and the nasopharynx and oropharynx variables (Table 3) showed moderately significant positive correlations between the posterior facial height and the oropharynx volume (r=0.315, p=0.004) and the total volume (r=0.318, p=0.004). None of the other correlations differed significantly from zero (p>0.05).

Regarding the comparison of nasopharynx and oropharynx variables between facial types (Table 3), there were statistically significant differences in the oropharynx volume (p=0.009), the minimum section of the oropharynx (p=0.009), and the total volume (p=0.027). Brachyfacial patients had the highest mean values, and dolichofacial patients had the lowest mean values, with statistically significant differences between these two facial types (p<0.05). Mesofacial patients had intermediate mean values, with no significant differences, either regarding brachyfacial patients (p>0.05) or dolichofacial patients (p>0.05).

Regarding the comparison by sex (Table 4), male patients had significantly higher mean values for nasopharyngeal volume (p=0.030), oropharyngeal volume (p=0.001), total volume (p<0.001), posterior facial height (p<0.001), anterior facial height (p<0.001), and palate depth (p=0.018). No significant differences were observed between male and female patients regarding the minimum section of the nasopharynx (p=0.367), the minimum section of the oropharynx (p=0.276), or the maxillary width (p=0.327).

Discussion

Many studies have demonstrated that upper airway volumes differ among skeletal classes.[17,18] Moreover, skeletal class II is often associated with reduced upper airway volume and may represent a risk factor for developing obstructive sleep apnea.

CBCT is a useful tool for determining airway obstructions and can help clinicians screen at-risk patients. CBCT is considered a reliable method in this investigation because we

Table 3. Correlations between the dentoskeletal variables and the nasopharyngeal and oropharyngeal variables.

Dentoskeletal variables	Nasopharynx		Oropharynx		Total volume
	Volume	Minimal sectional area	Volume	Minimal sectional area	
Posterior facial height	r = 0.171 (p = 0.129)	r = 0.074 (p = 0.513)	**r = 0.315 (p = 0.004)**	r = 0.138 (p = 0.223)	**r = 0.318 (p = 0.004)**
Anterior facial height	r = 0.135 (p = 0.233)	r = -0.050 (p = 0.660)	r = 0.208 (p = 0.064)	r = -0.048 (p = 0.673)	r = 0.216 (p = 0.054)
Palatal depth	r = 0.095 (p = 0.400)	r = 0.093 (p = 0.413)	r = 0.174 (p = 0.122)	r = -0.004 (p = 0.975)	r = 0.176 (p = 0.118)
Maxillary width	r = -0.025 (p = 0.826)	r = -0.045 (p = 0.692)	r = 0.061 (p = 0.593)	r = 0.016 (p = 0.891)	r = 0.044 (p = 0.699)
Facial biotype					
Brachyfacial (n=28)	M = 7.01 (SD = 2.50)	M = 13.88 (SD = 10.01)	M = 19.75 [a] (SD = 6.06)	M = 239.10 [a] (SD = 90.48)	M = 26.76 [a] (SD = 7.45)
Mesofacial (n=26)	M = 6.62 (SD = 2.22)	M = 14.41 (SD = 11.70)	M = 15.99 [ab] (SD = 6.73)	M = 182.58 [ab] (SD = 99.47)	M = 22.61 [ab] (SD = 8.20)
Dolichofacial (n=26)	M = 6.86 (SD = 2.49)	M = 11.46 (SD = 7.01)	M = 14.83 [b] (SD = 4.98)	M = 163.81 [b] (SD = 79.77)	M = 21.68 [b] (SD = 5.71)
ANOVA	p = 0.842	p = 0.521	**p = 0.009**	**p = 0.009**	**p = 0.027**

r – correlation coefficient; M – mean; SD – standard deviation

Table 4. Sex differences regarding dentoskeletal, nasopharyngeal, and oropharyngeal variables.

Variables	Sex		
	Female (n = 54)	Male (n = 26)	Student's t-test
Nasopharinx – volume	6.52 (2.48)	7.60 (2.06)	**p = 0.030**
Nasopharinx – minimal sectional area	13.48 (10.68)	12.69 (7.49)	p = 0.367
Oropharynx – volume	15.57 (5.74)	20.73 (7.46)	**p = 0.001**
Oropharynx – minimal sectional area	196.03 (96.94)	210.54 (110.75)	p = 0.276
Total volume	22.09 (7.29)	28.33 (7.85)	**p < 0.001**
Posterior facial height	73.68 (5.97)	85.08 (5.23)	**p < 0.001**
Anterior facial height	113.18 (6.83)	120.78 (7.21)	**p < 0.001**
Palatal depth	20.59 (2.89)	22.04 (2.72)	**p = 0.018**
Maxillary width	48.15 (6.20)	47.46 (6.84)	p = 0.327

aimed to determine if there is a correlation between the upper airway volume and the facial biotype, not to diagnose obstructive sleep apnea.

