Keywords
Airway, Cephalometry, Hyoid Bone, Obstructive Sleep Apnoea , Sexual dimorphism (according to MeSH guidelines and alphabetical order)

Authors:
[1]Dr. Hashmi K M
College / affiliation address with pin code: Nitte (Deemed to be University), AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), Mangalore, Karnataka, India – 575018.
Designation: Post Graduate
Department: Department of Orthodontics and Dentofacial Orthopaedics
ORCID ID: 0009-0002-8572-6865
Email Id: drhashminavaf@gmail.com

[2*]Prof (Dr) K Saidath
College / affiliation address with pin code: Nitte (Deemed to be University), AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), Mangalore, Karnataka, India – 575018.
Designation: Professor
Department: Department of Orthodontics and Dentofacial Orthopaedics
ORCID ID: 0000-0001-9412-591X
Email Id: saidath@yahoo.com

[3]Prof (Dr) M.S. Ravi
College / affiliation address with pin code: Nitte (Deemed to be University), AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), Mangalore, Karnataka, India – 575018.
Designation: Vice Principal and HOD
Department: Department of Orthodontics and Dentofacial Orthopaedics
ORCID ID: 0000-0002-5544-8799
Email Id: drmsravi@nitte.edu.in

[4]Dr. Achal Balachandran
College / affiliation address with pin code: Nitte (Deemed to be University), AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), Mangalore, Karnataka, India – 575018.
Designation: Post Graduate
Department: Department of Orthodontics and Dentofacial Orthopaedics
ORCID ID: 0009-0004-8581-2848
Email ld: achalbalachandran@gmail.com

[5]Dr. Shalmiya K I
College/affiliation address with Pin code: Govt. Dental College Thrissur, Medical college P.O, Peringandoor, Thrissur, Kerala, India-680596
Designation: Assistant professor
Department: Oral Medicine and Radiology
ORCID ID:0000-0003-1045-3460
Email Id: shalmiya04@gmail.com

Received:11-05-2026
Revised:15-06-2026
Accepted:25-06-2026
Doi:10.1922/ejprd.v34i7s.1580

Assessment of Pharyngeal Airway Space and Hyoid Bone Position in Individuals with Different Facial Growth Patterns

Structured Abstract

Introduction: The hyoid bone is an integral element of the oropharyngeal complex. Reduced PAS and an inferior hyoid bone position are linked to obstructive sleep apnoea and are orthodontically important.

Objective : To assess and compare the relationship between pharyngeal airway space and hyoid bone position among vertical, horizontal, and normal facial growth patterns in males and females.

Materials and Methods: This comparative study evaluated 102 lateral cephalograms, divided into three groups based on Jarabak's ratio (n = 34 each): normal, vertical, and horizontal growth patterns. Each group was further subdivided by gender. Pharyngeal airway dimensions and hyoid bone position were measured manually by trained orthodontists. Statistical analysis included independent t-test, one-way and two-way ANOVA with Tukey's post hoc test, and Pearson's correlation. A p-value < 0.05 was considered statistically significant.

Results: Significant differences in V–LPW and VP–HY were observed among growth patterns, while HP–HY showed significant gender differences. In the normal growth pattern group, VP–HY and HP–HY were significant. A negative correlation was found between PTM–UPW and HP–HY in females and between V–LPW and HP–HY in males.

Conclusion: The horizontal growth pattern exhibited the widest lower pharyngeal airway, whereas the vertical pattern showed a more posteriorly positioned hyoid bone. Males had a more inferior hyoid position. With the reduction in upper pharyngeal width, there is a tendency for inferior positioning of hyoid bone in females. In males, with the reduction in lower pharyngeal width, there is a tendency for inferior positioning of hyoid bone.

INTRODUCTION:

The hyoid bone and its relation with the pharyngeal space in health and disease has been an intriguing subject for years.[1] Gender, pattern of growth and anteroposterior skeletal relationship influences the relation between pharyngeal airway space and hyoid bone position. Till now there are no literature which focus on assessing correlation between pharyngeal airway and hyoid bone position in various growth patterns of mandible in South Indian population.

