Original Article

Mandibular morphology and pharyngeal airway space: A cephalometric study

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Abstract

Introduction: Mandibular retrognathism is considered to be the most important risk factor for upper airway obstruction. **Aim:** This cross-sectional study intended to examine the relationship between craniofacial morphology and the pharyngeal airway space (PAS) in patients with mandibular retrognathism and mandibular prognathism, when compared to normal subjects. The study also analyzed the influence of mandibular morphology on pharyngeal length (PL). **Materials and Methods:** The PAS was assessed in 92 females (age 15-30 years) further divided into three groups - Group 1- normal mandible ($76° \leq$ SNB $\leq 82°$; $n = 31$); Group 2- mandibular retrognathism (SNB $< 76°$; $n = 31$); Group 3-Mandibular prognathism (SNB $> 82°$; $n = 30$). All subjects were examined by lateral cephalometry with head position standardized using an inclinometer. Craniocervical angulation, uvula length, thickness and angulation were compared among different groups. **Results:** The results showed no statistically significant difference in the pharyngeal airway between the three groups. Measurements of PL showed statistically significant higher values for retrognathic mandible group than normal and prognathic mandible group. **Conclusion:** There is no significant difference between PAS between patients with mandibular retrognathism, normal mandible and mandibular prognathism. Mandibular retrognathism patients show a significantly higher uvula angulation than patients with mandibular prognathism. Craniocervical angulation showed maximum value in retrognathic mandible group followed by normal and prognathic mandible group respectively. Mean PL for retrognathic mandible patients was significantly higher than prognathic mandible patients.

Key words: Head posture, mandibular prognathism, mandibular retrognathism, obstructive sleep apnea, pharyngeal airway

INTRODUCTION

Respiratory function plays a significant role in the development of the face and occlusion.[1] It has been hypothesized that chronic nasal obstruction causes hyper divergent facial growth. Patients having "long face syndrome" are characterized by a vertically long lower face height, narrow alae, lip incompetency, a narrow maxillary arch, and a greater than normal mandibular plane angle.[2] Heredity, muscle tonicity, repeated adenoidal infection and inflammation and other environmental factors also may influence facial growth.[3,4]

There are significant relationships between the pharyngeal dimensions and craniofacial abnormalities. Craniofacial abnormalities such as maxillary retrusion, mandibular retrognathism, short mandibular body, and downward and backward rotation of the mandible in hyperdivergent patients may lead to narrowing of the pharyngeal airway space (PAS).[5,6] Literature supports the notion that mandibular deficiency is frequently associated with a narrower PAS. It is believed that a retrognathic mandible

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and decreased space between the cranial column and the mandibular corpus might lead to a posterior postured tongue and soft palate, increasing the chances of impaired respiratory function and possibly causing nocturnal breathing problems.

Variations in PAS have also been described with some sleep disorders such as obstructive sleep apnea. Advancement and setback operations are standard procedures for the correction of mandibular retrognathism and prognathism, respectively. Surgery for the mandibular deformity alters skeletal and soft tissue components, including the PAS.[7,8]

Changes in head posture significantly affect the size of the PAS. A significant relation ($r = 0.807$) between head posture and the PAS has been demonstrated.[9,10]

Evaluation of the PAS thus has a very important role in diagnosis and treatment planning in patients with obstructive sleep apnea and dentofacial deformity. Cephalometric analysis of the airway does permit precise measurements in a sagittal plane and has the advantages of convenience, low cost and minimal exposure to radiation.

Therefore, the aims of the present study were to:

1 Examine the relationship between PAS in patients with different mandibular sizes (mandibular retrognathism and mandibular prognathism), when compared to normal subjects and to test the hypothesis whether mandibular retrognathism is associated with reduced PAS
2 Study the influence of mandibular morphology on pharyngeal length (PL).

