ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 5, Issue – 3, May - 2022, Page No. : 521 - 530

Analysis of palatal morphology and upper airway area in skeletal class I and class II malocclusion

[1]Dr. Naseem K.T, MDS, Professor, Department of Orthodontics and Dentofacial Orthopedics, KMCT Dental College, Calicut, Kerala, India.

[2]Dr. Gayathri M J, Former Post Graduate Student, Department of Orthodontics and Dentofacial Orthopedics, KMCT Dental College, Calicut, Kerala, India.

[3]Dr. Binu Purushothaman, MDS, Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, KMCT Dental College, Calicut, Kerala, India.

[4]Dr. Fidha A H, Post Graduate Student, Department of Orthodontics and Dentofacial Orthopedics, KMCT Dental College, Calicut, Kerala, India.

[5]Dr. Shaleen U, Post Graduate Student, Department of Orthodontics and Dentofacial Orthopedics, KMCT Dental College, Calicut, Kerala, India.

[6]Dr. Amrutha Krishnan, Post Graduate Student, Department of Orthodontics and Dentofacial Orthopedics, KMCT Dental College, Calicut, Kerala, India.

Corresponding Author: Dr. Fidha A H, Post Graduate Student, Department of Orthodontics and Dentofacial Orthopedics, KMCT Dental College, Calicut, Kerala, India.

Citation of this Article: Dr. Naseem K.T, Dr. Gayathri M J, Dr. Binu Purushothaman, Dr. Fidha A H, Dr. Shaleen U, Dr. Amrutha Krishnan, "Analysis of palatal morphology and upper airway area in skeletal class I and class II malocclusion", IJDSIR- May - 2022, Vol. – 5, Issue - 3, P. No. 521 – 530.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Palatal morphology plays an important role in defining the skeletal and facial patterns of an individual. Different individual presents with different height, width, and length of the palate. Orthodontic treatment also causes change in palatal dimensions. Thus, understanding the variation in palatal morphology in various malocclusions is important. Maxillary constriction is associated with several problems that include cross bite, occlusal disharmony, aesthetics and functional problems such as narrowing of the pharyngeal airway. Hence the aim of the study is to investigate the different palatal morphologies and upper airway among Skeletal Class I, Class II malocclusion and to evaluate if any correlation exists among the palatal morphology and upper airway. The study is based on retrospective evaluation of lateral cephalograms and study models for the analysis of palatal morphologies and upper airway area. A total of 40 lateral cephalograms were grouped into 2 according to the ANB angle. 20 skeletal class I group with the mean age of 19.9 years, and 20 skeletal class II group with the mean age of 18.45 years. Upper airway area evaluated from lateral cephalograms. Intermolar and intercanine width and palatal depth were measured from the study models. Upper airway area shows statistical significance (p<0.001) and skeletal class II groups had smaller upper airway area when compared with class I group. A positive correlation was found between the palatal morphology and upper airway area among class II group whereas, a negative correlation in class I group

Keywords: Palatal morphology; Diagnostic Cast, Lateral Cephalogram, Skeletal Malocclusion Class I, Skeletal Malocclusion Class II, Upper airway

Introduction

The palate is the roof of the mouth that divides the oral and nasal cavities. The anterior bony hard palate and the posterior fleshy soft palate or velum are the two components of the palate. The anterior hard palate, which is a plate of bone covered by a moist, durable layer of mucous membrane tissue, makes up two-thirds of the entire palatal area. The palate is predicted to be related with the craniofacial complex as a whole, in addition to its connections with surrounding regions. Mastication and pronunciation are two of the most important activities of the palate. Its shape varies greatly between people and is determined by a variety of parameters such as breathing mode, tongue size and posture, tooth inclination, occlusion, and para-functional habits.