This study focuses on assessing the relation between hyoid bone position and pharyngeal airway space in various growth patterns of mandible in South Indian population in retrospective method. It has been reported that, by changing the position of mandible, the position of the hyoid bone and tongue are also changed with the consequent narrowing of the pharyngeal airway space (PAS). The narrowing of PAS and a lower hyoid bone position is considered as the risk factor for obstructive sleep apnoea.[2]

Thus, relation between pharyngeal airway space and hyoid bone plays an important role in diagnosis, treatment planning, evaluation of progress and final outcome of orthodontic treatment.

MATERIALS AND METHODS:

This comparative study included lateral cephalogram records of 102 individuals in the age group of 20-30 years, which were collected from the archives of the Department of Orthodontics and Dentofacial Orthopaedics at AB Shetty Memorial Institute of Dental Sciences, Mangalore. Individuals in the age group of 20 -30 years, individuals with complete pre-orthodontic records with high quality and clear lateral cephalograms, and individuals without any previous history of orthodontic treatment were included in the study. The sample size is estimated using the formula, and the required sample size = 102. Clearance for the study was obtained from the Institutional Ethics Committee (Ref. No. ETHICS/ABSMIDS/417/2024). All the samples will be allotted into 3 main groups (34 samples in each group) based on Jara back's ratio (PFH: AFH). Each of these groups will be subcategorized into 2 group based on gender (17 sample per group)

- **Group 1**-Individuals with normal growth pattern

Control group

Group 1A-Male [PFH: AFH=62-65%]

Group 1B -Female [PFH: AFH=62-65%]

- **Group 2**- Individuals with vertical growth pattern

Group 2A-Male [PFH: AFH<62%]

Group 2B -Female [PFH: AFH<62%]

- **Group 3**- Individuals with horizontal growth pattern

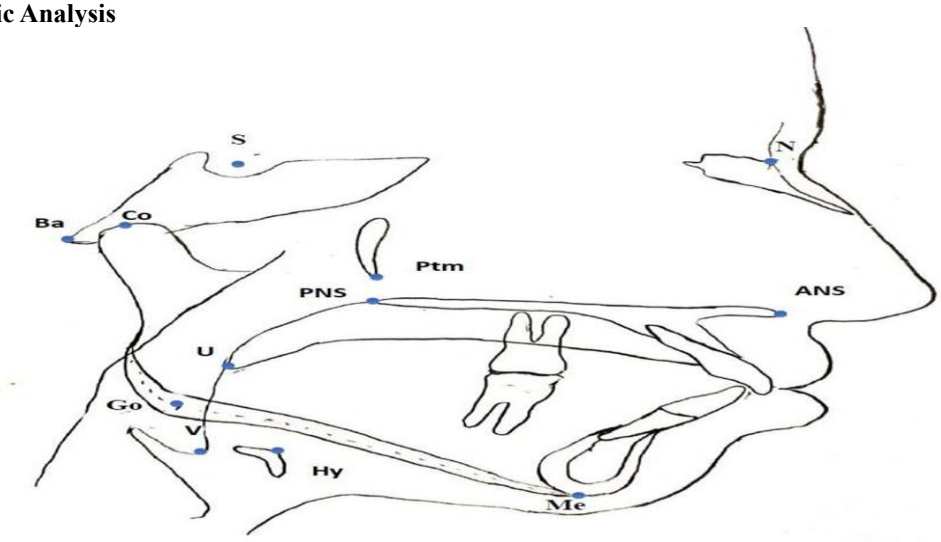
Group 3A-Male [PFH: AFH>65%]

Group 3B -Female [PFH: AFH>65%]

The lateral cephalograms were collected from the archives of the Department. They were traced manually on 5"x12" sheets of 0.003 matte acetate paper using 0.5mm lead pencil. The data were entered in Microsoft Excel and analyzed using SPSS version 23.