MATERIALS AND METHODS

Ninety-two subjects were selected from the total patients registered at the Department of Orthodontics and Dentofacial Orthopedics, Manipal from January 2013 to July 2014. All the subjects selected were Indian females and were 15-30 years of age. The methodology was explained to the patients and only after they consented, they were included in the study.

Subjects with a history of previous orthodontic treatment, functional jaw orthopedic treatment, any surgery involving the jaws, or surgery for adenoids; breathing disorders (such as snoring and obstructive sleep apnea); cleft lip and palate; and any systemic disease affecting normal growth were excluded from the study. Based on the degree of sagittal mandibular development in relation to the anterior cranial base, all female subjects were divided into three groups: Mandibular retrognathism ($n = 31$; defined by angle SNB $<76°$), Normal mandible ($n = 31$; $76° \leq$ SNB $\leq 82°$) and Mandibular prognathism ($n = 30$; SNB $>82°$).

Lateral cephalograms (Planmeca company, model Proline 2002cc, Finland, 66 kV, 10 mA, 1 s exposure) were taken with the orbital-auricular plane parallel to the floor and the teeth in centric occlusion or centric relation at the end of the expiratory phase. All subjects received the same instructions for radiographic positioning and were told to place the tongue in a relaxed position and to breathe through their nose after swallowing.

To overcome the influence of head posture on PAS and to standardize the head posture, a simple inclinometer with the help of spirit levels was prepared. An inclinometer is an instrument for measuring angles of slope, elevation or depression of an object with respect to gravity. In orthodontics, it can be used to record accurate registration of the head position of the patient. Ideally, such a device is constructed with contactless, precision potentiometers which can measure changes in single axis angles. In this study, inclinometer was prepared with the help of spirit level or bubble level, which is a plastic tube incompletely filled with colored spirit or alcohol leaving the bubble in the tube. This bubble positions in the center of the tube when placed on a horizontal surface. In the study, one spirit level was attached to the left arm of a pair of eyeglasses, parallel to the sagittal plane out of the subject's visual range without touching his/her temple plane to determine the changes in pitch. A second spirit level was placed in the center perpendicular to the sagittal plane to measure changes in roll at the bridge of the eyeglasses. When the spirit level was adjusted parallel to the floor, the bubble would remain in the center [Figure 1]. The entire frame of the eyeglasses was made of plastic with no metal screws so it did not cast any shadow or artifact on the lateral cephalogram that could interfere with the analysis [Figures 2a, b, and 3] After tracing the cephalograms on

Figure 1: Inclinometer prepared with the spirit levels

lead acetate sheet, pharyngeal airway was measured and compared.

The reference points and lines in the cephalometric analysis selected have been shown in Figure 4. Table 1 shows various variables used in the analysis.

Statistical analysis

All statistical analyses were performed using the SPSS software package (SPSS for Windows Xp, version 13.0, SPSS Inc, Chicago). Descriptive data that included arithmetic mean, standard deviation and range values were calculated for each variable as well as for each group and were used for analysis. A $P < 0.05$ was set to be statistically significant. ANOVA followed by *Post-hoc* Tukeys test was used to compare the difference among the groups for all the variables under study [Table 2]. Pearson correlation coefficient was done to assess the correlation between different variables.

All cephalometric tracings were done by a single investigator (SM). Tracings for 10% of the study subjects were repeated at random by the same investigator after 1 week for assessment of intra-examiner reliability. Intra-examiner reliability was calculated using intra-class correlation coefficient. The values ranged from 0.94 to 0.98 showing acceptable agreement between the tracings.