Palatal morphology is vital in determining an individual's skeletal and facial pattern. It can be influenced by orthodontic therapy, hence a thorough examination of the osseous or dental arch dimension is essential for orthodontic treatment planning. According to several studies, class II division 1 malocclusions have a greater palatal height and a narrower upper arch than class II division 2 malocclusions, while class I malocclusions have a greater palatal width and depth than class II and III malocclusions. The class II subjects, on the other hand, have a larger the length of palate.

The upper airway is a structure responsible for one of the main vital functions in the human organism—breathing. The interest in studying the upper airway has always been present in orthodontics, to clarify the relationship between pharynx structures and craniofacial complex growth and development. [3]

The influence of the mode of breathing on facial growth was in the focus of the orthodontic community in seventies. It was significant, but clinical irrelevant changes in transversal growth were seen following Adenoidectomy.

Removal of tonsils and adenoids was frequently recommended for changing the mode of breathing. The impact of mode of breathing and head posture on the facial growth pattern was described in the 'soft-tissue stretching hypothesis' by Solow and Kreiborg**,** who claimed that a change in jaw posture caused by mouth breathing could lead to stretching of the lips, cheeks, and musculature resulting in upright incisors and narrower dental arches, as observed in patients with long face with vertical growth pattern. [17]

Much attention has been paid to the relationship between respiratory function and facial morphology. Some articles analysed the dimensions of the upper airway in patients with different sagittal and vertical skeletal facial morphologies using lateral cephalograms.

Class II patients have a narrower antero-posterior pharyngeal dimension, and this narrowing is specifically noted in the Nasopharynx area at the hard palate level, in the Oropharynx at the level of the tip of the soft palate. [4]

The present study aimed to evaluate the palatal morphology and the upper airway area in Skeletal Class

I and Class II malocclusion.by using study models and the pre-treatment lateral cephalogram, to evaluate whether any correlation exist in between the airway and palatal morphology.

Materials and methodology

The present study is an institutional based retrospective study. A sample of 40 Pre-treatment lateral cephalogram and study models were collected, participants above 14 years were considered. Based on ANB angle they were divided into two groups.

Group I: - 20 Skeletal Class I malocclusion (ANB angle: 0-4) and

Group II: - 20 skeletal Class II (ANB angle :>4) malocclusion. Chronic obstructive or restrictive lung diseases, previous history of pharyngeal surgery or tonsillectomy, Cleft lip and palate, Patients with previous history of orthodontic treatment were excluded from the study.

The study models of maxillary arch were analyzed for intercanine, intermolar width and palatal depth.

Intercanine width was measured from the upper right to left canine cusp tips.

Figure 1: measurement of intercanine width,

The intermolar width was measured with the same method from the mesio-buccal cusp tips on one side of the first molars to other side

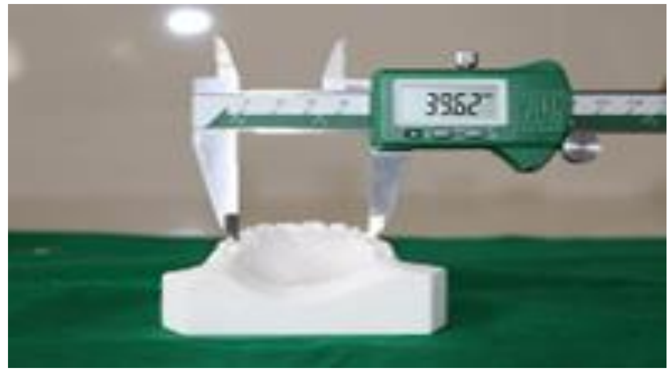
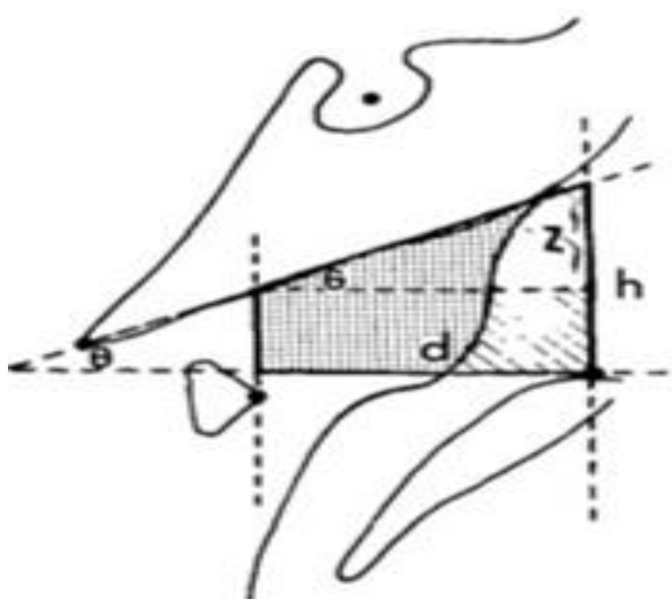