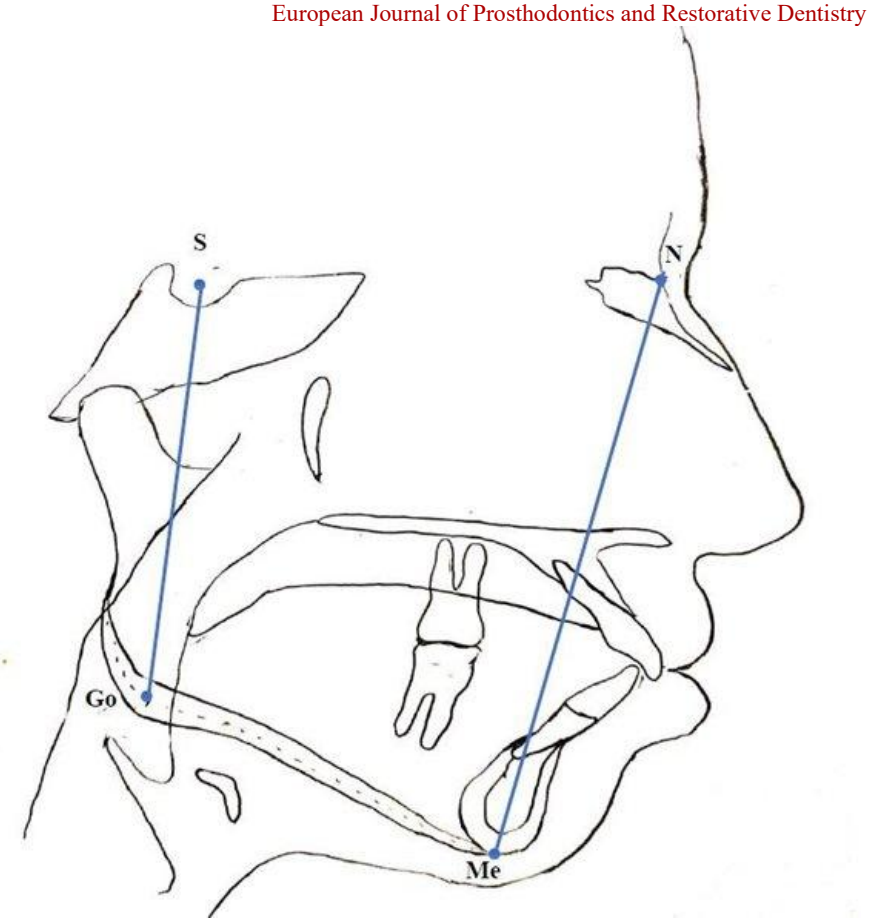
Landmarks Used (Figure 1)

Cephalometric Analysis



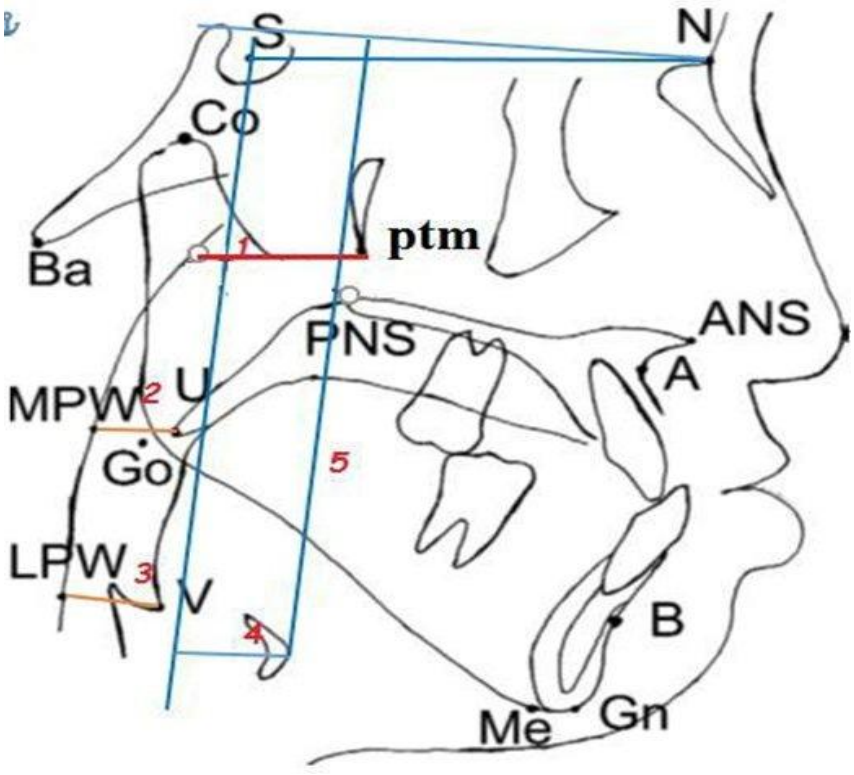
1. Sella (S)
2. Nasion (N)
3. Gonion (Go)
4. Menton (Me)
5. Pterygomaxillary fissure (Ptm)
6. Posterior pharyngeal wall (PPW)
7. U point : The tip of the soft palate
8. Vallecula (V pt)
9. Hyoidale(Hy)