Table 1: Various variables used in the cephalometric analysis

Variables	Description
OPT/NSL	Defined as the craniocervical angulation at the uppermost part of the cervical spine. It is defined as the inside angle between the intersection of OPT line (line joining Cv2tg and Cv2ip points) and the NSL line (extension of SN plane) Where Cv2tg point is tangent point of OPT line on the odontoid process of the second cervical vertebra and Cv2ip point is the most inferior posterior point on the corpus of the second cervical vertebra
PAS-UP	Defined as the minimal sagittal linear distance between the uvula and the posterior pharyngeal airway space
PAS-TP	Defined as the minimal sagittal linear distance between the back of the tongue and the posterior pharyngeal airway space
PL	Pharyngeal length measured as the linear measurement between the PNS to the base of epiglottis
UL	Uvula length measured as the linear distance from point PNS to the tip of soft palate outline
UT	Uvula thickness as the linear measurement of the maximum cross sectional dimension of soft palate outline
UA	Uvula angulation measured as the inside angle between the intersection of palatal plane (ANS-PNS) to the line joining PNS to the tip of soft palate outline
LAFH	Lower anterior facial height measured as the linear distance between the cepahlometric points ANS to Me
Go-Gn	Mandibular body length measured as the distance between cephalometric points Go-Gn

PAS – Pharyngeal airway space; LAFH – Lower anterior facial height; PL – Pharyngeal length; UA – Upper airway; Go-Gn – Gonion to Gnathion; PNS – Posterior nasal spine; ANS – Anterior nasal spine; UL – Uvula length; UT – Uvula thickness

RESULTS

A comparison of various craniofacial morphologic variables obtained in the three groups is shown in Table 2.

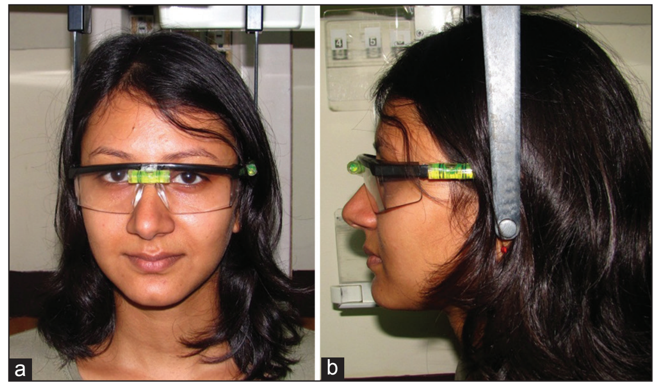

Figure 2: (a and b) Patient positioned in the cephalostat with inclinometer

Figure 3: Lateral cephalogram taken with the help of inclinometer

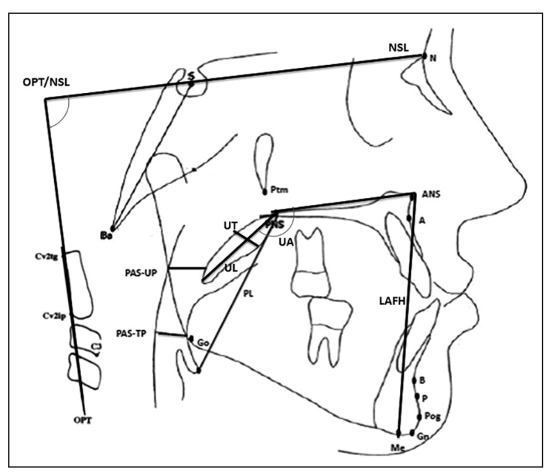

Figure 4: Various linear and angular measurements

A statistically significant difference was noted in the mandibular body length (Go-Gn) between all the three groups [Table 3].

The values of McNamara upper and lower airway space (PAS-UP, PAS-TP) were comparable in all the three groups being maximum in the prognathic mandible and minimum in the retrognathic mandible group, but with no statistically significant difference.

Statistically significant difference was noted in uvula angulation between retrognathic and prognathic mandible ($P = 0.007$). This variable is large when the mandible is small. No significant difference was found among the three groups while comparing uvula length (UL) and uvula thickness (UT).

Craniocervical angulation (OPT/NSL) showed statistically significant difference between the three groups. A decreased craniocervical angulation correlated with a large mandible ($P < 0.001$).

