

ORIGINAL ARTICLE

## The influence of nasopharyngeal patency on the morphology of nasomaxillary complex

ZBIGNIEW PALUCH<sup>1</sup>, JANUSZ WOJTYNA<sup>2</sup> & MACIEJ MISIOŁEK<sup>3</sup>

<sup>1</sup>Private Orthodontic Practice, Racibórz, Poland, <sup>2</sup>Private Dental Practice, Skoczów, Poland, and

<sup>3</sup>Department of Otolaryngology, Medical University of Silesia, Zabrze, Poland

### Abstract

**Objective.** The aim of this study was to compare the nasomaxillary complex in subjects with nasopharyngeal obstruction symptoms and the group with normal nasopharyngeal patency. **Materials and methods.** The study analyzed lateral cephalograms and dental plaster casts of 229 orthodontic subjects from the orthodontic clinic, i.e. 129 (56%) females and 100 (44%) males, age range of 6–30 years (mean age = 13.79). The analysis of radiographs and cephalometric measurements were performed using Orto-TestPor-ZPaluch software. The study population examined according to the stage of cervical vertebral maturation was divided into three sub-groups [*the CVM A group consisted of 57 (24.9%) subjects, the CVM B group consisted of 85 (37.1%) subjects and the CVM C group consisted of 87 (38%) subjects*]. **Results.** In the youngest age group with less than 50% airway patency, smaller values of SNA angle were observed together with diminished anterior palatal width compared with the non-obiterated group. The decrease in the area of the nasomaxillary complex and the decrease in posterior palatal width were observed in the oldest age group with less than 50% airway patency as compared to the subjects with normal patency. **Conclusions.** The nasomaxillary complex morphology in subjects with decreased nasopharyngeal patency predisposes to air flow impediment through nasal respiratory passage. Non-extraction treatment of the upper dental arch and possible maxillary expansion can be considered when orthodontic treatment is planned in subjects with decreased patency of < 50% and CVM A.

**Key Words:** *airway obstruction, cephalometry, maxilla*

### Introduction

A long-standing discussion over the significance of the way of breathing and upper airway obstruction in the development of the facial skeleton has not resulted in any final clear conclusion as yet [1–4]. Proper functioning of the nasopharynx is the outcome of its respiratory and immune functions. Pharyngeal tonsil hypertrophy, which blocks the airflow through posterior nares, results in nasal obstruction. Clinically, it results in the occurrence of snoring and/or sleep apnoea, recurrent sinusitis and otitis media as well as hearing deterioration. According to many authors, prolonged mouth breathing during the intensive development of the organism may result in many significant consequences which appear in a form of structural adaptations in the head and neck regions [5,6] as well as abnormal development of dental occlusion [7,8]. So far very little attention has been

paid to the influence of reduced airway patency on the metrical morphology of the nasomaxillary complex.

Both estimating the size of the pharyngeal tonsil and finding a relationship between its enlargement and clinical symptoms cause many difficulties. Throughout several decades many direct and indirect methods have been introduced (some of which were more criticized than others). All of them concerned the evaluation of the third tonsil. These included palpation, posterior rhinoscopy, fiberoptic endoscopy and imaging examination. Lateral cephalometric radiograph became the most common [9]. Over the years many measuring systems of lateral cephalometric radiographs have been recommended in terms of their usefulness for diagnosing pharyngeal tonsil hypertrophy and upper airways obstruction [10–13].

The nasomaxillary complex is a structure separated from the craniofacial complex based on the developmental characteristics, distinguishing it from the

remaining components such as the cranial vault, the base of the skull and the mandible [14]. It is the initial part of the upper airways and contains olfactory nerve endings and takes part in voice resonance and in the mastication process as the place of muscles and teeth attachment.

The aim of this study was to analyze the influence of the patency of the nasopharynx on the morphology of the nasomaxillary complex in subjects who underwent orthodontic diagnostics.