Planes for growth patterns (Figure 2)



1. S -Go : Sella - Gonion
2. N -Me : Nasion – Menton

Variables measured along with the reference lines (Figure 3)



1. Horizontal reference line: A line drawn 7 degrees from Sella-nasion plane

2. Vertical reference line: A perpendicular drawn to the horizontal reference passing through the pterygoid point.

Following measurements will be made:

3. Ptm-UPW: Distance from pterygomaxillary fissure to upper pharyngeal wall representing the nasopharyngeal airway space.
4. U-MPW: distance from tip of the soft palate to middle pharyngeal wall, representing the oropharyngeal airway space.
5. V-LPW: Distance from vallecula to lower pharyngeal wall, representing the hypopharyngeal airway space.
6. VRP-Hy: Distance from vertical reference plane to hyoidale
7. HRP-Hy: Distance from horizontal reference plane to hyoidale

RESULTS :

Comparison among the three growth patterns showed that V-LPW and VP-HY demonstrated statistically significant differences, whereas PTM-UPW, U-MPW, and HP-HY did not differ significantly across normal, vertical, and horizontal growers . Post-hoc Tukey HSD analysis revealed that horizontal growers had significantly greater V-LPW compared to normal growers, while differences between normal and vertical growers and between vertical and horizontal growers were not statistically significant. With respect to the vertical position of the hyoid bone, vertical growers showed a significantly more posterior hyoid position compared to both normal and horizontal growers, whereas no significant difference was observed between normal and horizontal groups (Table 1).

TABLE 1: Comparison of Airway and Hyoid Measurements Among Normal, Vertical, and Horizontal Growth Patterns

Variables	Groups	N	Mean (mm)	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Sum of Squares	Mean Square	F	p value
						Lower Bound	Upper Bound				
PTM-UPW	Normal	34	18.44	5.212	.894	16.62	20.26	2.961	1.480	.061	.941
	Vertical	34	18.71	4.970	.852	16.97	20.44				
	Horizontal	34	18.85	4.574	.784	17.26	20.45				
U-MPW	Normal	34	9.41	2.676	.459	8.48	10.35	21.020	10.510	1.335	.268
	Vertical	34	10.24	3.429	.588	9.04	11.43				
	Horizontal	34	9.18	2.167	.372	8.42	9.93				
V-LPW	Normal	34	13.56	4.384	.752	12.03	15.09	165.941	82.971	6.301	.003*
	Vertical	34	14.94	3.789	.650	13.62	16.26				
	Horizontal	34	16.68	2.434	.417	15.83	17.53				
VP- HY	Normal	34	-3.32	7.104	1.218	-5.80	-.84	1271.529	635.765	14.461	.000*
	Vertical	34	-9.44	5.533	.949	-11.37	-7.51				
	Horizontal	34	-1.09	7.128	1.222	-3.58	1.40				
HP-HY	Normal	34	105.82	11.213	1.923	101.91	109.74	339.784	169.892	1.877	.158
	Vertical	34	101.56	8.546	1.466	98.58	104.54				
	Horizontal	34	102.53	8.529	1.463	99.55	105.51				

*The mean difference is significant at the 0.05 level

Gender comparison revealed that PTM-UPW, U-MPW, V-LPW, and VP-HY did not show statistically significant differences between males and females, while HP-HY demonstrated a statistically significant gender difference, indicating a more inferior hyoid position in males (Table 2).

