Evaluation of the Nasopharyngeal Free Airway Space based on Lateral Cephalometric Radiographs and Endoscopy

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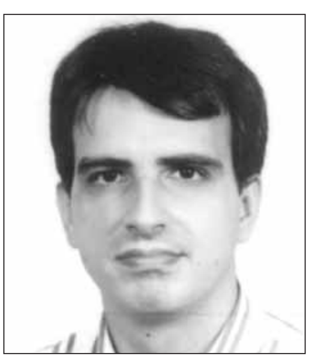

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Purpose: To calculate the mean anteroposterior size of the nasopharyngeal airway in nose- and mouth-breathing participants aged 6–12 years in order to obtain cephalometric standards for prediction of nasopharyngeal airway obstruction and to compare those results with the findings of nasopharyngeal endoscopy.
Participants: Three samples were studied. *Sample I* consisted of 170 nose-breathing Brazilian children of Caucasian origin (85 boys and 85 girls). *Sample II* consisted of 60 Swedish mouth-breathing children (37 boys and 23 girls). The ages of the children of both samples were 6–12 years, and both samples were divided into three age groups. *Sample III* consisted of 29 Brazilian mouth-breathing children (13 boys and 16 girls) aged 7–12 years.
Methods: Lateral cephalometric radiographs were taken of all participants and the nasopharyngeal airway space was measured on those radiographs. The mode of breathing was clinically evaluated for all children. The nasal obstruction in the children from *sample II* was confirmed by posterior rhinomanometry. In *sample III* otolaryngologists also examined the nasopharynx by posterior rhinoscopy and endoscopy. Means of the nasopharyngeal sizes for nose- and mouth breathers aged 6–12 years were calculated. Besides descriptive statistics Kappa (κ) statistics also were performed to evaluate the correlation between cephalometric and endoscopic findings.
Results: The k-values show moderate agreement between the evaluation of the nasopharyngeal free airway space by measurements on lateral radiographs and clinical endoscopic examination for the variables Ptm-ad$_1$ (κ = 0.52) and Ptm-ad$_1$-ad$_2$-Ptm (κ = 0.44). The variable Ptm-ad$_2$ showed perfect agreement (κ = 1.00).
Conclusion: Ptm-ad$_2$ should be routinely measured on each cephalogram to evaluate whether a patient suffers from obstruction of the nasal airway.

Keywords: lateral cephalometric radiographs, nasopharyngeal endoscopy, adenoids, nasopharyngeal airway space, mouth breathing

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INTRODUCTION

The size of the nasopharyngeal airway is **particularly** important in determining whether the mode of breathing is nasal or oral. The posterior nasopharyngeal wall is covered by lymphoid tissue that often undergoes hypertrophy (adenoids) during the period prior to puberty. This adenoidal enlargement increases the chance of nasopharyngeal airway obstruction.
The relationship between the nasopharynx size and adenoid size is crucial (Linder-Aronson, 1970; Linder-Aronson and Henrikson, 1973; Linder-Aronson and Leighton, 1983; Subtelny, 1954; Ricketts, 1954, 1968).

The size of the nasopharyngeal airway can be assessed by direct clinical inspection (posterior rhinoscopy, endoscopy) or from lateral cephalograms. Since lateral cephalometric analysis already forms part of the diagnostic routine in most orthodontic cases, it is often chosen for the assessment of the nasopharyngeal airway size. It must be fully recognized that we are dealing with a three-dimensional space that is seen in only two dimensions on a cephalogram. A high correlation has been found between the results of posterior rhinoscopy and the size of adenoids on the posterior nasopharyngeal wall seen on lateral radiographs (Linder-Aronson, 1970; Holmberg and Linder-Aronson, 1979).

Table 1 Mean age and number of children in each age group of samples I, II and III.

Age groups	Sample I		Sample II		Sample III	
(years)	Mean age	Number	Mean age	Number	Mean age	Number
6–7	7.3	50	7.2	33	7.7	2
8–9	9.1	60	9.0	14	9.2	15
10–11	10.1	60	10.1	13	10.9	12

Because the nasopharyngeal space increases with the age of the child and the lymphoid tissue on the posterior wall of the nasopharynx usually diminishes before puberty (Linder-Aronson and Leighton, 1983; McNamara, 1984; Subtelny and Koepp-Baker, 1956; Todd, 1936), it is helpful to obtain standards for the sagittal size of the nasopharyngeal airway at different ages. Such standards are of special interest for children aged 6–12 years, because usually these are the ages for orthodontic treatment.