The present study found positive correlations between upper airway volume and the dentoskeletal variables. The correlations were significant between the anterior facial height, the oropharynx volume, and the total pharynx volume. Furthermore, we also found significant differences in the upper airway among the three facial biotypes, thus emphasizing the relationship between the upper airway and craniofacial morphology.

Establishing a cause-effect relationship between the upper airway and craniofacial morphology is quite difficult. However, we here demonstrate that an altered maxillomandibular position is linked to a reduction in the airway space, which represents a risk factor for developing obstructive sleep apnea syndrome.

Most studies in the literature used the skeletal class instead of the facial biotype we considered here. Therefore, to our knowledge, this is a pioneer study investigating the association between facial biotypes and upper airway space.

We observed no significant differences between facial biotypes regarding nasopharyngeal volume and minimal section area. This finding corroborates a previous study from Rohan et al.,[19] who found that pharyngeal airway volume, both nasopharyngeal and oropharyngeal, does not differ significantly between different vertical jaw relationships. On the other

hand, Joseph et al.[20] found statistically significant differences in the nasopharyngeal volume between patients with hyperdivergent growth and normodivergent growth, with the former having a narrower nasopharynx than the latter. According to those authors, the facial growth pattern appears to impact not only the airway dimensions but also its morphology, particularly in the nasopharynx region. Feres et al.'s study[21] also reported reduced nasopharyngeal volume in dolichofacial patients, explaining that it could result from those patients' excessively vertical facial features.

Our study found significant differences between facial biotypes regarding oropharynx volume and minimal section area. Brachyfacial individuals presented significantly higher values for oropharynx volume compared to dolichofacial individuals. This finding agrees with a previous study by Joseph et al.,[20] who found hyperdivergent individuals had narrower anteroposterior pharyngeal dimensions than normodivergent, especially in the oropharynx. Skeletal features like maxillary and mandibular retrusion and vertical maxillary excess may explain that difference.

Our study suggests that mean airway volume is significantly higher in males than females, possibly due to their anatomic size differences, as suggested by several previous studies.[22-24] Males presented higher nasopharynx and oropharynx volumes than females. On the other hand, we found no significant differences between males and females in the minimal section area of the oropharynx and nasopharynx.

Regarding facial features, males showed higher anterior and posterior facial heights than females. This finding is coherent with previous studies from Kharbanda et al.[25] in an Indian population, who found higher values for vertical facial parameters in males than females. Similar results were observed by Vieira et al.[26] in their study in a Brazilian-Asiatic population, which indicated a sex dimorphism regarding facial vertical growth. Palatal depth was also significantly higher in males than females in the present study. Al-Zubair[27] obtained similar results, although their measurements were made on maxillary casts using a palatometer.

Conclusions

Our results suggest that the facial biotype is correlated with airway space. Dolichofacial individuals seem to have less airway space than the brachyfacial group, possibly due to their facial features that promote more vertical facial growth. Also, males had higher mean airway volume and facial feature values than females in this study.

Conflict of interest

The authors have no conflicts of interest to declare.

Ethical disclosures

Protection of human and animal subjects. The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Confidentiality of data. The authors declare that they have followed their work center protocols on access to patient data and for its publication.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

CRediT authorship contribution statement

Ana Rita Carvalho: Investigation; Methodology; Writing – original draft. **Maria Cristina Figueiredo Pollmann:** Investigation; Methodology; Supervision; Validation; Writing – review & editing. **Eugénio Joaquim Pereira Martins:** Investigation; Methodology; Supervision; Validation; Writing – review & editing.

ORCID

Ana Rita Carvalho 0000-0001-9125-8661
Maria Cristina Figueiredo Pollmann 0000-0002-8160-7917
Eugénio Joaquim Pereira Martins 0000-0002-4802-8913