TABLE 2: Comparison of airway and hyoid measurements according to gender

Variables	Groups	N	Mean (mm)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean Difference	Std. Error Difference	t	p value
						Lower	Upper				
PTM-UPW	Female	51	18.37	4.976	.697	-2.511	1.335	-0.588	0.969	-0.607	0.545
	Male	51	18.96	4.812	.674						
U-MPW	Female	51	9.53	2.572	.360	-1.268	0.954	-0.157	0.560	-0.280	0.780
	Male	51	9.69	3.063	.429						
V-LPW	Female	51	14.92	2.965	.415	-1.780	1.231	-0.275	0.759	-0.362	0.718
	Male	51	15.20	4.534	.635						
VP- HY	Female	51	-5.86	5.960	.835	-5.395	0.414	-2.490	1.464	-1.701	0.092
	Male	51	-3.37	8.591	1.203						
HP-HY	Female	51	97.49	7.344	1.028	-14.633	-8.622	-11.627	1.515	-7.675	0.000*
	Male	51	109.12	7.944	1.112						

*The mean difference is significant at the 0.05 level.

Among individuals with a normal growth pattern, VP-HY and HP-HY showed statistically significant gender differences, whereas airway dimensions did not differ significantly between males and females. In the vertical growth pattern, HP-HY alone showed a statistically significant gender difference, with males exhibiting a more inferior hyoid position, while all airway dimensions and VP-HY were comparable between genders. Similarly, in the horizontal growth pattern, HP-HY showed a statistically significant difference between males and females, whereas airway dimensions and VP-HY were not significantly different.

Two-way ANOVA demonstrated that PTM-UPW was not significantly influenced by growth pattern, gender, or their interaction, indicating stability of the upper pharyngeal airway across groups. Likewise, U-MPW showed no significant main or interaction effects, confirming comparable middle pharyngeal airway dimensions across growth patterns and genders.

For V-LPW, two-way ANOVA revealed a statistically significant main effect of growth pattern, with post-hoc analysis confirming significantly greater values in horizontal growers compared to normal growers, while gender and interaction effects were not significant.

Analysis of VP-HY showed a highly significant main effect of growth pattern, with vertical growers exhibiting a significantly more posterior hyoid position than both normal and horizontal growers; gender and interaction effects were not statistically significant.

Evaluation of HP-HY demonstrated a highly significant main effect of gender, with males consistently showing a more inferior hyoid position across all growth patterns, while growth pattern and interaction effects were not statistically significant.

Correlation analysis revealed that pharyngeal airway dimensions did not show significant correlations with hyoid bone position in normal, vertical, or horizontal growth patterns. In gender-based correlation analysis, PTM-UPW showed a weak but statistically significant negative correlation with HP-HY in females, while V-LPW demonstrated a weak but statistically significant negative correlation with HP-HY in males; all other correlations were non-significant (Table 3, Table 4).

TABLE 3: Correlation between Pharyngeal Airway Dimensions and Hyoid Bone Position in Females

		VP_HY	HP_HY
PTM_UPW	Pearson Correlation	-.017	-.289*
	Sig. (2-tailed)	.904	.040*
	N	51	51
U_MPW	Pearson Correlation	-.257	.207
	Sig. (2-tailed)	.069	.144
	N	51	51
V_LPW	Pearson Correlation	-.098	.170
	Sig. (2-tailed)	.495	.233
	N	51	51
* The mean difference is significant at the .05 level.			

TABLE 4: Correlation between Pharyngeal Airway Dimensions and Hyoid Bone Position in Males

		VP_HY	HP_HY
PTM_UPW	Pearson Correlation	-.060	-.161
	Sig. (2-tailed)	.676	.259
	N	51	51
U_MPW	Pearson Correlation	-.107	-.192
	Sig. (2-tailed)	.454	.178
	N	51	51
V_LPW	Pearson Correlation	-.114	-.288*
	Sig. (2-tailed)	.425	.041*
	N	51	51
*The mean difference is significant at the .05 level.			