Standards should be available both for nose breathers without any ear, nose or throat problems and for mouth breathers for whom the cause is enlarged adenoids on the posterior nasopharyngeal wall. Regarding relief of nasal obstruction before orthodontic treatment, such standards, together with other criteria for nasal obstruction and mouth-breathing will help orthodontists select children that need to be referred to an ear, nose and throat specialist.

The aim of this study was to calculate the mean anteroposterior size of the nasopharyngeal airway in nose- and mouth breathers aged 6–12 years in order to obtain cephalometric standards, to allow prediction of nasopharyngeal airway obstruction, and also to correlate the cephalometric with the endoscopic findings of the nasopharynx in mouth or functional mouth breathers.

MATERIAL AND METHODS

Participants

The present investigation was undertaken using three samples:

Sample I consisted of 170 patients of Caucasian origin (85 boys and 85 girls) from the Department of Orthodontics, School of Dentistry, UFF, Niterói City and Rio de Janeiro, Brazil. These patients were divided into three groups: 6–7 years, 8–9 years, and 10–11 years. Patients that systematically used either topical or systemic medication for the nose were excluded from the sample. The selection criterion was that participants must predominantly breathe through the nose. The mean ages and numbers are shown in Table 1.

Sample II consisted of 60 children (37 boys and 23 girls) from the county of Örebro, Sweden. These children were mouth breathers, for whom an otological examination had indicated adenoidectomy for nasal obstruction. An otorhinolaryngologist undertook the examination, and the nasal obstruction was confirmed by posterior rhinomanometry. The mouth breathers were divided into three age groups: 6–7 years, 8–9 years, and 10–11 years. The mean ages and numbers are shown in Table 1.

Sample III consisted of 29 patients (13 boys and 16 girls, aged 7–12 years) from the Department of Orthodontics, Araraquara School of Dentistry, UNESP, Araraquara City, São Paulo, Brazil. These children exhibited mouth breathing and were snoring and drooling during sleep. The respiratory patterns were determined using the criteria established by Linder-Aronson (1979) and Bresolin et al (1982). However, there were some doubts about this sample as to whether the participants were true mouth breathers or just functional mouth breathers. The mean ages and numbers are shown in Table 1.

Clinical Evaluation

Sample I

The children underwent history taking and clinical examination. The clinical examination consisted of three tests to identify mouth breathers. First the patient was asked to close the lips and breathe deeply through the nose. Nose breathers normally demonstrate a good reflex control of the alar muscles, which regulate the size and contour of the external part of the nostrils, which dilate while inspiring. Even the nose breathers with temporary nasal congestion will demonstrate reflex alar muscles contraction and dilation of the nostrils during voluntary inspiration. The mouth breathers, however, even

when able to breath through the nose, do not alter the size and contour of the nostrils and occasionally contract the nose openings when they inspire (Moyers, 1958).
The second test recorded mouth or nose breathing by holding a cold dental mirror alternately in front of the nose and mouth. The patient was seated in a relaxed position with the head upright. The ability to breathe through the nose was tested for each nasal passage separately, by seeing whether the participant could breathe calmly for 30 seconds when one nostril and the mouth were closed.
The third test was a functional test. The patients were asked to bend their knees 10 times in rapid succession. If, directly afterwards, they were able to continue breathing without difficulty calmly through the nose for 30 seconds, they were classified as pure nose breathers (Linder-Aronson and Bäckström, 1960).

Sample II
All children underwent a clinical examination by an otologist involving anterior and posterior rhinoscopy as well as an inspection of the ears, nose and throat. An orthodontist, noting whether condensation formed on a cold mirror held in front of the nose and mouth when the child expired, also assessed the mode of breathing. The children classified as nose breathers had no infection of the upper respiratory tract at the time.