## Materials and methods

### Materials

The study material consisted of medical documentation including lateral cephalometric radiographs and plaster models of 229 subjects (i.e. 129 females and 100 males) diagnosed and treated orthodontically from 2004–2009 at the orthodontic clinic in Racibórz, Poland. The mean age was 13.79 (SD = 6.22), the age range was 6.17–30 years. The primary study inclusion criteria were the age of 6–30 years, the presence of first permanent molar teeth, a lateral cephalometric radiograph of appropriate quality, orthodontic plaster models, no history of previous orthodontic and laryngological surgical treatment (adenoidectomy, tonsillectomy) and no history of injuries to the facial skeleton.

### Methods

**Cephalometry.** All the images selected for the study were scanned at 300 DPI (i.e. dots per inch). Digital copies of the images were analyzed by the same researcher. DesignCAD software combined with the author's original (ZP) overlays package (Orto-TestPor-ZPaluch) written in Microsoft Visual C++. The package was used to analyze the radiographs. The cephalometric landmarks used in the study are presented in Table I and the measurements and the reference lines in Table II.

In the study the nasomaxillary complex is defined as the surface area of the polygon constructed by ANS, PNS, tu, Pt1, J and N landmarks. The surface area is expressed in mm<sup>2</sup>. The suggested outline of the surface area of the nasomaxillary complex based on the listed cephalometric landmarks is presented in Figure 1.

**Maturation stages.** Subjects were grouped into six cervical vertebral maturation stages. Cervical Vertebral Maturation (CVM) Method modified by Baccetti et al. [15] was used. For the purpose of this study, stage I and II subjects were classified to the younger age group (CVM A), subjects with stages III and IV to the middle age group (CVM B) and those with V and VI stages to the oldest age group (CVM C). The characteristics of sub-groups depending on Cervical Vertebral Maturation stages are presented in Table III.

Table I. Definitions of cephalometric points used in the study.

Cephalometric points used in the study	
N	Nasion, most anterior point on the frontonasal suture
S	Sella, the midpoint of the sella turcica
So	Mid-point of the Sella-Basion line
Ba	Basion, most interior point in the sagittal plane on the anterior margin of the foramen magnum
A	Deepest point on the anterior curvature of the maxillary alveolar process
ANS	Anterior nasal spine, the apex of the anterior nasal spine
PNS	Posterior nasal spine, the most posterior point on the hard palate
tu	Most posterior point of the maxillary tuberosity contour
Pt1	Most anterior contour point of the pterygopalatine fossa
J	Construction point, perpendicular projection of Pt1 point onto the N-S line
Z4	Intersection point of the nasopharyngeal adenoid tissue with the posterior pterygopalatine fossa contour
Z44	Point on the cranial base on the extension towards the PNS-Z4 line
Ad3	Intersection point of the PNS-S line and the posterior upper nasopharyngeal wall
Ad33	Point on the external cranial base contour on the PNS-S line
Ad2	Intersection point of PNS-So line and the posterior nasopharyngeal wall
Ad22	Point on the external cranial base contour on the PNS-So line
Ad1	Intersection point of the PNS-Ba line and the posterior nasopharyngeal wall
Ad11	Point on the external cranial base contour on the PNS-Ba line

**Respiratory tract patency.** Four patency indices on chosen levels of the nasopharynx were established (Figure 2). The indices are expressed as the ratio of the lumen width of the airways (PNS-ad1, PNS-ad2, PNS-ad3, PNS-Z4) to the total dimension of the nasopharynx (PNS-ad11, PNS-ad22, PNS-ad33, PNS-Z44).

It was arbitrarily established that the critical value of patency which qualified a particular subject to the group of subjects with airway obstruction was below 50%. The number of subjects in such groups is presented in Table IV.

**Orthodontic plaster cast measuring.** Using plaster cast models of maxillary dentition for each subject, the following were determined: the anterior (EF) and the posterior (GH) width of the dental arch, the anterior (AB) and the posterior (AC) length of the dental arch and the anterior (IJ) and the posterior (KL) palatal height (Figure 3). A digital caliper (Brüder Mannesmann Werkzeuge, Remscheid, Germany) and a three-

Table II. The characteristics of the measurements and reference lines used in the study.