Figure 2: measurement of Intermolar width

The depth of palate was taken as vertical distance from a point on palatal width line (linear distance between the Mesiolingual cusp tip of right and left first molar) to the palatal vault in the midline

Figure 3: measurement of palatal depth

The area of the bony nasopharynx frequently defined as a trapezoid demarcated by the following lines [39]



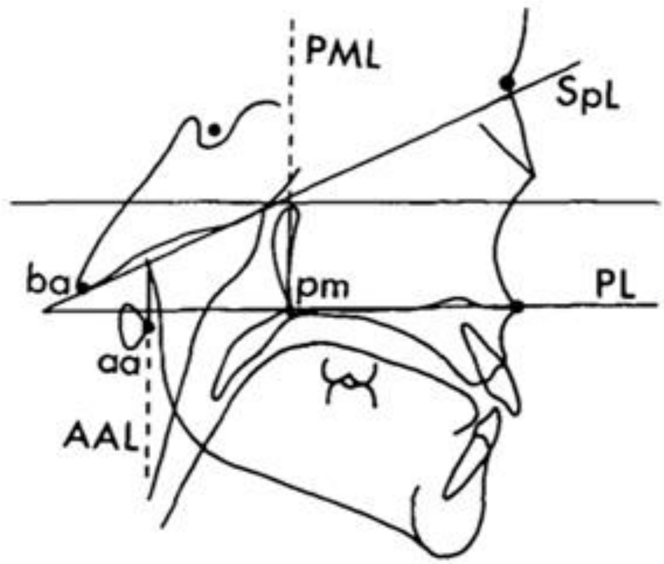


Figure 4: Measurement of upper airway area.; palatal line (PL): sphenoid line (SpL), tangent to lower border of sphenoid registered on basion: anterior arch of the atlas line (AAL) line perpendicular to palate line registered on AA and pterygomaxillary line (PML) line perpendicular to palate line registered on PM.

AA-PNS; the pterygoid vertical between PNS and the intersection of this vertical line and the ba-N line; a line drawn through AA, parallel to the pterygoid vertical and extended to intersect the ba-N line; the section of the ba-N line between the pterygoid vertical and the vertical erected through point AA. The upper airway area calculated from this trapezoid form. (Formula ½ (a+b) h). AA- Anterior arch of the atlas. The most anterior (ventral) point on the anterior arch of the atlas (C1) assumed to be in the median sagittal plane**.** ba (also Ba). Basion line. The most posterior limit of the lowest point in the midline on the anterior margin of

the foramen magnum (this is external basion or ecto basion).PL- palatal line. SpL-sphenoid line tangent to lower border of sphenoid registered on basion. AAL- anterior arch of the atlas line (line perpendicular to palate line registered on aa). PML-pterygomaxillary

line (line perpendicular to palate line registered on pm)

Statistical analysis

All statistical procedures were performed using Statistical Package for Social Sciences (SPSS) 20.0. Calculations for power (80%) of study were performed before the commencement of the study. All quantitative variables expressed in mean and standard Deviation. Qualitative variables expressed in percentages. Shapiro-Wilk test was used for testing the normality assumption of the quantitative data. Independent t test was used to find the association between variables. Pearson correlation coefficient was used to find the correlation between significant variables. Probability value ($p < 0.05$) was considered statistically significant.