In the study, the mean PL for retrognathic patients was significantly higher than prognathic patients ($P = 0.032$). The PL significantly correlated with lower anterior facial height (LAFH) in the entire study population [Figure 5, Table 4]. In prognathic patients LAFH and PL had significant moderate positive correlation ($P = 0.026$). However, no significant correlation was seen in normal and retrognathic patients between LAFH and PL [Table 5].

DISCUSSION

The pharynx is a tube-shaped structure that plays an important role in respiration and deglution. The dimensions of the pharynx continue to grow rapidly until 13 years[11] of age and then quite slow until adulthood.[12] King[13,14] had reported no significant change in the depth of nasopharynx after 12 years of age. In the present study, the age range of the subjects was 15-30 years to ensure that the pharyngeal structures had reached adult proportions. Our study sample consisted of only female subjects

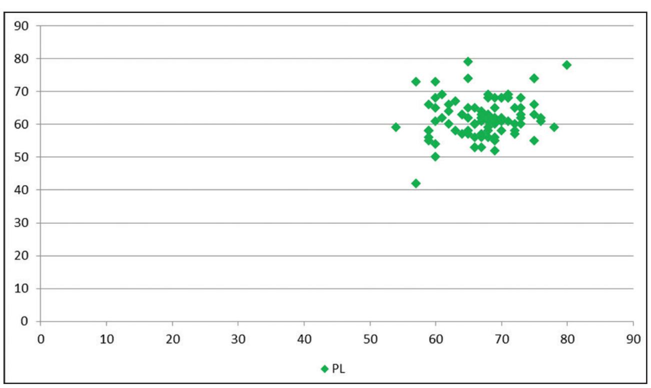

Figure 5: Correlation between pharyngeal length and lower anterior facial height

Table 2: Comparison of various cephalometric variables using ANOVA followed by Post-hoc Tukeys test

Variable	Group	*n*	Mean	SD	*P*	*Post-hoc* test
UL (mm)	Normal mandible	31	34.10	3.28	0.331	—
	Retrognathic	31	34.68	3.75		
	Prognathic	30	33.40	2.91		
UT (mm)	Normal mandible	31	8.97	1.38	0.813	—
	Retrognathic	31	9.03	1.62		
	Prognathic	30	9.20	1.32		
UA (®)	Normal mandible	31	132.24	6.20	0.007	2>3
	Retrognathic	31	133.71	7.11		
	Prognathic	30	128.07	7.69		
OPT/NSL (®)	Normal mandible	31	98.32	6.85	<0.001	2>1>3
	Retrognathic	31	100.65	7.77		
	Prognathic	30	92.03	9.02		
PAS-UP (mm)	Normal mandible	31	9.84	3.30	0.47	—
	Retrognathic	31	9.13	2.94		
	Prognathic	30	10.03	2.80		
PAS-TP (mm)	Normal mandible	31	10.00	3.41	0.094	—
	Retrognathic	31	9.95	3.03		
	Prognathic	30	11.53	3.08		
LAFH (mm)	Normal mandible	31	66.45	5.52	0.053	—
	Retrognathic	31	69.00	4.07		
	Prognathic	30	66.07	5.49		
PL (mm)	Normal mandible	31	61.61	5.16	0.032	2>3
	Retrognathic	31	64.29	5.83		
	Prognathic	30	60.30	6.76		

SD – Standard deviation; PL – Pharyngeal length; LAFH – Lower anterior facial height; PAS – Pharyngeal airway space; UL – Uvula length; UT – Uvula thickness; UA – Upper airway; Go-Gn – Gonion to Gnathion