<i>Airway measurements</i>		
1	PNS-Ad1	nasopharyngeal airway dimension on the PNS-Ba line
2	Ad1-Ad11	soft tissue thickness on the posterior nasopharyngeal wall on the PNS-Ba line
3	PNS-Ba	lower depth of the bony nasopharynx
4	PNS-Ad2	nasopharyngeal airway dimension on the PNS-So line
5	Ad2-Ad22	soft tissue thickness in the upper nasopharynx on the PNS-So line
6	PNS-So	upper depth of the bony nasopharynx
7	PNS-Ad3	nasopharyngeal airway dimension on the PNS-S line
8	Ad3-Ad33	soft tissue thickness on the nasopharyngeal roof on the PNS-S line
9	PNS-S	posterior upper facial height
10	PNS-Z4	vertical dimension of the posterior nasal choanae
11	Z4-Z44	soft tissue thickness on the nasopharyngeal roof on the PNS-Z4 line extension
12	PNS-Z44	height of the bony nasopharynx
<i>Angular measurements</i>		
13	SNA angle	angle between NSL and NA lines
14	NSL/NL angle	angle between NSL and NL lines
<i>Area measurements</i>		
15	NHTLL	surface area of nasomaxillary complex
<i>Reference lines</i>		
NSL		line between sella (S) and nasion (N) representing the anterior cranial fossa
NL		palatal plane, the line connecting the anterior nasal spine (ANS) with the posterior nasal spine (PNS)
N-A		nasion-A line

dimensional Korkhaus compass (Dentaurum, Ispringen, Germany) with an accuracy of 0.1 mm were used for the measurements.

*Measurement error.* To detect the error during digitization of cephalometric radiographs, landmarks identification and metric, angular or area measurements, the second scanning and the computerized cephalometric radiograph assessment of the 25 randomly selected subjects were done after the 2-week interval by the same specialist. The repeated analysis of the dental plaster casts was also performed. Using the *t*-test, a systemic error was calculated for each measurement. Random error was also calculated based on the Dahlberg's formula. Method error for all the analyzed parameters was within the acceptable range and it did not question the reliability of the findings.

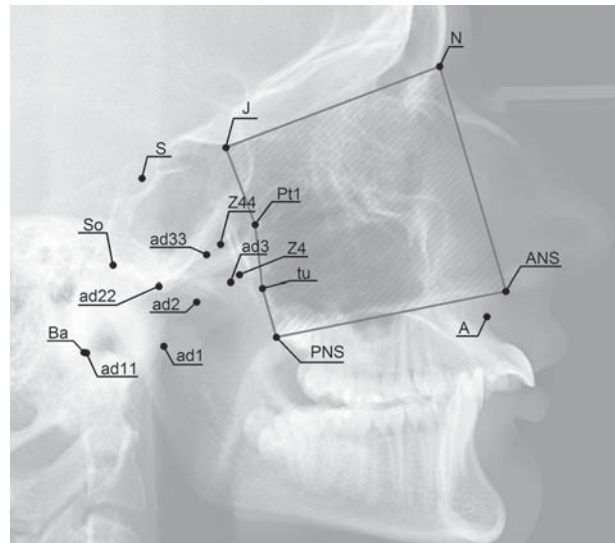


Figure 1. The surface area of the nasomaxillary complex (NHTLL) in a lateral cephalometric radiograph.

### Statistical analyses

In statistical analyses involving variables with normal distributions, parameter tests were used (e.g. for comparative purposes Student's *t*-test was used). In cases of the analysis of the differences between the mean values of variables with distributions other than normal, a non-parametric Mann-Whitney U-test was used. In the analyses the threshold of statistical significance was set at  $p < 0.05$ . Statistical Package for Social Science (SPSS) (version 17.0) and Statistica 9 were used for statistical calculations.

