Developmental Changes of Pharyngeal Airway Structures from Young to Adult Persons

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This cross-sectional study investigated developmental changes of pharyngeal airway structures. The materials were comprised of 120 lateral cephalometric radiographs and were divided into three stages according to the dental age. Results indicated that the upper pharyngeal depth increased with age, whereas, the lower pharyngeal depth was established early in life. The pharynx increases its capacity predominantly by vertical expansion. The developmental changes in pharyngeal structures were significantly greater in males than in females.

Key words: *airway, pharyngeal, development, children*
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INTRODUCTION

The pharynx is situated immediately posterior to the mouth and nasal cavity, and is cranial to the esophagus, larynx, and trachea. It is a tube-shaped structure formed by muscles and membranes and can be anatomically divided into three parts: the nasopharynx, oropharynx, and laryngopharynx. The nasopharynx, which forms the upper part of the respiratory system, is situated behind the nasal cavity and above the soft palate. Anteriorly, it connects with the nasal cavity. Posteriorly, it continues downward as the oropharynx. The oropharynx is the portion of the pharynx that lies posterior to the mouth; it is continuous above with the nasopharynx via the pharyngeal isthmus and below with the laryngopharynx. The laryngopharynx includes the pharyngoesophageal junction, the piriform sinus, and the posterior pharyngeal wall.

The nasopharynx and oropharynx have significant locations and functions because both of them form a part of the unit in which respiration and deglutition are carried out; they also include lymphoid tissue in their structures.[1-3] Hypertrophy of the adenoidal pad and tonsils can cause chronic mouth breathing, loud snoring, and obstructive sleep apnea.[4-6]

There is a need for knowledge of the changes in the pharyngeal airway that occur in the untreated normal person during the active growth years and beyond. Such information would form a baseline from which to plan therapy and may provide insights into normal developmental changes.

The purposes of the present study were twofold: (1) to investigate the pharyngeal airway structural changes seen during development from the early mixed dentition into adulthood in untreated normal Taiwanese persons and (2) to identify any differences between males and females.

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MATERIALS AND METHODS

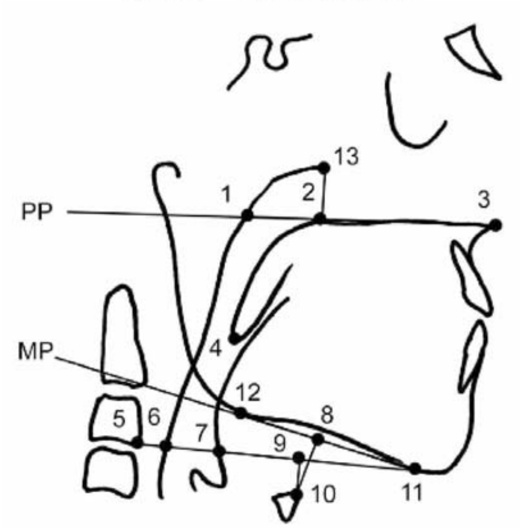
The materials for this investigation were obtained from the files of our department and consisted of lateral cephalometric radiographs of 120 normal Taiwanese (60 females and 60 males), aged 6~35 years. All subjects had natural dentitionS and no craniofacial anomalies, syndromes, clefting, or symptoms or signs of dysfunction of the masticatory system. Standard lateral cephalometric radiographs with the teeth in habitual occlusion and with the head oriented horizontally with the Frankfort (FH) plane were taken with a cephalostat in accordance with standard cephalometric procedures. The materials were divided into three stages according to the dental age: early mixed dentition (stage 1), early permanent dentition (stage 2), and complete permanent dentition (stage 3). The materials in each stage were comprised of 20 lateral cephalometric radiographs.

The radiographs were traced by hand over an illuminated viewer onto acetate paper, and 11 appropriate cephalometric reference points were digitized (Figure 1) on a digitizer connected to a personal computer to construct seven linear measurements (L1 to L7) and two areas (A1 and A2) describing the pharyngeal airway dimension (Figure 2). All tracings and digitization of radiographs were carried out by the same person. The midlines of all contours of bilateral structures were traced to minimize errors due to positioning, differential magnification, and/or symmetry.

All cephalometric landmarks were coordinated with the X and Y axes; the X-axis is the FH plane and the Y-axis is the line perpendicular to the FH plane from the Sella reference point. Calculations were performed by means of the computerized cephalometric system, Winceph (vers. 7.0, Rise Co., Japan). Twenty lateral cephalometric radiographs, randomly selected, were traced twice to assess the intra-examiner reliability. Differences between the means of the first and second tracings for each of the variables were tested by means of paired t-tests to evaluate the error of the method, and all were well within an acceptable range.