Results

Upper airway area were measured and calculated manually from the lateral cephalogram of each samples. For analysing the palate inter canine, inter molar and palatal depth were measured accurately with a digital calliper. Shapiro-Wilk test was used for testing the normality assumption of the quantitative data. Independent t test was used to find the association between variables. Pearson correlation coefficient was used to find the correlation between significant variables.

Among the 40 samples 18 were females and 22 were males and the average age of the sample was 19.17 years. Among the 4 variables (intercanine width, intermolar width, palatal depth and upper airway area) in between the class I and II malocclusion, the upper airway area shows statistically significance. Other 3 variables show no statistical significance ($P > .05$). (Table 1)

Table 1: Intergroup Differences of the airway area

Groups	Mean	SD	T value	P value
Class I	537.95	55.01	6.62	<0.001**
Class II	419.90	58.55		

The upper airway area were significantly smaller in skeletal class II groups (p<0.001) when compared with skeletal class I.

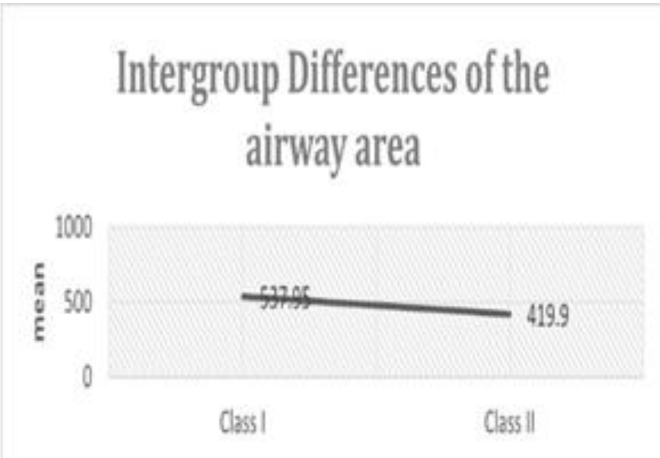


Figure 5: The inter group difference in upper airway area.

The correlation between the intercanine width, inter molar width, palatal depth and upper airway in skeletal class II group were significantly positive (P- 0. 624, 0.506,0.496 respectively)

Table 2: positive correlation between the intercanine width, intermolar width, palatal depth, and airway in skeletal class II group

There was a negative correlation between intercanine, intermolar width, palatal depth and upper airway area in skeletal class I group (Pearson correlation-0.044, -0.302, -0.133,1 respectively)

Correlations						
		Airway area	ANB Angle	Intercanine Width	Intermural Width	Palatal Depth
Airway area	Pearson Correlation	1	-0.185	-0.044	-0.302	-0.133
	P value		0.435	0.854	0.196	0.578
	N	20	20	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations						
		Airway Area	ANB Angle	Intercanine Width	Intermolar Width	Palatal Depth
Airway Area	Pearson Correlation	1	-0.011	0.624**	0.506*	0.496*
	P value		0.962	0.003	0.023	0.026
	N	20	20	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3: Negative correlation between intercanine width, inter molar width, palatal depth, and airway area in skeletal class I group

Discussion

Sufficient anatomical dimensions of the airway were very dependent for normal respiration. In recent years, many authors in their studies have found that skeletal pattern variations could predispose upper airway obstruction. In this study, Skeletal Class I and Class II subjects were analysed for upper airway area

Since Angle (1907) discovered that Class II Division 1 malocclusion is associated with obstruction of the pharyngeal airway space (PAS) and mouth-breathing subjects, several studies have evaluated the upper airway in patients with different skeletal patterns. Much attention has been paid to the relationship between respiratory function and facial morphology. Some articles have analysed the measurements of the upper airway in patients with different sagittal and vertical skeletal facial morphologies using lateral cephalograms. Class II malocclusion may be a complex clinical entity that entails a mixture of various three-dimensional features like mandibular deficiency and transverse discrepancy due to a narrow maxillary arch, Class II patients have a narrower antero-posterior pharyngeal dimension, and this narrowing is specifically noted within the nasopharynx area at the hard palate level and within the oropharynx at the level of the tip of the soft palate and the mandible. [2,4]