### Results

The results of the comparison of the groups formed depending on the degree of airways obstruction are presented in Tables V and VI. They include the stages of the cervical vertebral maturation depending on the parameters determining the nasomaxillary complex.

In cases of the measurements on the plaster models for the posterior palatal width in the oldest age group (CVM C), its significantly lower value was noted in the group in subjects with airway narrowing. The same significant decrease in the palatal width but in

Table III. The sub-group characteristics depending on cervical vertebral maturation stages.

CVM	AGE (years)			
	M	SD	Min	Max
A ( $n = 57$ ) 24.9%	8.11	1.90	6.17	12.42
B ( $n = 85$ ) 37.1%	10.99	1.65	7.17	14.83
C ( $n = 87$ ) 38%	20.26	5.10	11.67	30.00

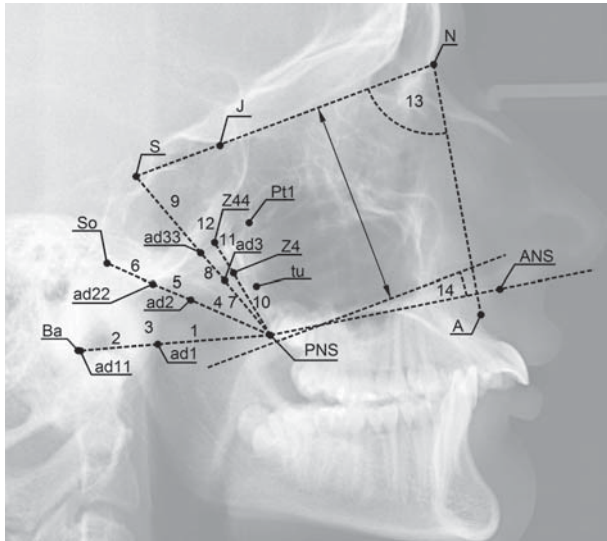


Figure 2. Measurements of the nasopharynx from Table II.

the anterior part was noted in subjects with decreased airway patency in the youngest age group (CVM A). A significantly lower value of SNA angle was observed in the same group. A similar relationship in the CVM C group concerned the whole area of the nasomaxillary complex (NHTLL) determined in this study, which was significantly smaller in subjects with the impaired nasopharyngeal patency.

**Discussion**

In the youngest age group with airway patency below 50%, lower values of SNA angle were observed compared to the non-obliterated group. Faria et al. [16] presented similar results in the study on 35 children aged 7–10 and a statistically significant decrease in the value of SNA angle was noted in mouth-breathing children as compared to nasal-breathing children.

Table IV. The number of subjects in particular groups depending on respiratory tract patency.

	Total	Female	Male
CVM A			
< 50%	33	15	18
> 50%	24	9	15
CVM B			
< 50%	43	16	27
> 50%	42	27	15
CVM C			
< 50%	25	20	5
> 50%	62	42	20

Therefore, the position of retrusive maxilla in these subjects is consistent with the observations of other researchers [17,18]. However, Harari et al. [7] found no differences in the value of the SNA angle between the mouth-breathing subjects and the control group.

According to Subtelny [17], significant obstruction of the nasopharynx can have the influence on the decrease in total dimension of the nasomaxillary complex. Such a statistically significant relationship was noted exclusively in the oldest study group, where NHTLL area was significantly smaller in subjects with decreased patency. After the analysis of this study results, it is possible to answer a question posed by Subtelny whether habitual mouth-breathing results in weakened development of the nasomaxillary complex or *vice versa*. It may be noted that the first option appears to be more correct as under-development of the nasomaxillary complex is not found in younger subjects.