Table 3: Comparison of SNB and Go-Gn values among 3 groups

SNB value as well as Go-Gn (mandibular body) was taken

Variable	Group	*n*	Mean	SD	*P*	*Post-hoc* test
SNB	Normal mandible	31	78.77	1.84	<0.001	3>1>2
	Retrognathic	31	72.77	1.97		
	Prognathic	30	83.75	1.17		
Go-Gn	Normal mandible	31	78.13	5.05	<0.001	3>1>2
	Retrognathic	31	76.23	4.41		
	Prognathic	30	81.40	3.60		

SD – Standard deviation; Go-Gn – Gonion to Gnathion

Table 4: Correlation in the whole sample

LAFH	PL
Pearson correlation	0.220*
Significant (two-tailed)	0.036
n	92

*Correlation is significant at the 0.05 level (two-tailed). Significant positive weak correlation between LAFH versus PL. LAFH – Lower anterior facial height; PL – Pharyngeal length because they seek (in age group >15 years) orthodontic treatment more often than males.[15] This also helped to avoid influence of gender on pharyngeal dimensions.[16]

Head posture has been suggested to influence the dimensions of the PAS.[8] Thus, in order to eliminate the effects of head posture on the dimension of the PAS, lateral cephalograms were taken with patients wearing a simple inclinometer.

Lateral cephalometric films are considered reliable to record airway dimensions[17] as Cameron *et al.*[18,19] found a significant positive relationship between nasopharyngeal airway size on cephalometric films and its true volumetric size as determined from cone beam computed tomography scan in adolescents.

Subjects were divided into three groups based on the SNB angle. However, this does not by pass the influence of cranial base inclination on mandibular position (SNB), so mandibular body length (Go-Gn) was measured for all the three groups which showed a statistically significant difference [Table 3]. The results of our study showed that the mandibular position (SNB) had no effect on the dimensions of the pharyngeal airway passage. No statistically significant difference (P = 0.47 and 0.094 respectively) in the (PAS-UP, PAS-TP) between the three groups was observed. Pearson's correlation between PAS-UP and PAS-TP to other cephalometric variables is shown in Table 6a, 6b, 7a, 7b.

Past research on PAS has shown that a long soft palate was associated with smaller oropharyngeal depth and was more common among subjects who snored and had obstructive sleep apnea.[19] According to Jena *et al.*[20] and Muto *et al.*[21] the increased length of the soft palate among subjects with mandibular retrognathism could be the result of the backward position of the tongue, which compressed the soft palate and resulted in decreased thickness and increased length of the soft palate. The soft palate was thicker among subjects with a prognathic mandible followed by retrognathic and normal mandible. On the contrary, Abu Allhaija and Al-K Abu hateeb[22-24] reported a thinner soft palate among Class I subjects compared with Class II and Class III subjects. Therefore, the UL was correlated in subjects with different (prognathic and retrognathic) mandibular morphology. But no significant correlation was noted in this study.

Uvula angulation showed a statistically significant difference (P = 0.007) between mandibular retrognathism

Table 5: Correlation in the individual groups

Groups	LAFH	PL
Normal mandible	Pearson correlation	−0.162
	Significant (two-tailed)	0.384
	n	31
Retrognathic	Pearson correlation	0.195
	Significant (two-tailed)	0.293
	n	31
Prognathic	Pearson correlation	0.406*
	Significant (two-tailed)	0.026
	n	30

*Correlation is significant at the 0.01 level (two-tailed). No significant correlation seen in normal and retrognathic patients between LAFH versus PL. In prognathic patients LAFH versus PL had significant moderate positive correlation.
LAFH – Lower anterior facial height; PL – Pharyngeal length

Table 6a: Correlation between PASUP and other variables

PASUP	SNA	SNB	SNP	UL	UT	UA	OPTNSL	PASTP	LAFH	PL
Pearson correlation	0.056	0.092	0.096	−0.208*	−0.086	−0.071	0.308**	0.663**	0.039	−0.101
Significant (two-tailed)	0.595	0.386	0.363	0.046	0.413	0.503	0.003	0.000	0.716	0.338
n	92	92	92	92	92	92	92	92	92	92