DISCUSSION:

The relationship between the hyoid bone and the pharyngeal airway in both normal and pathological conditions has long been a subject of considerable interest. The hyoid bone serves as an anchoring structure for the supra and infrahyoid musculature, which together constitute an integral component of the oropharyngeal complex. Factors such as gender, facial growth pattern, and anteroposterior skeletal relationships have been shown to influence the positional relationship between the hyoid bone and the pharyngeal airway space. Owing to the intimate anatomical and functional association between the pharynx and the hyoid bone, there is significant orthodontic interest in investigating the interactions that exist between these structures.

PHARYNGEAL AIRWAY DIMENSIONS

Comparison of pharyngeal airway dimensions across different facial growth patterns revealed that the upper and middle pharyngeal airway widths did not differ significantly among individuals with normal, vertical, and horizontal growth patterns. This suggests that these regions of the airway are relatively unaffected by variations in facial growth. These findings are in contrast to Bhagyalakshmi et al. (2018), who reported reduced upper pharyngeal airway dimensions in individuals with vertical growth pattern.[4] Similar observations were reported by Jaipal Singh Tarkar et al. (2016), who found that the upper oropharyngeal width was narrower in subjects with vertical growth patterns.[3]

However, a significant variation was observed in the lower pharyngeal airway width, with individuals exhibiting a horizontal growth pattern demonstrating a wider lower airway compared to those with a normal growth pattern. This finding indicates that the lower pharyngeal airway may be influenced by overall facial growth pattern, particularly in horizontal growth patterns. This result conflicts with the findings of Bhagyalakshmi et al. (2018), who reported no significant differences in lower airway dimensions among different growth patterns.[4]

With respect to gender differences, individuals with a normal facial growth pattern showed no statistically significant differences between males and females in the upper, middle, or lower pharyngeal airway spaces, indicating comparable airway dimensions across genders.

Similarly, in individuals with a vertical facial growth pattern, no significant gender- related differences were observed in the upper, middle, or lower pharyngeal airway dimensions, suggesting comparable airway morphology between males and females within this group.

In individuals with a horizontal facial growth pattern, the upper, middle, and lower pharyngeal airway dimensions also did not differ significantly between males and females, indicating that airway widths are generally comparable across genders in this growth pattern.

These findings were in accordance with the findings of Daniel et al (2007) who found that men and women have similar airway dimensions.[8] Similar findings were also given by Heeralal et al (2018).[9]

Overall, the findings of this study suggest that the upper and middle pharyngeal airway is largely independent of both skeletal growth pattern and sex. Individuals with a horizontal growth pattern exhibited a wider lower airway, when compared with the normal group. So, skeletal growth pattern, particularly a horizontal growth tendency, plays a meaningful role in determining lower pharyngeal airway width, whereas gender has minimal impact.

HYOID BONE POSITION

In the present study, anteroposterior position of the hyoid bone varied significantly across different facial growth patterns. Individuals with a vertical growth pattern exhibited the most posterior hyoid position, whereas those with a horizontal growth pattern showed the most anterior placement, with normal growers positioned intermediate between the two.

Conflicting results were obtained by Jaipal Singh Tarkar et al(2025) who found that hyoid bone was inferiorly and posteriorly positioned in subjects with horizontal growth pattern.[7]

In individuals with normal growth pattern, the position of the hyoid bone demonstrated a clear gender-based variation. Males exhibited a more inferior and anterior positioning of the hyoid bone when compared to females. This finding indicates that, despite similar airway dimensions, sexual dimorphism exists in hyoid bone positioning in individuals with normal growth patterns, which may reflect differences in craniofacial morphology or muscular attachments between genders.

In individuals with vertical growth pattern, position of the hyoid bone with respect to vertical plane did not differ appreciably between genders. However, a significant gender-based difference was noted in the position of the hyoid bone with respect to a horizontal plane, with males exhibiting a more inferiorly positioned hyoid compared to females. This finding highlights the presence of sexual dimorphism in hyoid bone positioning despite the absence of notable differences in pharyngeal airway dimensions among individuals with a vertical growth pattern.

In individuals with horizontal growth pattern, vertical and anteroposterior position of the hyoid bone also showed minimal gender-related variation, except for the hyoid position with respect to a horizontal plane, where males exhibited a more inferior placement compared to females. This suggests that, despite similar airway dimensions, sexual dimorphism exists in hyoid bone positioning among horizontal growers.