Sample III
The purpose of including this group was to compare endoscopic findings with that of nasopharyngeal airway size measurements on lateral cephalograms. The participants of this sample were evaluated with a standard nasopharyngeal videoendoscopy examination, performed on the same day as the lateral cephalometric radiograph. A flexible fibrescope was passed carefully into the nasal cavity along the floor of the nose, allowing the otorhinolaryngologist to inspect the nasopharynx. The diagnostic observations obtained from this examination were considered the gold standard for diagnosing a nasopharyngeal obstruction. The patients were graded as '1' (normal to moderate hypertrophy) or '2' (severe to obstructive hypertrophy) (Fig. 1).

Cephalometric Evaluation

Standard cephalometric radiographs were taken with the child's head immobilized in a wall-mounted cephalostat and oriented to the Frankfort horizontal plane with the median-sagittal plane parallel to the film. The first author performed the tracings and the measurements. The enlargement of the median plane was 8% for samples I and III and 6.5% for sample II.

Reference points

The cephalometric reference points used in this study (Fig. 2) were:
Ba (**Ba**sion) = the most postero-inferior point on the clivus of os occipitale
Ptm (**Pt**erygo**m**axillare) = the intersection between the nasal floor and the posterior contour of the maxilla
S (**S**ella) = the centre of the sella turcica
So = the midpoint on the line joining Sella and Basion
ad$_1$ = the intersection of the line Ptm-Ba and the posterior nasopharyngeal wall
ad$_2$ = the intersection of the posterior nasopharyngeal wall and the line Ptm-So.

Measurements

The following measurements were made:
Ptm-ad$_1$ = linear distance from the point Ptm to the point ad$_1$, in mm
Ptm-ad$_2$ = linear distance from the point Ptm to the point ad$_2$, in mm
Ptm-ad$_1$–ad$_2$-Ptm = the area of the nasopharyngeal airway space, in mm2
Ptm-ad$_1$–ad$_2$-Ptm x 100 / Ptm-So–Ba-Ptm = the percentage between the area of the nasopharyngeal airway space and the area of the 'bony nasopharynx'.
The linear distances were measured with a digital calliper[1]. The areas were measured with a planimeter for small surfaces[2] (Fig. 2).

Statistical analysis

The error of method (_) for intra-individual measurements was calculated from the formula

$$\_ = \sqrt{\frac{\Sigma d^2}{2n}}$$

where d is the difference between two measurements and n is the number of double determinations.
Arithmetic mean and **s**tandard **d**eviation (SD) were calculated for each variable.

[1] Starret, São Paulo, Brazil, series no. 001296
[2] Type Ingut 9544-11: A. Ott, Bayern, Germany