Derichsweiler (1956) was against the concept of nasal obstruction being a primary etiologic factor in dentofacial deformity. Watson and Colleagues (1968) also had similar opinion and they suggested that when airway resistance was high, mouth opening invariably resulted, but skeletal deformity did not always occur. Korkhaus (1960), on the other hand, suggested that maxillary arch form is a primary factor in determining nasal cavity size and breathing mode also.

In 1918, Norlund introduced the 'compression theory' which stated that constriction of the maxillary arch is related to the absence of the lateralizing pressure of the tongue against the palate. In response to nasal obstruction, the tongue drops, and the medializing effects of the buccal musculature is left unopposed. The effect is enhanced by a pressure differential across the hard palate in the absence of nasal airflow, resulting a narrow, high-arched palate.

Despite the fact that several reports on the association of airway obstruction among different growth patterns especially the obstructive sleep apnoea patients were evaluated, there is no study that have investigated the relationship of palatal morphology and upper airway area among different skeletal malocclusion. Hence, the present study aimed to assess the palatal morphology and upper airway area among skeletal class I and class II malocclusions.

The results from this study showed that the statistical significance in upper airway area among the skeletal Class I and Class II malocclusion groups, where the class II group shows lesser value than class I. Similarly, Ligia Vieira Claudino et al (2013 [3] also reported that the Class II subjects had smaller minimum and mean areas (lower pharyngeal portion, velopharynx, and oropharynx) than did the Class III group and significantly less uniform velopharynx morphology than did the Class I and Class III groups. Z. H Zheng et al [31] (2014) showed that the volume and the most constricted cross-sectional area of the airway varied with different anteroposterior skeletal patterns. The NA volume of Class I and Class III subjects was significantly larger than that of patients with a Class II skeletal pattern. Whereas Faruk ezzet et al [8] (2011) showed that no statistically significant orofacial airway differences were determined between low angle and normal growth subjects. High angle subjects had a larger tongue gap than those with normal and low angles. Additionally, nasopharyngeal airway space and upper PAS measurements were larger and palatal tongue space was narrower in low angle than in high angle subjects

A. Palatal morphology

The present study shows there was no statistical significance in palatal depth, intercanine width and intermolar width among skeletal class I and class II malocclusion. Similarly If fat Batool et al[28] evaluated the study casts and lateral cephalograms of 12 to 14 years old skeletal Class II patients with no previous history of orthodontic treatment or air way related surgery and the upper airway space was measured on the cephalograms as described by McNamara, Maxillary inter molar width was measured on the corresponding study casts using a digital calliper and they did not find any statistically significant correlation between upper airway space and maxillary intermolar width. Vasquez et al [32] also reported that Class II malocclusion with maxillary protrusion showed no deficiency in transverse dentoskeletal relationships

Marinelli et al [34] pointed out that Class II malocclusion with mandibular retrusion was associated with reduced maxillary intercanine and intermolar widths, whereas Roberta Lione et al [11] (2014) evaluated the Subjects with prolonged mouth breathing showed a greater reduction of the palatal surface area and volume resulting to a different development of the palatal morphology in comparison with subjects with normal breathing pattern.

Marcos Roberto et al (2006) Prabhakaran Mani et al [10] (2011) Valeria Paoloni et al [2] (2017) showed that, Class II high-angle patients tended to have narrower and higher palate, while Class II low-angle patients were related to wider and more shallow palate. Narrow pharyngeal airway space is one of the predisposing factors for mouth breathing and obstructive sleep apnoea. Nasir Mushtaq et al [33] (2014) evaluated the intercanine inter molar width among three malocclusion groups and shows no statistically significant differences were found for the intercanine and intermolar widths among the three malocclusion groups.