No significant differences were found in the angle inclination of the palatal plane to the cranial base plane (NSL/NL) between the group with

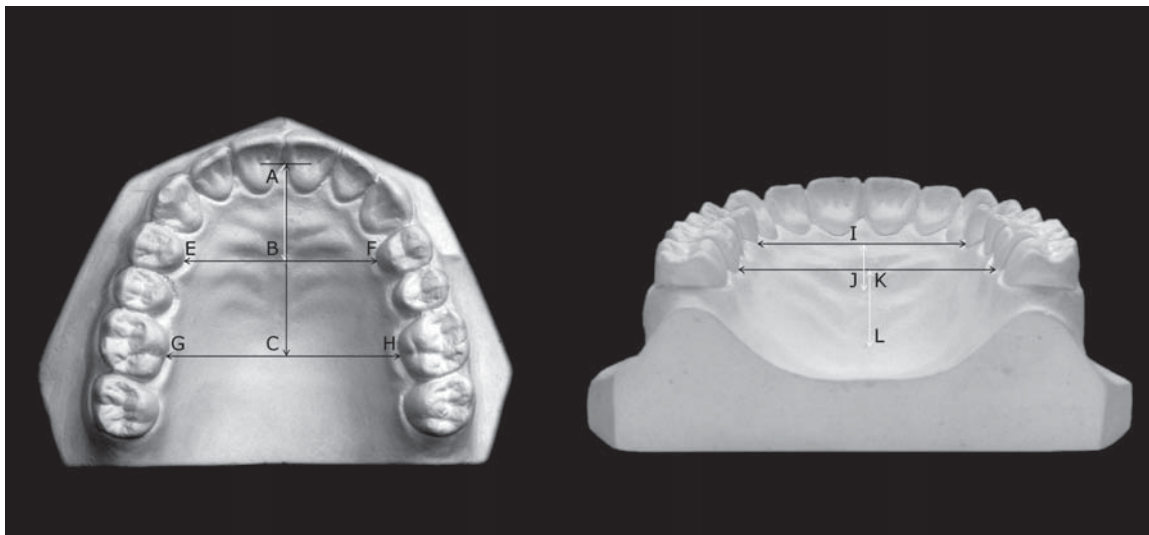


Figure 3. Measurements of the anterior (EF) and posterior (GH) width, the anterior (AB) and the posterior (AC) length of the maxillary dental arch and the anterior (IJ) and the posterior (KL) palatal height.

Table V. Comparison of groups of subjects with patency < 50% and > 50% including classification based on CVM into the age groups depending on the parameters of the nasomaxillary complex (without normal distribution).

Variable	CVM group	Patency	n	M	Mann-Whitney U-test (without normal distribution)		
					sum of ranks	U	p
posterior height	A	< 50%	33	8.276 667	890.000	329.0000	0.282 456
		> 50%	24	8.608 333	763.000		
	B	< 50%	43	9.761 628	1890.000	862.0000	
		> 50%	42	9.709 524	1765.000		
	C	< 50%	25	11.956	1088.500	763.5000	
		> 50%	62	12.069	2739.500		
posterior width	A	< 50%	33	33.309 09	920.500	359.5000	0.560 663
		> 50%	24	33.745 83	732.500		
	B	< 50%	43	33.932 56	2007.000	745.0000	
		> 50%	42	33.269 05	1648.000		
	C	< 50%	25	31.612	807.000	482.0000	
		> 50%	62	34.379	3021.000		
anterior height	A	< 50%	33	5.966,667	976.000	377.0000	0.764 933
		> 50%	24	5.820 833	677.000		
	B	< 50%	43	5.620 930	1914.500	837.5000	
		> 50%	42	5.483 333	1740.500		
	C	< 50%	25	5.912	1097.000	772.0000	
		> 50%	62	5.923	2731.000		
anterior length	A	< 50%	33	14.381 82	920.000	359.0000	0.555 232
		> 50%	24	14.587 50	733.000		
	B	< 50%	43	14.027 91	2013.000	739.0000	
		> 50%	42	13.552 38	1642.000		
	C	< 50%	25	12.940	1152.500	722.5000	
		> 50%	62	12.694	2675.500		
ANS-PNS	A	< 50%	33	41.832 12	922.000	361.0000	0.577 109
		> 50%	24	41.853 33	731.000		
	B	< 50%	43	43.443 02	1794.500	848.5000	
		> 50%	42	43.696 90	1860.500		
	C	< 50%	25	44.447	907.000	582.0000	
		> 50%	62	45.893	2921.000		
NHTLL	A	< 50%	33	1802.194	939.000	378.0000	0.777 294
		> 50%	24	1796.800	714.000		
	B	< 50%	43	1995.663	1780.000	834.0000	
		> 50%	42	2027.971	1875.000		
	C	< 50%	25	2093.944	857.000	532.0000	
		> 50%	62	2277.835	2971.000		