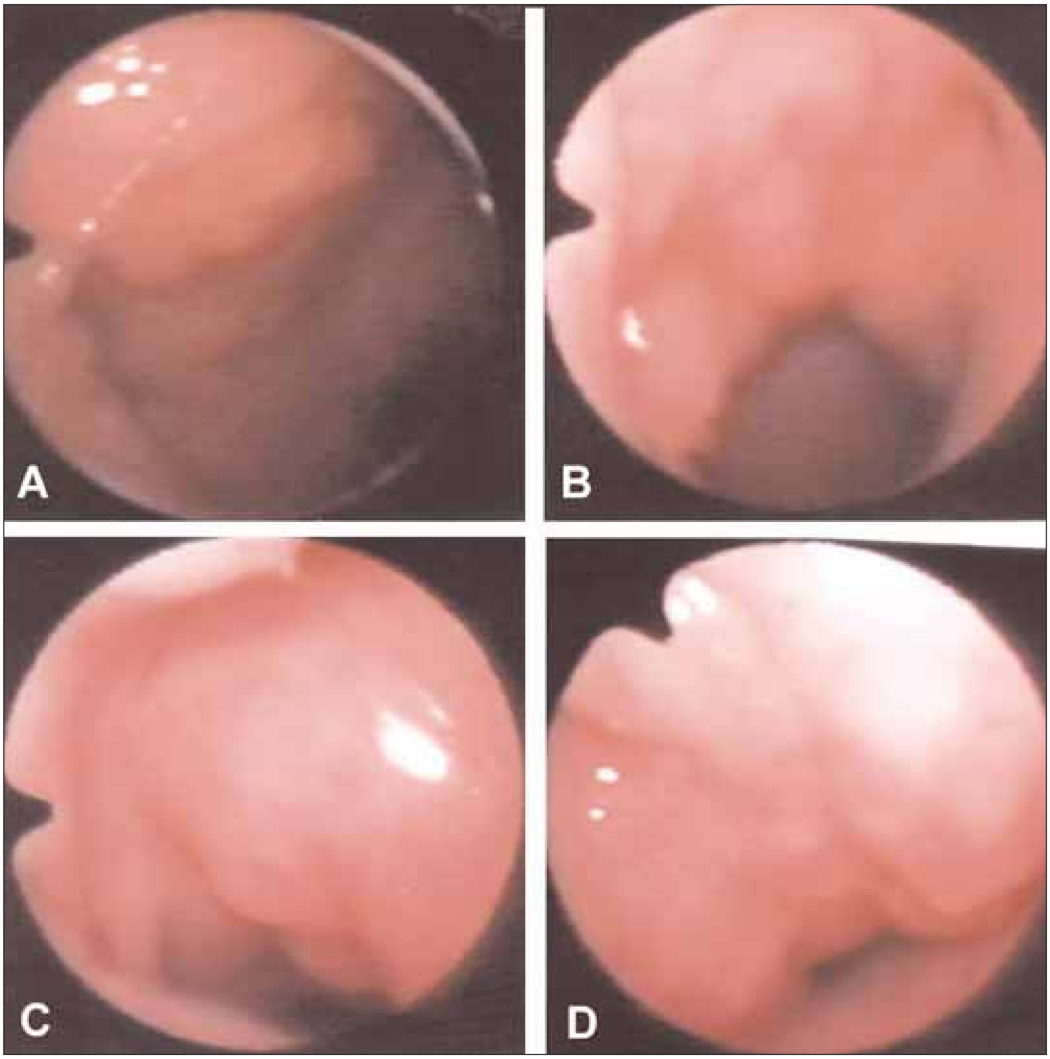

Fig. 1 Endoscopic classification of the adenoids:
A = normal or little hypertrophy,
B = moderate hypertrophy,
C = severe hypertrophy,
D = obstructive adenoids.

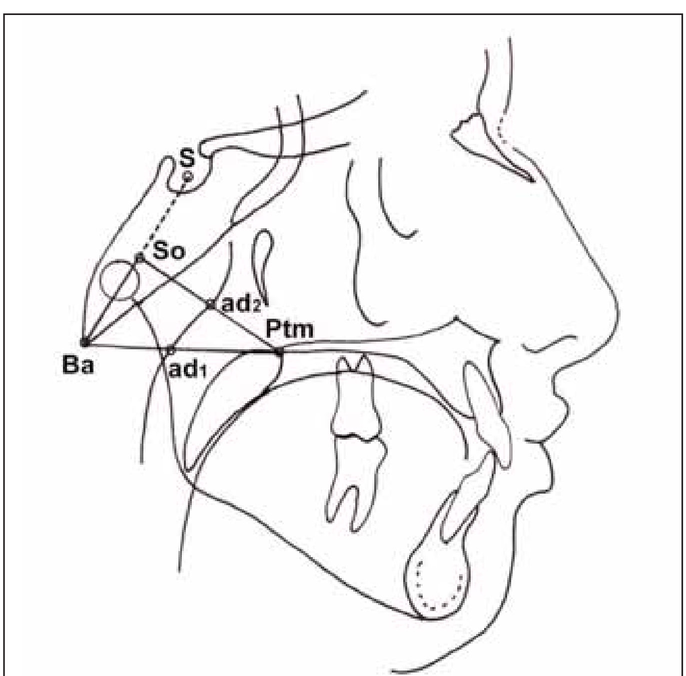

Fig. 2 Cephalometric tracing with the reference points Ba, Ptm, S, So, ad_1 and ad_2, the linear measurements Ptm-ad_1 and Ptm-ad_2, and the areas Ptm-ad_1–ad_2-Ptm and Ptm-So–Ba-Ptm.

Table 2 Arithmetic means and standard deviations (SD) for the measurements Ptm-ad_1 and Ptm-ad_2, according to the age, of the nose breathers of the sample I and mouth breathers of the sample II. The values are corrected for the enlargement of 8.0 % (sample I) and 6.5 % (sample II).