REFERENCES

1. Shokri A, Miresmaeili A, Ahmadi A, Amini P, Falah-Kooshki S. Comparison of pharyngeal airway volume in different skeletal facial patterns using cone beam computed tomography. J Clin Exp Dent. 2018;10:e1017-28.
2. Gowda RS, Raghunath N, Sahoo KC, Shivlinga BM. Comparative Study of Mandibular Morphology in Patients with Hypodivergent and Hyperdivergent Growth Patterns Comparative Study of Mandibular Morphology in Patients with Hypodivergent and Hyperdivergent Growth Patterns: A Cephalometric Study. J Indian Orthod Soc. 2013;47:377-81.
3. Zhong Z, Tang Z, Gao X, Zeng X-L. A Comparison Study of Upper Airway among Different Skeletal Craniofacial Patterns in Nonsnoring Chinese Children. Angle Orthod. 2010;80:267-74.
4. Di Carlo G, Polimeni A, Melsen B, Cattaneo PM. The relationship between upper airways and craniofacial morphology studied in 3D. A CBCT study. Orthod Craniofac Res. 2015;18:1-11.
5. Indriksone I, Jakobsone G. The influence of craniofacial morphology on the upper airway dimensions. Angle Orthod. 2015;85:874-80.
6. Zhao Z, Zheng L, Huang X, Li C, Liu J, Hu Y. Effects of mouth breathing on facial skeletal development in children: a systematic review and meta-analysis. BMC Oral Health. 2021;21:108.
7. Guilleminault C, Sullivan SS, Huang Y-S. Sleep-Disordered Breathing, Orofacial Growth, and Prevention of Obstructive Sleep Apnea. Sleep Med Clin. 2019;14:13-20.
8. Huang L, Gao X. The interaction of obesity and craniofacial deformity in obstructive sleep apnea. Dentomaxillofac Radiol. 2021;50:20200425.

9. Chernick V, West JB. Chapter 4 - The Functional Basis of Respiratory Disease. In: Chernick V, Boat TF, Wilmott RW, Bush A, editors. Kendig's Disorders of the Respiratory Tract in Children (Seventh Edition). Philadelphia: W.B. Saunders; 2006. p. 29-64.

10. Suomalainen A, Kiljunen T, Käser Y, Peltola J, Kortesniemi M. Dosimetry and image quality of four dental cone beam computed tomography scanners compared with multislice computed tomography scanners. Dentomaxillofac Radiol. 2009;38:367-78.

11. Ricketts RM. Orthodontic Diagnosis and Planning: Their roles in preventive and rehabilitative dentistry: Rocky Mountain/Orthodontics; 1982.

12. Bolzan GP, Souza JA, Boton LM, Silva AMT, Corrêa ECR. Facial type and head posture of nasal and mouth-breathing children. J Soc Bras Fonoaudiol. 2011;23:315-20.

13. Geramy A, Bouserhal J, Martin D, Baghaeian P. Bone stress and strain modification in diastema closure: 3D analysis using finite element method. Int Orthod. 2015;13:274-86.

14. Sfondrini MF, Gallo S, Pascadopoli M, Gandini P, Roncoroni C, Scribante A. Upper Airway Dimensions among Different Skeletal Malocclusions: A Retrospective Observational Study by Cephalometric Analysis. Dent J (Basel). 2024;12:12.

15. Ricketts R, Roth R, Chaconas S, Schulhof R, Engel G. Bioprogressive technique of Ricketts. Buenos Aires: Panamericana. 1983

16. Walter SD, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. Stat Med. 1998;17:101-10.

17. Rodrigues J, Evangelopoulos E, Anagnostopoulos I, Sachdev N, Ismail A, Samsudin R, et al. Impact of class II and class III skeletal malocclusion on pharyngeal airway dimensions: A systematic literature review and meta-analysis. Heliyon. 2024;10:e27284.

18. Zheng ZH, Yamaguchi T, Kurihara A, Li HF, Maki K. Three-dimensional evaluation of upper airway in patients with different anteroposterior skeletal patterns. Orthod Craniofac Res. 2014;17:38-48.

19. Diwakar R, Sighu MS, Prabhakar M, Grover S, Phogat R. Three-dimensional evaluation of pharyngeal airway in individuals with varying growth patterns using cone beam computed tomography. J Indian Orthod Soc. 2015;49:85-8.

20. 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;56:135-9.

21. Feres MFN, Enoki C, Anselmo-Lima WT, Matsumoto MAN. Dimensões nasofaringeanas e faciais em diferentes padrões morfológicos. Dental Press J Orthod. 2010;15:52-61.

22. Diwakar R, Kochhar AS, Gupta H, Kaur H, Sidhu MS, Skountrianos H, et al. Effect of Craniofacial Morphology on Pharyngeal Airway Volume Measured Using Cone-Beam Computed Tomography (CBCT)-A Retrospective Pilot Study. Int J Environ Res Public Health. 2021;18:5040.

23. Grauer D, Cevidanes LSH, 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;136:805-14.

24. 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;19:1497-507.

25. Kharbanda OP, Sidhu SS, Sundrum KR. Vertical proportions of face: a cephalometric study. Int J Orthod. 1991;29:6-8.

26. Vieira FP, Pinzan A, Janson G, Fernandes TM, Sathler RC, Henriques RP. Facial height in Japanese-Brazilian descendants with normal occlusion. Dental Press J Orthod. 2014;19:54-66.

27. Al-Zubair N. Determinants Factors of Yemeni Maxillary Arch Dimensions. Saudi Dent J. 2014;27:50-4.