Johnson et al [35] compared the palatal dimensions (width, length and depth) in adult occlusion and malocclusions (class I crowded, class II div 1, class II div 2, and class III) and found that class II div1 palate were narrowest in width and class II div 2 palate were shortest in length, class III and class I crowded subjects had the deepest palate and class II div 2 had the shallowest palate.

Kristina Lopatienė et al (2002) [29] showed the significant association between nasal- resistances and increased over jet, open bite and maxillary crowding. The tendency of greater nasal resistance was observed for the patients with the first permanent molars relationship Angle Class II and posterior cross-bite.

B. Airway

In our study, lateral cephalograms were examined manually for assessment of upper airway area where as Hakan ela et al (2011) [22] examined the airway volume with CBCT which shows that the oropharyngeal airway volumes of Class II patients were smaller in comparison with Class I and Class III patients. It was observed that the position of mandible with respect to cranial base had an impact on the OP airway volume. The only significant difference for the nasopharyngeal volume was between the Class I and Class II groups, with a smaller volume observed for the Class II group. Similarly, Stig Isidor et al (2018) [18] showed that an increase in the upper airway volume was found after treatment with functional appliances in class II group. This difference was mainly associated with the changes at the oropharynx level, which differed significantly from what was observed within the Class I group

C. Palatal morphology and airway

Palatal width and depth have been compared in many literatures. Historically, narrow palates have been associated with greater palatal depth and wider palate have been associated with shallow palatal depths. Ahmed et al (2009) [36] confirmed this relationship, finding that palatal width is mainly negatively correlated to palatal depth, specifically at the inter-molar area. The present study found a positive correlation of palatal morphology and upper airway among class II malocclusion group and negative correlation in Class I group.

Recent studies (Kecik et al 2017) [1] reported that palatal area, palatal width, and airway volume in OSA patients measured significantly smaller than non-OSA subjects and a positive correlation between the oropharyngeal area and the palatal volume. Hence maxillo-mandibular skeletal morphology, cranial base, hyoid position, tongue volume, head position, and upper airway soft tissue size, shorter narrower, and tapered maxillary arch with a mandibular deficiency all these are associated with OSA. Most of this skeletal class II features might be the indicators of obstructive sleep apnoea.

Conclusion

After analysing the different variants in Skeletal Class I and Class II malocclusion such as intercanine width, intermolar width, palatal depth and upper airway, statistical significant results were obtained in upper airway area. A significant correlation exists between palatal morphology and upper airway area in skeletal class II malocclusion group.

Obstructive sleep apnea is a common sleep associated breathing disorder with profound effects on the health and quality of life of individual suffering from it. Orthodontist should be well aware of the symptoms of this disorder. Orthodontists are well suited for the treatment of OSA.

Whenever a constricted airway is noted, it should be accompanied with some craniofacial morphological difference especially the palatal morphology most probably the retrognathic mandible with prognathic maxilla leads to reduced airway dimensions, interceptive treatment modalities should be made to correct these discrepancies as soon as it is noticed.

References

1. Kecik D. Three-dimensional analyses of palatal morphology and its relation to upper airway area in obstructive sleep apnea. Angle Orthod. 2017Mar;87(2):300-306.

2. Valeria Paoloni, Roberta Lione, Francesca Farisco, Demetrios J Halazonetis, Lorenzo Franchi, and Paola Cozza Morphometric covariation between palatal shape and skeletal pattern in Class II growing subjects European Journal of Orthodontics, 2017, 1–6

3. Claudino LV, Mattos CT, Ruellas AC, Sant' Anna EF. Pharyngeal airway characterization in adolescents related to facial skeletal pattern: a preliminary study. Am J Orthod Dentofacial Orthop. 2013 Jun;143(6)

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

5. de Freitas MR, Alcazar NM, Janson G, de Freitas KM, Henriques JF. Upper and lower pharyngeal airways in subjects with Class I and Class II malocclusions and different growth patterns. Am J Orthod Dentofacial Orthop. 2006 Dec

6. Dalmau E, Zamora N, Tara zona B, Gandia JL, Paredes V. A comparative study of the pharyngeal airway space, measured with cone beam computed tomography, between patients with different craniofacial morphologies. J Craniomaxillofac Surg. 2015 Oct ;43 (8): 1438-4.