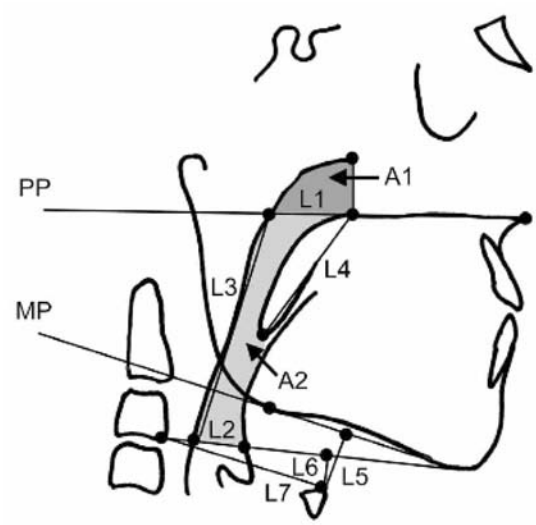
Statistical analysis was performed using the computer software SigmaStat and SigmaPlot for Windows. All measurements for each stage were analyzed with Student's t-test for sexual dimorphism. The level of significance was set to $p < 0.05$. Analysis of variance (ANOVA) in both genders was used for comparison of mean values for each measurement among the three stages.

Figure 1 Reference points



1: the point of intersection of the palatal plane and posterior pharyngeal wall
2: PNS (anterior nasal spine)
3: ANS (posterior nasal spine)
4: Uvula (the most inferior point of the soft palate)
5: C3 (the third vertebra)
6: the point of intersection of the straight line between reference points 5 and 11 and posterior pharyngeal wall
7: the point of intersection of the straight line between reference points 5 and 11 and tongue base
8: the point of intersection of the perpendicular line from reference point 10 to the mandibular plane
9: the point of intersection of the perpendicular line from reference point 10 to the straight line between reference points 5 and 11
10: Hyoid bone (the most anterior point of the hyoid bone)
11: Menton (the most anteroinferior point of the mandibular lower border)
12: Lower Gonion (the most posteroinferior point of the mandibular lower border)
13: the point of intersection of the posterior pharyngeal wall and the line that cross reference point 2 and perpendicular to palatal plane
PP: palatal plane (the straight line that cross ANS and PNS)
MP: mandibular plane (the straight line that cross Menton and Lower Gonion)

Figure 2 Measurements



L1: (Upper pharyngeal depth) the distance between reference point 1 and 2
L2: (Lower pharyngeal depth) the distance between reference point 6 and 7
L3: (Pharyngeal length) the distance between reference point 1 and 6
L4: (Soft palate length) the distance between reference point 2 and 4
L5: (Hyoid bone to Mandibular plane) the distance between reference point 8 and 10
L6: (Hyoid bone to C3-Menton plane) the distance between reference point 9 and 10
L7: (C3 to Hyoid bone) the distance between reference point 5 and 10
A1: (Dimension of nasopharynx) the area surrounded with a curve between reference points 1 to 13, a straight line between reference points 13 to 2 and a straight line between reference points 2 to 1.
A2: (Dimension of oropharynx) the area surrounded with a curve between reference points 1 to 6, a straight line between reference points 6 to 7, a curve between reference points 7 to 2 and a straight line between reference points 2 to 1.

RESULTS

Table 1 shows the mean values and standard deviations of the measurements that exhibited differences among each stage for both genders. The results revealed that all of the measurements in both genders increased from stages 1 to 3. The upper pharyngeal depth (L1), pharyngeal length (L3), soft palate length (L4), and hyoid bone positions (L6 and L7) in males significantly increased during the observation periods; however, no statistically significant differences were present in growth profiles of any of the measurements in females.

Few measurements showed significant differences between males and females in stage 1 (early mixed dentition); however, mean values of the pharyngeal length (L3), hyoid bone position (L5 and L7), oropharynx dimension (A2), and soft palate length (L4) in males were greater than those in females in stage 3 (complete permanent dentition).

DISCUSSION

The airway can be divided into the upper airway, which consists of the nasal passages, mouth, and pharynx, and the lower airway, which contains the larynx, trachea, and bronchi in the lungs. A normal airway is dependent on sufficient anatomical dimensions of the airway.

Lymphoid masses increase rapidly in infancy and early childhood, experience a slower development thereafter, peak before adolescence, and gradually decline to adult values. Tonsils are clumps of lymph tissue which form a ring around the back of the mouth. The two clumps on the sides are the palatine tonsils; back behind and below the tongue are the lingual tonsils; and hidden by the palate, directly behind the nose are the adenoids. Enlargement of the tonsils and adenoids can cause a muffled voice, snoring with pauses in breathing (apnea), and "Darth Vader"-type breathing during the day. Obstructive symptoms can occur when rapid growth of the lymphatic system during the first 7 years occurs in children with a small throat and shallow sockets for the tonsils. Tonsils can appear to block the breathing and swallowing space.