Age group (years)	Mode of breathing	n	Ptm-ad_1 (mm) Mean	SD	Ptm-ad_2 (mm) Mean	SD
6–7	nose	50	18.2	3.8	13.2	2.0
6–7	mouth	33	9.9	3.7	8.6	3.1
8–9	nose	60	19.1	3.6	14.9	2.2
8–9	mouth	14	12.4	4.8	8.8	3.6
10–11	nose	60	21.0	3.4	16.2	2.5
10–11	mouth	13	11.7	4.4	10.0	3.5

Table 3 Arithmetic means and standard deviations (SD) for the measurements Ptm-ad_1-ad_2-Ptm and Ptm-ad_1-ad_2-Ptm x 100 / Ptm-So-Ba-Ptm, according to the age of the nose breathers of sample I and the mouth breathers of sample II. The values are corrected for enlargement of 8 % (sample I) and 6.5 % (sample II).

Age group (years)	Mode of breathing	n	Ptm-ad_1-ad_2-Ptm (mm_) Mean	SD	Ptm-ad_1-ad_2-Ptm x 100 / Ptm-So-Ba-Ptm (%) Mean	SD
6–7	nose	50	69.6	23.3	18.0	5.7
6–7	mouth	33	25.3	15.5	7.4	4.5
8–9	nose	60	73.1	24.8	18.4	5.4
8–9	mouth	14	36.9	24.9	10.2	6.7
10–11	nose	60	85.1	24.9	20.4	5.7
10–11	mouth	13	35.5	21.2	9.0	5.0

The Kappa (κ) index was computed to determine the degree of concordance between the radiographic classification of the nasopharyngeal airway space and the endoscopic classification of the adenoids for each measurement from the formula:

$$k = \frac{P_o - P_c}{1 - P_c},$$

where Po represents the proportion of agreement observed and Pc represents the proportion of agreement expected due to chance.
The statistical tests were performed with the aid of 'Analyse-it' version 1.71 for Microsoft Excel. For κ statistics the values of the measurements Ptm-ad_1, Ptm-ad_2 and Ptm-ad_1 – ad_2-Ptm relating to the participants of sample III were also categorized as '1' or '2', based on the arithmetic means derived for nose- and mouth breathers of sample II.

RESULTS

The intra-observer error in determining the values of the four cephalometric measurements used in this study was calculated using 15 randomly selected cases. It was found that the error of method was 0.84 mm for the measurement Ptm-ad_1, 0.67 mm for Ptm-ad_2, 4.22 mm^2 for Ptm-ad_1-ad_2-Ptm, and 1.25 % for Ptm-ad_1-ad_2-Ptm x 100 / Ptm-So-Ba-Ptm. The intra-observer error of method, therefore, is of little importance in this study.
Means and standard deviations for the variables Ptm-ad_1, Ptm-ad_2, Ptm-ad_1 – ad_2-Ptm and Ptm-ad_1 – ad_2-Ptm x 100 / Ptm-So – Ba -Ptm of the three age groups of the nose breathers of sample I and mouth breathers of sample II are presented in Tables 2 and 3, respectively.
Table 2 shows that the nasopharyngeal airway space for nose breathers aged 6 – 12 years, expressed by the linear distance Ptm-ad_1, varies between 18.2 and 21.0 mm. For the mouth breathers the values are 7 – 10 mm lower for the same age groups. Table 2 also shows that, depending on the age, the nasopharyngeal air-

Table 4 Gender, age, results of the endoscopic examination and the values of the measurements Ptm-ad_1, Ptm-ad_2 and Ptm-ad_1-ad_2-Ptm of the participants of sample III. The values are corrected for the enlargement of 8.0 %. M = male, F = female.