obstructed respiratory tract and the group with patent respiratory tract.

Freng and Kvam [19] conducted a study on adolescents with congenital choanal atresia who had not been surgically treated during their development periods. The subjects developed a shortened and retrusive maxilla due to the altered respiratory route. In the present study there was no tendency to shortening

anteroposterior dimensions of the base of the maxilla in cephalograms (ANS-PNS) or plaster casts in the group with patency <50%. However, a significant narrowing of the posterior width of the maxilla was observed in the oldest group (CVM C). Also, a narrowing of the anterior width of the maxilla was observed in the youngest group of subjects (CVM A) with airway obstruction.

Table VI. Comparison of groups of subjects with patency &lt; 50% and &gt; 50% including classification based on CVM into the age groups depending on the parameters of the nasomaxillary complex (normal distribution).

Variable	CVM group	Patency	n	M	Student's <i>t</i> -test (normal distribution)		
					<i>t</i>	df	<i>p</i>
posterior length	A	< 50%	33	29.745 45	-0.620 53	55	0.537 471
		> 50%	24	30.350 00			
	B	< 50%	43	30.500 00	1.120 92	83	0.265 555
		> 50%	42	29.876 19			
	C	< 50%	25	28.728	0.617 60	85	0.538 488
		> 50%	62	28.329			
anterior width	A	< 50%	33	26.793 94	-2.233 13	55	0.029 629
		> 50%	24	28.166 67			
	B	< 50%	43	26.888 37	1.201 44	83	0.232 996
		> 50%	42	26.157 14			
	C	< 50%	25	25.076	-1.554 23	85	0.123 845
		> 50%	62	26.139			
SNA	A	< 50%	33	79.963 94	-2.384 80	55	0.020 563
		> 50%	24	81.948 33			
	B	< 50%	43	80.436 05	-1.585 38	83	0.116 682
		> 50%	42	81.483 57			
	C	< 50%	25	80.872	-0.031 59	85	0.974 872
		> 50%	62	80.904			
NSL-NL	A	< 50%	33	7.0030 3	1.224 57	55	0.225 956
		> 50%	24	5.9416 7			
	B	< 50%	43	7.1120 9	0.644 62	83	0.520 948
		> 50%	42	6.6769 0			
	C	< 50%	25	6.023	-1.661 49	85	0.100 300
		> 50%	62	7.523			

Harari et al. [7] noted a significant constriction of the upper dental arch on the level of molars and canines in mouth-breathing subjects compared to the control group. The mean age of their subjects was  $12.49 \pm 1.94$  years.

A lateral cephalometric radiograph does not fully reflect nasopharyngeal morphology as it merely shows nasopharyngeal state in the sagittal section during examination. Further studies need to include prospective evaluation assessing the formation of the complex depending on the degree of the nasopharyngeal obstruction in the same subjects over the period of many years. It would be important to determine duration of obstruction considering its influence on the formation of the nasomaxillary complex.

## Conclusions

Morphology of the nasomaxillary complex in subjects with decreased nasopharyngeal patency shows pre-disposing features to air flow impediments by the nasal respiratory route. Non-extraction treatment in the upper dental arch with possible maxillary

expansion can be considered when orthodontic treatment is planned in subjects with decreased patency below 50% and CVM A.

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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