*Correlation is significant at the 0.05 level (two-tailed); **Correlation is significant at the 0.01 level (two-tailed). LAFH – Lower anterior facial height; PL – Pharyngeal length; UL – Uvula length; UT – Uvula thickness; UA – Upper airway

Table 6b: Correlation between PASUP and other variables in individual groups

Groups	PASUP	SNA	SNB	SNP	UL	UT	UA	OPTNSL	PASTP	LAFH	PL
Normal mandible	Pearson correlation	−0.004	−0.017	0.036	−0.331	−0.045	0.149	0.576**	0.760**	0.046	−0.213
	Significant two-tailed	0.982	0.927	0.846	0.069	0.809	0.425	0.001	0.000	0.805	0.249
	n	31	31	31	31	31	31	31	31	31	31
Retrognathic	Pearson correlation	−0.010	−0.245	−0.247	−0.180	−0.057	0.026	0.332	0.681**	0.223	−0.172
	Significant two-tailed	0.956	0.185	0.180	0.332	0.762	0.891	0.068	0.000	0.229	0.356
	n	31	31	31	31	31	31	31	31	31	31
Prognathic	Pearson correlation	−0.152	0.124	0.120	−0.027	−0.197	−0.287	0.299	0.526**	−0.009	0.158
	Significant two-tailed	0.423	0.513	0.528	0.887	0.296	0.124	0.108	0.003	0.962	0.404
	n	30	30	30	30	30	30	30	30	30	30

*Correlation is significant at the 0.05 level (two-tailed); **Correlation is significant at the 0.01 level (two-tailed). LAFH – Lower anterior facial height; PL – Pharyngeal length; UL – Uvula length; UT – Uvula thickness; UA – Upper airway

Table 7a: Correlation between PASTP and other variables in the whole study sample

PASTP	SNA	SNB	SNP	UL	UT	UA	OPTNSL	PASUP	LAFH	PL
Pearson correlation	0.045	0.182	0.185	−0.011	−0.083	0.046	0.203	0.663**	−0.016	0.061
Significant two-tailed	0.672	0.083	0.077	0.916	0.433	0.661	0.052	0.000	0.880	0.561
n	92	92	92	92	92	92	92	92	92	92

LAFH – Lower anterior facial height; PL – Pharyngeal length; UL – Uvula length; UT – Uvula thickness; UA – Upper airway

Table 7b: Correlation between PASTP and other variables in individual groups

Groups	PASTP	SNA	SNB	SNP	UL	UT	UA	OPTNSL	PASUP	LAFH	PL
Normal mandible	Pearson correlation	−0.070	0.005	0.090	0.003	−0.071	0.298	0.473**	0.760**	−0.168	−0.099
	Significant two-tailed	0.707	0.977	0.631	0.987	0.704	0.103	0.007	0.000	0.365	0.598
	n	31	31	31	31	31	31	31	31	31	31
Retrognathic	Pearson correlation	−0.121	−0.019	−0.019	0.062	0.088	0.137	0.247	0.681**	0.162	0.031
	Significant two-tailed	0.518	0.921	0.921	0.742	0.636	0.463	0.181	0.000	0.385	0.869
	n	31	31	31	31	31	31	31	31	31	31
Prognathic	Pearson correlation	−0.193	0.029	−0.035	−0.005	−0.374*	−0.032	0.305	0.526**	0.132	0.383*
	Significant two-tailed	0.308	0.880	0.853	0.977	0.042	0.866	0.102	0.003	0.486	0.037
	n	30	30	30	30	30	30	30	30	30	30

LAFH – Lower anterior facial height; PL – Pharyngeal length; UL – Uvula length; UT – Uvula thickness; UA – Upper airway

and prognathism. Maximum inclination of the soft palate was found in patients with mandibular retrognathism, literature[20,21] explains that the mandibular retrognathism is associated with posterior location of the soft palate and narrowing of the oropharyngeal airway due to the backward position of the tongue and its contact with the soft palate.