The size of the nasopharynx is of particular importance in determining whether the mode of breathing is nasal or oral. Because nasal airway inadequacy is one of the major environmental causes of malocclusions observed in growing children, many studies have been carried out to reveal the association between nasal respiratory impairment and dentofacial developmental anomalies.[7-9] Investigations carried out on subject have pointed out the roles of enlarged adenoids,[10-11] allergic rhinitis,[12,13] and enlarged tonsils14 on the effective mode of breathing.

In this study, the areas of the nasopharynx (A1) and oropharynx (A2) were measured separately. Both dimensional measurements, which can be used to demonstrate the respiratory capacity, and several linear measurements were used in the assessing the pharyngeal structures. This study found no statistically significant differences in the lower pharyngeal depth (L2) among the three stages in either gender. This suggests that the lower pharyngeal depth is formed at an early age of life. The upper pharyngeal depth (L1) and pharyngeal length (L3), especially in males, continues growing until adulthood. The increase in the dimensions of the nasopharynx (A1) was

Table 1

The results of statistics analysis of the measurements among each stage (Anova) and between males and females (t-test)

Measurement	Sex	Stage 1		Stage 2		Stage 3		Anova
		Mean	SD	Mean	SD	Mean	SD	
L1	Female	17.73	4.42	18.80	4.72	20.37	1.57	NS
Upper pharyngeal depth	Male	17.35	6.08	19.68	3.19	21.29	2.43	P = 0.016
	t-test	NS		NS		NS		
L2	Female	10.91	2.98	11.54	3.18	11.78	3.44	NS
Lower pharyngeal depth	Male	13.47	4.20	13.54	4.41	14.03	4.10	NS
	t-test	P = 0.032		NS		NS		
L3	Female	48.10	3.91	48.92	7.23	49.47	5.62	NS
Pharyngeal length	Male	51.36	4.82	52.67	4.92	56.58	4.38	P = 0.003
	t-test	P = 0.024		NS		P = <0.001		
L4	Female	28.77	2.98	29.93	2.80	30.50	3.52	NS
Soft palate length	Male	30.24	3.20	31.53	2.25	33.85	4.45	P = 0.006
	t-test	NS		NS		P = 0.012		
L5	Female	6.29	2.77	6.43	3.84	6.98	4.64	NS
Hyoid bone to	Male	7.22	6.35	10.06	4.34	10.55	5.23	NS
Mandibular plane	**t-test**	NS		P = 0.008		P = 0.028		
L6	Female	-3.81	3.28	-3.67	4.83	-1.87	2.87	NS
Hyoid bone to	Male	-2.96	5.07	0.47	4.79	0.54	4.57	P = 0.002
C3-Menton plane	**t-test**	NS		P = 0.010		NS		
L7	Female	30.26	3.01	31.18	2.55	31.40	3.03	NS
C3 to Hyoid bone	Male	32.06	3.12	33.02	4.93	36.56	3.95	P = 0.002
	t-test	NS		NS		P = <0.001		
A1	Female	205.35	67.48	207.63	67.12	242.96	56.31	NS
Dimension of nasopharynx	Male	182.39	72.57	197.89	58.29	257.45	69.31	P = 0.002
	t-test	NS		NS		NS		
A2	Female	578.63	155.92	591.36	140.20	596.15	114.05	NS
Dimension of oropharynx	Male	666.07	138.45	684.09	154.61	759.2	167.90	NS
	t-test	NS		NS		P = <0.001		

obvious from stages 2 to 3. These may be due to a decrease in size of the adenoids from child to adult. Only two measurements, the lower pharyngeal depth (L2) and pharyngeal length (L3), among the nine measurements showed significant differences between gender in stage 1, indicating that the pharyngeal structures are not affected by gender in the early mixed dentition. However, it was observed that the pharyngeal length (L3), hyoid bone position (L5 and L7), oropharynx dimension (A2), and soft palate length (L4) in males were greater than those in females in stage 3. A previous study15 showed that patients with obstructive sleep apnea syndrome (OSAS) have significantly different cephalometric features compared with normal patients: an inferiorly positioned hyoid bone and enlarged soft palate. Habitual snoring was found in 16.0% of males and 6.5% of females.[16] A male predominance was noted. In this study, the gender differences in stage 3 might clarify the reasons why men snore more often than women.

The aim of this study was to contribute to our understanding of the developmental changes of the pharyngeal airway structures from young to adult persons. Differences in developmental changes between females and males obtained in this study may explain age and gender differences in the prevalences of some diseases in the pharyngeal region.

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