7. Preston, C Brian & Tobias, Phillip & Salem, Omar Skeletal age and growth of the nasopharynx in the sagittal plane: A cephalometric study. Seminars in Orthodontics. 10. 16-38. 10.1053/j.sodo.2003.10.002.

8. Faruk Izzat Ucar, Tancan Uysal Orofacial airway dimensions in subjects with Class I malocclusion and different growth patterns Angle Orthod. 2011; 81:460–468.

9. T. M. Graber, Kenneth R. Bzoch, Tsuneo Aoba; A Functional Study of The Palatal and Pharyngeal Structures. Angle Orthod 1 January 1959; 29 (1): 30–40

10. Mani P, Muthu Kumar K, Krishnan P, Senthil Kumar KP. Upper and lower pharyngeal airway space in West-Tamil Nadu population. J Pharm Bio allied Sci. 2015 Aug;7(Suppl 2): S539-42.

11. Lione R, Buongiorno M, Franchi L, Cozza P. Evaluation of maxillary arch dimensions and palatal morphology in mouth-breathing children by using digital dental casts. Int J Pediatr Otorhinolaryngol. 2014 Jan;78(1):91-5.

12. Banabilh SM, Samsudin AR, Suzina AH, Dinsuhaimi S. Facial profile shape, malocclusion and palatal morphology in Malay obstructive sleep apnea patients. Angle Orthod. 2010 Jan;80(1):37-42

13. Puranik, Divya & Bhat, Shweta. Spatial changes in upper airway induced by change in head postures in horizontal, average and vertical growth pattern: A comparative lateral cephalometric study. Indian Journal of Orthodontics and Dentofacial Research. 4. 208-215. 10.18231/2455-6785.2018.0040.

14. Godt A, Koos B, Hagen H, Göz G. Changes in upper airway width associated with Class II treatments (headgear vs activator) and different growth patterns. Angle Orthod. 2011 May;81(3):440-6.

15. Zimmerman JN, Lee J, Pliska BT. Reliability of upper pharyngeal airway assessment using dental CBCT: a systematic review. Eur J Orthod. 2017 Oct 1;39(5):489-496.

16. In drink sone I, Jakobson G. The influence of craniofacial morphology on the upper airway dimensions. Angle Orthod. 2015 Sep;85(5):874-80.

17. Di Carlo G, Polimeni A, Mel seen B, Cattaneo PM. The relationship between upper airways and craniofacial morphology studied in 3D. A CBCT study. Orthod Craniofac Res. 2015 Feb;18(1):1-11.

18. Isidor S, Di Carlo G, Cornelis MA, Isidor F, Cattaneo PM. Three-dimensional evaluation of changes in upper airway volume in growing skeletal Class II patients following mandibular advancement treatment with functional orthopaedic appliances. Angle Orthod. 2018 Sep;88(5):552-559.

19. Kim MA, Kim BR, Choi JY, Youn JK, Kim YJ, Park YH. Three-dimensional changes of the hyoid bone and airway volumes related to its relationship with horizontal anatomic planes after bimaxillary surgery in skeletal Class III patients. Angle Orthod. 2013 Jul;83(4):623-9.

20. Kirjavainen M, Kirjavainen T. Upper airway dimensions in Class II malocclusion. Effects of headgear treatment. Angle Orthod. 2007 Nov;77(6):1046-53.