Craniocervical angulation (OPT/NSL) was found be significantly different ($P < 0.001$) among the three groups with maximum value in retrognathic mandible group followed by normal and prognathic mandible group respectively. Thus subjects with retrognathic mandible had an extended head posture (increased craniocervical angulation) to compensate for the airway space. Moderate cranial extension was thought to decrease the resistance to airflow in the upper airway thickness.[25] Woodside and Linder-Aronson[26] also postulated that mouth breathers tip their head backward in an attempt to increase their airway.

Pharyngeal length showed statistically significant ($P = 0.032$) variation between mandibular retrognathism and prognathism patients. The mean PL for retrognathic mandible patients was significantly higher ($P = 0.032$) than prognathic mandible patients. These results correlate with the findings of Pae *et al.*[27,28] who suggested that longer pharynx is more suspectible to collapse (the cross-sectional area of the pharynx being constant). Thus, patients with a retrognathic mandible are more predisposed to developing obstructive sleep apnea. On the contrary, Kerr reported that Class II subjects had short PL compared with Class III subjects.[29]

The PL and LAFH in the whole study population showed a significant ($P = 0.220$) positive correlation. This finding correlates with Kerr[29] and confirms the logical premise that subjects with long faces generally have longer nasopharynges. This can serve as an important diagnostic factor for obstructive sleep apnea.

A few limitations of this study are lack of sample size predetermination and the results based on two dimensional measurements on a lateral cephalogram. However future studies can focus on a bigger sample and 3 dimensional analysis of PAS for better results.

CONCLUSIONS

Hypothesis that mandibular retrognathism is associated with reduced PAS is rejected. There is no significant difference between PAS between patients with mandibular retrognathism, normal mandible and mandibular prognathism. Mandibular retrognathism patients show a significantly higher uvula angulation than patients with mandibular prognathism. Craniocervical angulation showed maximum value in retrognathic mandible group followed by normal and prognathic mandible group respectively. Mean PL for retrognathic mandible patients was significantly higher than prognathic mandible patients.