Number	Gender	Age (years)	Endoscopic findings	Ptm-ad_1 (mm)	$Ptma_2$ (mm)	Ptm-ad_1-ad_2-Ptm (mm^2)
01	M	11.03	1	18.9	12.3	66.3
02	F	8.11	1	20.1	16.1	81.9
03	F	10.0	1	17.2	12.9	57.8
04	F	10.11	1	14.0	11.2	35.7
05	M	11.01	1	12.3	10.3	31.2
06	F	9.02	1	10.8	10.8	29.3
07	F	9.01	1	15.6	13.0	56.7
08	F	9.01	1	18.9	13.1	51.7
09	F	9.09	1	17.2	14.1	46.0
10	F	9.07	1	16.0	10.5	47.5
11	M	9.09	1	18.5	17.7	76.0
12	F	8.09	1	22.5	15.7	94.3
13	M	10.07	1	21.3	19.8	114.8
14	M	11.04	1	25.4	14.4	133.9
15	M	8.05	2	8.1	6.6	17.5
16	F	10.06	1	25.0	16.1	111.8
17	M	9.04	1	11.5	10.5	24.9
18	F	10.09	1	12.8	13.0	34.0
19	M	10.02	1	15.5	14.5	51.9
20	M	8.05	1	21.5	16.8	82.2
21	F	8.02	1	14.9	12.0	50.6
22	F	11.03	1	18.8	13.5	60.7
23	M	10.11	1	27.1	22.4	131.7
24	F	10.08	2	7.9	6.9	12.5
25	M	9.05	1	14.1	11.7	43.1
26	M	9.05	1	17.2	12.0	57.8
27	F	9.07	1	10.9	10.2	27.1
28	M	7.09	1	18.1	12.9	53.0
29	F	7.05	1	13.9	11.6	35.8

way space for nose breathers expressed by the linear distance Ptm-ad_2 on average measures 13.2 – 16.1 mm. For the mouth breathers the values are 4.5 – 6.0 mm lower.

The surface Ptm-ad_1 – ad_2-Ptm for nose breathers aged 6 – 12 years varies between 69.6 and 85.1 mm^2, as shown in Table 3. For the mouth breathers the values are 36.2 – 49.7 mm^2 lower. Table 3 also shows that nose breathers aged 6 – 12 years, Ptm-ad_1 – ad_2-Ptm x 100 / Ptm-So-Ba-Ptm varies between 17.9 and 20.4 %. For the mouth breathers the values are 8.2 – 11.4 % lower.

Table 4 shows the characteristics of the participants of sample III.

Table 5 shows the Kappa (κ) values between endoscopic findings and means of cephalometric measurements of mouth breathers of the three groups aged 6 – 7, 8 – 9 and 10 – 11 years respectively, revealing moderate (0.52, 0.44) to perfect (1.00) agreement.

DISCUSSION

The shape and appearance of the posterior wall of the nasopharynx can be assessed by clinical inspection (posterior rhinoscopy or endoscopy) or by lateral radiographs.

Table 5 Kappa (κ) value between endoscopic findings and measurements on lateral cephalograms of mouth-breathers; means are used for the three age groups. The endoscopic findings are grouped according to the amount of adenoid hypertrophy.

Measurements on lateral cephalograms		Endoscopic findings Normal adenoids to moderate hypertrophy = 1 Severe hypertrophy to obstructive adenoids = 2
$Ptm\text{-}ad_1$		
Age group 6–7 years:	More than 9.9 mm = 1 Less than 9.9 mm = 2	
Age group 8–9 years:	More than 12.4 mm = 1 Less than 12.4 mm = 2	κ = 0.52*
Age group 10–11 years:	More than 11.7 mm = 1 Less than 11.7 mm = 2	
$Ptm\text{-}ad_2$		
Age group 6–7 years:	More than 8.6 mm = 1 Less than 8.6 mm = 2	
Age group 8–9 years:	More than 8.8 mm = 1 Less than 8.8 mm = 2	κ = 1.00**
Age group 10–11 years:	More than 10.0 mm = 1 Less than 10.0 mm = 2	
$Ptm\text{-}ad_1\text{–}ad_2\text{-}Ptm$		
Age group 6–7 years:	More than 25.3 mm^2 = 1 Less than 25.3 mm^2 = 2	
Age group 8–9 years:	More than 36.9 mm^2 = 1 Less than 36.9 mm^2 = 2	κ = 0.44*
Age group 10–11 years:	More than 35.5 mm^2 = 1 Less than 35.5 mm^2 = 2	

* moderate agreement
** perfect agreement

An adequate nose-breathing capacity is important for orthodontic treatment and a stable result. When planning orthodontic therapy, the ability of the patient to breathe through the nose should be assessed. It is, therefore, of value to supplement clinical techniques for establishing the mode of breathing with a simple and objective method for estimating the size of the nasopharyngeal airway.