21. Abdalla Y, Brown L, Sonnesen L. Effects of rapid maxillary expansion on upper airway volume: A three-dimensional cone-beam computed tomography study. Angle Orthod. 2019 Nov;89(6):917-923

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

23. Ludwig Monzavifar , Diederich, Cephalometric assessment of the posterior airway space using a new tongue positioning system in OSAS patients. Int J Oral Maxillofac Surg 34, Suppl. 1, S 164 – S 165

24. Gokce SM, Gorgulu S, Gokce HS, Bengi AO, Karacayli U, Ors F. Evaluation of pharyngeal airway space changes after bimaxillary orthognathic surgery with a 3-dimensional simulation and modelling program. Am J Orthod Dentofacial Orthop. 2014 Oct;146(4):477-92.

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

26. Efendiyeva R, Aydemir H, Karasu H, Toygar-Memikoğlu U. Pharyngeal airway space, hyoid bone position, and head posture after bimaxillary orthognathic surgery in Class III patients: long-term evaluation. Angle Orthod. 2014 Sep;84(5):773-81.

27. 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 Nov;19(6):1497-507.

28. Iffat Batool, Syed Ausaf Ali Rizvi, Assad Abbas, Mehwish Shaheed. Correlation of upper airway space and maxillary intermolar width Pak Armed Forces Med J 2010; 60(1): 1235

29. Lopatiene K, Babarskas A. Ortodontines anomalijos, nosies bei nosiarykles patologija

[Malocclusion and upper airway obstruction]. Medicine (Kaunas). 2002;38(3):277-83.

30. Jarrett, Daniel, "Analysis of Palatal and Upper Airway Dimensions in Patients with Excessive Daytime Sleepiness: A Retrospective Cone-Beam Computed Tomography Study" (2020). UNLV Theses, Dissertations, Professional Papers, and Capstones. 3908.

31. 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 Feb;17(1):38-48.

32. Vásquez MJ, Baccetti T, Franchi L, McNamara Jr JA. Dentofacial features of Class II malocclusion associated with maxillary skeletal protrusion: a longitudinal study at the circumpubertal growth period. American Journal of Orthodontics and Dentofacial Orthopedics. 2009 May 1;135(5):568-e1.

33. Mushtaq, Nasir. (2014). Intercanine and intermolar widths in Angle Class I, II and III malocclusions. Pakistan Oral & Dental Journal Vol 34, No. 1 (March 2014). 34. 83-86

34. Marinelli A, Mariotti M, Defraia E. Transverse dimensions of dental arches in subjects with Class II malocclusion in the early mixed dentition. Progress in orthodontics. 2011 May 1;12(1):31-7.

35. Johnson JG, Kuntz TR, Staley RN, Jakobsen JR. Comparison of palatal dimensions in adult normal occlusions and malocclusions. Injournal of dental research 1994 jan 1 (vol. 73, pp. 292-292). 1619

36. M Ahmad Z. Palatal dimensions and its correlation with the circumference of upper anterior teeth. Al-Rafidain Dental Journal. 2009 Sep 1;9(2):259-67.

37. Xiang M, Hu B, Liu Y, Sun J, Song J. Changes in airway dimensions following functional appliances in growing patients with skeletal class II malocclusion: A systematic review and meta-analysis. Int J Pediatr Otorhinolaryngol. 2017 Jun; 97:170-180.

38. Parcha E, Bitsanis E, Halazonetis DJ. Morphometric covariation between palatal shape and skeletal pattern in children and adolescents: a cross-sectional study. Eur J Orthod. 2017 Aug 1;39(4):377-385.

39. Handelman CS, Osborne G. Growth of the nasopharynx and adenoid development from one to eighteeen years. The Angle Orthodontist. 1976 Jul 1;46(3):243-59.

40. Mustafa, Ayman & Tashtush, Ayssar & Alshboul, Othman & Allouh, Mohammed & Altarifi, Ahmad. (2019). Morphometric Study of the Hard Palate and Its Relevance to Dental and Forensic Sciences. International Journal of Dentistry. 2019. 1-6. 10.1155/2019/1687345