According to the findings of the present study, the hyoid bone was positioned significantly lower in males than in females, indicating a clear gender-related difference in hyoid bone position.

This is in accordance with the findings of Asal Acharya and others (2022).[6]They found that males demonstrated an inferior hyoid position than females.[17]Mortazavi et al(2018) also had similar findings such that the hyoid bone is positioned more superior and posterior in females than males.[10]

The interaction between growth pattern and gender was also not significant, indicating that the effect of growth pattern on hyoid position is consistent across sexes.

Overall, skeletal growth pattern appears to be a major determinant of the anteroposterior hyoid position. Also, sex is the primary determinant of the vertical hyoid position, whereas growth pattern plays a minimal role.

Overall, these findings suggest that while upper and middle airway dimensions are largely independent of growth pattern, lower airway width and anteroposterior hyoid position are influenced by the type of facial growth, highlighting the functional adaptation of the hyoid-pharyngeal complex to skeletal morphology.

CORRELATIONS BETWEEN PHARYNGEAL AIRWAY DIMENSIONS AND HYOID BONE POSITION

The findings of the study suggest that in normal, vertical and horizontal growth patterns; variations in airway space occur independently of hyoid positioning.

In females, most pharyngeal airway dimensions were not significantly associated with hyoid bone position.

However, the upper pharyngeal airway width showed a weak but statistically significant negative correlation with the vertical placement of the hyoid, suggesting that a more inferior hyoid position may be associated with decreased upper airway space in females.

In males, most pharyngeal airway dimensions were not significantly associated with hyoid bone position. However, the lower pharyngeal airway width showed a weak but statistically significant negative correlation with the vertical placement of the hyoid, suggesting that a more inferior hyoid position may be associated with decreased lower airway space in males.

Previous studies examining the pharyngeal airway space and hyoid bone position in individuals with different growth patterns have given variable results.[10-18]Enacal et al(1994)found that hyoid bone moved downwards in accordance with the narrowing of lower airway space.[10] Lan and He-Kyong found that in subjects with anteriorly and superiorly positioned hyoid bones, the pharyngeal airway volumes were smaller due to the soft tissue impingement on the airway.[14]

Overall, the findings of the present study, together with existing literature, reinforce the concept that upper and middle pharyngeal airway dimensions were consistent across genders and facial growth patterns (normal, vertical, horizontal), showing no significant influence from sex or skeletal morphology. Lower airway width varied according to growth pattern, being widest in individuals with a horizontal growth pattern, whereas those with normal and vertical growth patterns showed narrower and largely overlapping dimensions. Gender had minimal influence on lower airway width. The anteroposterior position of the hyoid bone differed by growth pattern, with vertical growth pattern showing the most posterior, horizontal growth pattern the most anterior, and normal growth pattern intermediate, while vertical hyoid position was consistently more inferior in males, independent of growth pattern. Overall, airway dimensions were largely independent of hyoid position, with minor exceptions: in females, upper airway width weakly correlated with vertical hyoid placement, and in males, lower airway width showed a similar weak correlation. These findings indicate that upper and middle airway widths are stable, lower airway and anteroposterior hyoid position reflect skeletal growth pattern, vertical hyoid placement is sex-dependent, and airway-hyoid relationships are interdependent.

CONCLUSION

The pharyngeal airway dimensions and hyoid bone position are influenced more by facial growth pattern than by gender, with notable region- specific effects. Upper and middle pharyngeal airway width remain stable across different growth patterns and between sexes, indicating their relative independence from skeletal morphology and sexual dimorphism. In contrast, lower pharyngeal airway width is significantly affected by growth pattern, with horizontal growers exhibiting a wider lower airway. The anteroposterior position of the hyoid bone varies according to facial growth type, reflecting functional adaptation to skeletal configuration, while its vertical position is primarily sex- dependent, with males consistently showing a more inferior placement. Overall, airway dimensions and hyoid position are dependent of each other. These findings highlight the importance of considering facial growth pattern, rather than gender alone, when evaluating airway morphology and hyoid positioning in clinical and orthodontic assessments.