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REFERENCES

1. Holmberg H, Linder-Aronson S. Cephalometric radiographs as a means of evaluating the capacity of the nasal and nasopharyngeal airway. Am J Orthod 1979;76:479-90.
2. O'Ryan FS, Gallagher DM, La Bane JP, Epke BN. The relation between nasorespiratory function and dentofacial deformity: A review. Am J Orthod 1982;82:403-10.
3. O'Ryan FS, Labanc JP, Kageler WV, Epker BN. Nasorespiratory function in individuals with vertical maxillary excess. Part 1. Measurement. J Clin Orthod 1984;18:342-6.
4. Ferro A, Nucci LP, Ferro F, Gallo C. Long-term stability of skeletal Class III patients treated with splints, Class III elastics, and chincup. Am J Orthod Dentofacial Orthop 2003;123:423-34.
5. Liao YF, Huang CS, Chuang ML. The utility of cephalometry with the Muller maneuver in evaluating the upper airway and its surrounding structures in Chinese patients with sleep-disordered breathing. Laryngoscope 2003;113:614-9.
6. Opdebeeck H, Bell WH, Eisenfeld J, Mishelevich D. Comparative study between the SFS and LFS rotation as a possible morphogenic mechanism. Am J Orthod 1978;74:509-21.
7. Achilleos S, Krogstad O, Lyberg T. Surgical mandibular advancement and changes in uvuloglossopharyngeal morphology and head posture: A short-and long-term cephalometric study in males. Eur J Orthod 2000;22:367-81.
8. Achilleos S, Krogstad O, Lyberg T. Surgical mandibular setback and changes in uvuloglossopharyngeal morphology and head posture: A short-and long-term cephalometric study in males. Eur J Orthod 2000;22:383-94.
9. Muto T, Yamazaki A, Takeda S, Kawakami J, Tsuji Y, Shibata T, *et al.* Relationship between the pharyngeal airway space and craniofacial morphology, taking into account head posture. Int J Oral Maxillofac Surg 2006;35:132-6.
10. Perillo L, Femminella B, Farronato D, Baccetti T, Contardo L, Perinetti G. Do malocclusion and temporomandibular disorders correlate with body posture? J Oral Rehabil 2011;38:242-52.
11. Jeans WD, Fernando DC, Maw AR, Leighton BC. A longitudinal study of the growth of the nasopharynx and its contents in normal children. Br J Radiol 1981;54:117-21.
12. Tourné LP. Growth of the pharynx and its physiologic implications. Am J Orthod Dentofacial Orthop 1991;99:129-39.
13. Tsai HH. Developmental changes of pharyngeal airway structures from young to adult persons. J Clin Pediatr Dent 2007;31:219-21.
14. King EW. A roentgenographic study of pharyngeal growth. Angle Orthod 1952;22:32-7.
15. Sharma JN. Pattern of distribution of malocclusions in patients seeking orthodontic treatment at BPKIHS from Sunsari District of Nepal. Health Renaiss 2010;8:93-6.
16. Kollias I, Krogstad O. Adult craniocervical and pharyngeal changes — A longitudinal cephalometric study between 22 and 42 years of age. Part II: Morphological uvulo-glossopharyngeal changes. Eur J Orthod 1999;21:345-55.
17. Malkoç S, Usümez S, Iseri H. Long-term effects of symphyseal distraction and rapid maxillary expansion on pharyngeal airway dimensions, tongue, and hyoid position. Am J Orthod Dentofacial Orthop 2007;132:769-75.
18. Cameron CG, Franchi L, Baccetti T, McNamara JA Jr. Long-term effects of rapid maxillary expansion: A posteroanterior cephalometric evaluation. Am J Orthod Dentofacial Orthop 2002;121:129-35.
19. Akcam MO, Toygar TU, Wada T. Longitudinal investigation of soft palate and nasopharyngeal airway relations in different rotation types. Angle Orthod 2002;72:521-6.
20. Jena AK, Singh SP, Utreja AK. Sagittal mandibular development effects on the dimensions of the awake pharyngeal airway passage. Angle Orthod 2010;80:1061-7.
21. Muto T, Yamazaki A, Takeda S. A cephalometric evaluation of the pharyngeal airway space in patients with mandibular retrognathia and prognathia, and normal subjects. Int J Oral Maxillofac Surg 2008;37:228-31.
22. Abu Allhaija ES, Al-Khateeb SN. Uvulo-glosso-pharyngeal dimensions in different anteroposterior skeletal patterns. Angle Orthod 2005;75:1012-8.
23. Subtelny JD. A cephalometric study of the growth of the soft palate. Plast Reconstr Surg (1946) 1957;19:49-62.
24. Ruscello DM, Tekieli ME, Jakomis T, Cook L, Van Sickels JE. The effects of orthognathic surgery on speech production. Am J Orthod 1986;89:237-41.
25. Ricketts RM. Respiratory obstruction syndrome. Am J Orthod 1968;54:495-507.
26. Woodside DG, Linder-Aronson S. The channelization of upper and lower anterior face heights compared to population standard in males between ages 6-20 years. Eur J Orthod 1979;1:25-40.
27. Pae EK, Lowe AA, Fleetham JA. A role of pharyngeal length in obstructive sleep apnea patients. Am J Orthod Dentofacial Orthop 1997;111:12-7.
28. Pae EK, Kuhlberg A, Nanda R. Role of pharyngeal length in patients with a lack of overbite. Am J Orthod Dentofacial Orthop 1997;112:179-86.
29. Kerr WJ. The nasopharynx, face height, and overbite. Angle Orthod 1985;55:31-6.

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