The various methods advanced for evaluating adenoidal size pre-operatively are controversial. Different symptoms and clinical evaluations have been both advocated and condemned. Depending on the methodology, measurement of the radiological adenoidal shadow has been difficult to correlate with the clinical patency of the nasopharyngeal airway and to the actual size of the removed adenoid (Wormald and Prescott, 1992).

A previous study has shown that the size of the adenoids, as assessed by posterior rhinoscopy, correlates strongly (r = 0.71) with assessments based on lateral radiographs, despite the circumstance that the latter picture is only two-dimensional (Linder-Aronson, 1970).

The nose-breathing sample (sample I) in this study collected from a Brazilian population revealed values of nasopharyngeal airway space very similar to the ones found for nose breathers aged 6–12 years in a Swedish study (Linder-Aronson and Henrikson, 1973). The $Ptm\text{-}ad_1$ values for the Swedish children were 17.1 mm (6–7 year-olds), 20.1 mm (8–9 year-olds), and 20.5 mm (10–11 year-olds). For the variable $Ptm\text{-}ad_2$ the values were 12.8 mm, 15.1 mm and 15.8 mm for the different age groups. It is of great interest to note that the nasopharyngeal values differed very little for the two groups with different ethnic backgrounds.

Since the nasopharyngeal space grows with the age of the child and because the lymphoid tissue on the posterior wall of the nasopharynx usually diminishes during and after puberty, it was considered necessary to investigate the size of the nasopharyngeal airway at different ages.

The three samples selected for this study are considered appropriate, as children aged 6–12 years are often subject to orthodontic treatment. Evaluation of the mode of breathing is very important if they are treated with appliances that require them to breathe through the nose, e.g. activator appliance, etc. Careful registration of the mode of breathing both clinically and by cephalometric analysis of a lateral radiograph is part of the diagnostic routine in most orthodontic cases. When evaluating the nasopharyngeal airway in mouth-breathing children, the orthodontic examination should be supplemented with an otologic examination of the nasopharyngeal airway space. Therefore, it is of great value to have cephalometric criteria of nasopharyngeal obstruction before referring a patient for otologic examination.

The results show that the distances Ptm-ad_1 and Ptm-ad_2, the area Ptm-ad_1–ad_2-Ptm, and the nasopharyngeal area as a percentage of the total nasopharynx (Ptm-ad_1-ad_2-Ptm x 100 / Ptm-So-Ba-Ptm) give a good indication of the anteroposterior size of the nasopharyngeal airway. For clinical purposes it seems that the linear measurements Ptm-ad_1 and Ptm-ad_2 provide sufficient information of the nasopharyngeal airway space. Measurements of the area Ptm-ad_1–ad_2-Ptm add no further information.

There is a very good agreement between the clinical findings by endoscopy and cephalometric analysis of the nasopharyngeal airway for the variable Ptm-ad_2. This is in accordance with the findings of Wang et al (1991) who found a highly significant correlation between the endoscopic and lateral X-ray findings. However, there is only a moderate agreement for the variables Ptm-ad_1 and Ptm-ad_1–ad_2-Ptm. Therefore, the linear cephalometric measurement Ptm-ad_2 seems to give the best information of the nasopharyngeal airway in a lateral radiograph.

It is recommended that orthodontists suggest that mouth-breathing children have an otologic examination of the nasopharyngeal airway if the cephalometric analysis of the nasopharyngeal airway shows Ptm-ad_1 distances of < 9.9 mm at the age of 6–7 years, < 12.4 mm at the age of 8–9 years, or < 11.6 mm at the ages 10–11 years.

The corresponding values for the Ptm-ad_2 distance are < 8.6 mm (6–7 years), < 8.8 mm (8–9 years), or < 10.0 mm (10–11 years).

For the area Ptm-ad_1–ad_2-Ptm the corresponding values are < 25.3 mm_ (6–7 years), < 36.9 mm2 (8–9 years), or < 35.5 mm2 (10–11 years).

CONCLUSIONS

When planning orthodontic therapy the ability of the child to breathe through the nose, and the mode of breathing should be evaluated clinically and cephalometrically by measuring Ptm-ad_2 and Ptm-ad_1 data on the anteroposterior size of the nasopharyngeal airway. An otologic examination should be initiated when these values are smaller than the age specific values found in this study.

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