REFERENCES:

1. Jose NP, Shetty S, Mogra S, Shetty VS, Rangarajan S, Mary L. Evaluation of hyoid bone position and its correlation with pharyngeal airway space in different types of skeletal malocclusion. Contemporary Clinical Dentistry. 2014 Apr;5(2):187.
2. Ozbek MM, Miyamoto K, Lowe AA, Fleetham JA. Natural head posture,upper airway morphology and obstructive sleep apnea severity in adults. Eur J Orthod 1998;20:133-43.
3. Tarkar JS, Parashar S, Gupta G, Bhardwaj P, Maurya RK, Singh A, Singh P. An evaluation of upper and lower pharyngeal airway width, tongue posture and hyoid bone position in subjects with different growth patterns. Journal of clinical and diagnostic research: JCDR. 2016 Jan 1;10(1):ZC79.
4. Lakshmi KB, Yelchuru SH, Chandrika V, Lakshmikar OG, Sagar VL, Reddy GV. Comparison between growth patterns and pharyngeal widths in different skeletal malocclusions in South Indian Population. Journal of International Society of Preventive and Community Dentistry. 2018 May 1;8(3):224-8.
5. Jose NP, Sehgal A, Shetty S, Mary L, MV A. Correlation between hyoid bone and pharyngeal airway space in differing vertical skeletal dysplasia. Biomedical and Pharmacology Journal. 2019 Mar 25;12(1):353-6.
6. Acharya A, Mishra P, Shrestha RM. Pharyngeal airway space dimensions and hyoid bone position in various craniofacial morphologies. Journal of Indian Orthodontic Society. 2022 Apr;56(2):150-7.
7. Singh P, Nambiar S, Desai A, Philip N, Ongole R. Assessment of Hyoid Bone Position and its Correlation With Airway Dimensions in Different Sagittal Malocclusions Using Cone Beam Computed Tomography. International Journal of Dentistry. 2025;2025(1):6702204.
8. Daniel MM, Lorenzi MC, da Costa Leite C, Lorenzi-Filho G. Pharyngeal dimensions in healthy men and women. Clinics. 2007 Jan 1;62(1):5-10.
9. Chokotiya H, Banthia AK, K SR CK, Sharma P, Awasthi NA. A study on the evaluation of pharyngeal size in different skeletal patterns: A radiographic study. J Contemp Dent Pract. 2018 Oct 1;19(10):1278-83.
10. Mortazavi S, Asghari-Moghaddam H, Dehghani M, Aboutorabzade M, Yaloodbardan B, Tohidi E, Hoseini-Zarch SH. Hyoid bone position in different facial skeletal patterns. Journal of clinical and experimental dentistry. 2018 Apr 1;10(4):e346.
11. Enacar A, Aksoy AU, Sençift Y, et al. Changes in hypopharyngeal airway space and in tongue and hyoid bone positions following the surgical correction of mandibular prognathism. Int J Adult Orthodon Orthognath Surg 1994; 9: 285–290.

12. Chauhan R, Bagga DK, Agrawal P, et al. Radiographic Evaluation of the Hyoid Bone Position and Pharyngeal Airway Depth in Anteroposterior Dysplasia. Int J Clin Pediatr Dent 2019; 12: 101–106.
13. Stepovich ML. A cephalometric positional study of the hyoid bone. Am J Orthod 1965; 51: 882–900.
14. Vuong L, Kang H-K. A cross-sectional retrospective study of normal changes in the pharyngeal airway volume in white children with different skeletal patterns. Part 2: Cervical vertebral maturation method and hyoid bone. Am J Orthod Dentofacial Orthop 2021; 159: e377–e388.
15. Tsai HH. The positional changes of hyoid bone in children. J Clin Pediatr Dent 2002;27:29-34.
16. Graber LW. Hyoid changes following orthopedic treatment of mandibular prognathism. Angle Orthod 1978;48:33-8.
17. Tallgren A, Solow B. Hyoid bone position, facial morphology and head posture in adults. Eur J Orthod 1987;9:1-8.
18. Tumpkin J, Kudlick E. The hyoid bone position in mouth breathers: Cross sectional study. Am J Orthod Dentofacial Orthop 1989;96:361.