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Vertical and sagittal morphology of the facial skeleton and the pharyngeal airway

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SUMMARY

Aim. The aim of this study was to evaluate the relationship between sagittal and vertical facial skeletal morphology, and the morphology of the upper and lower pharyngeal airway.

Material and methods. Pharyngeal airway structures were studied in 101 healthy children (36 boys and 65 girls) aged 7-17 years who were referred for orthodontic treatment. The sample was divided into two groups: according size of the ANB angle group Class I: angle till 4º was considered as skeletal Angle Class I; group Class II: ANB angle more than 4º, considered as skeletal Angle Class II. The vertical pattern was classified using the SN-MP angle, with angle less than 34 taken as normal, and more than 34 – as high vertical growth patterns. The linear measurements and angles were calculated using special purpose software (Dolphin v. 11.0). Pharyngeal width was measured at different point levels using Arnett/Gunson airway analysis.

Results. A statistically significant difference between the two groups, and airway width on all levels was statistically significantly narrower in Angle Class II. Pearson's correlation coefficient showed a negative statistically significant dependence between nasopharyngeal airway, oropharyngeal airway space, and SN-MP angle.

Conclusion. Statistically significantly narrower airways were found in patients with ANB more than 4°. In groups divided by SN-MP angle statistically significant difference have not found. Nasopharyngeal airway and oropharyngeal airway spaces statistically significantly negatively correlated with the SN-MP angle: the bigger the SN-MP angle, the smaller were nasopharyngeal and oropharyngeal airway spaces.

Key words: class II malocclusion, cephalometry, upper airway dimensions, airway width.

INTRODUCTION

Normal airway growth is one of the important factors that can affect normal growth of the craniofacial structures. The effects of respiratory function on craniofacial growth have been studied for decades, and the results of the studies are controversial: some studies reported a significant relationship between pharyngeal and craniofacial structures (1, 2), while other scientist did not find any correlation. The pharyngeal airway is composed of three parts: the nasopharynx, oropharynx, and hypopharynx (3). Pharyngeal space size is determined primarily by the relative growth and size of the soft tissues surrounding the dentofacial skeleton (4). The normal upper airway space is 15-20 mm, while the lower airway space is 11-14 mm (1). There is a significant relationship between pharyngeal dimensions and craniofacial abnormalities (5). In their study, Memon *et al.* found that skeletal features such as retrusion of the maxilla and mandible and vertical maxillary excess in hyperdivergent patients may lead to narrower anteroposterior dimensions of the airway (6). Alves *et al.* in their study stated that class II patients have a narrower anteroposterior pharyngeal dimension, and this narrowing is specifically noted in the nasopharyngeal area at the level of the hard palate, and in the oropharynx at the level of the tip of the soft palate and the mandible (7). Other scientists came to the conclusion that Class II division 1 malocclusion is associated with a narrower upper airway structure without retrognathia (8). Controversial results were reported in the study performed by Ceylan et al, by de Freitas *et al.* and by Chauhan *et al.* stating that the

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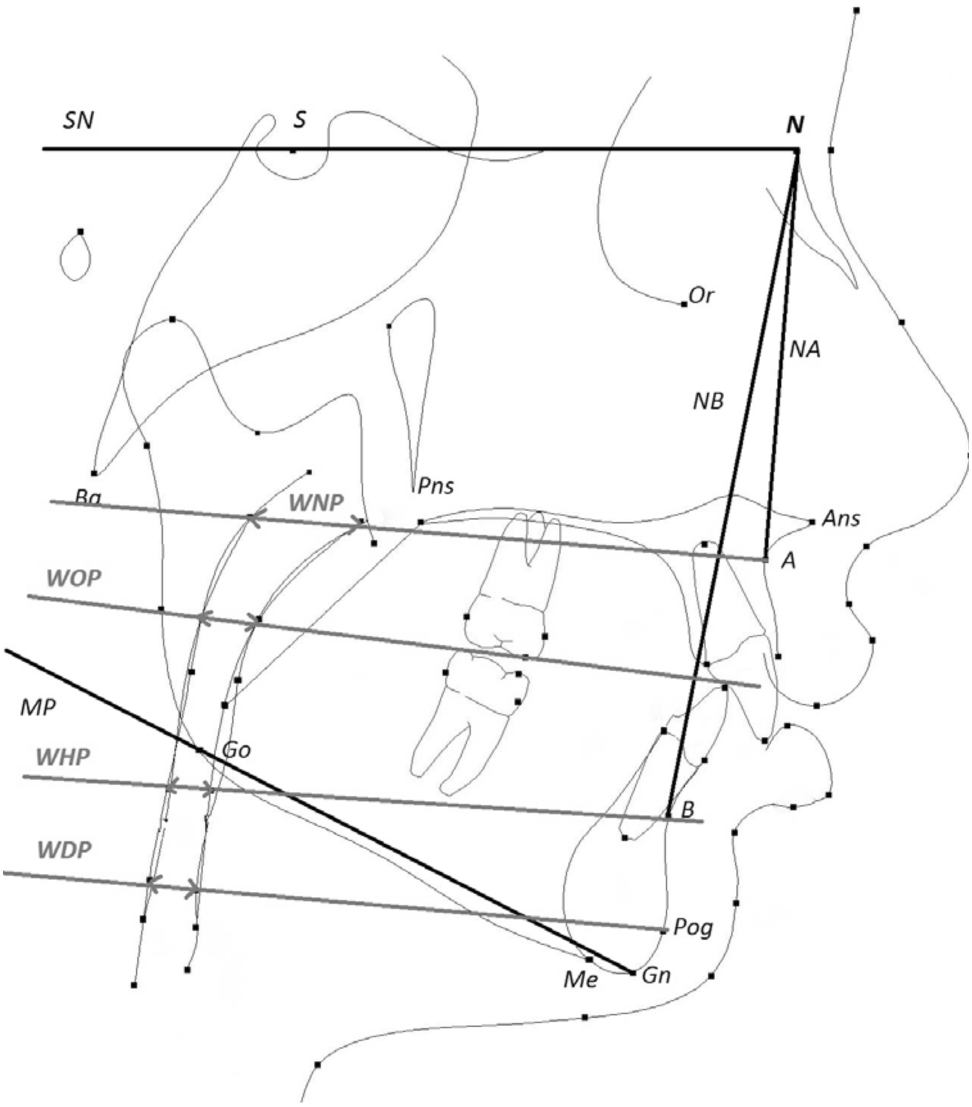

Fig. Reference points and lines used for this study

pharyngeal structures were not affected by changes of the ANB angle (9-11). The knowledge of the pharyngeal dimensions of various sagittal and vertical facial types is very important and can help an orthodontist in various ways – especially during orthodontic diagnosis and treatment planning (6, 12). The aim of the study was to evaluate the relationship between sagittal and vertical facial skeletal morphology and the upper and lower pharyngeal airway morphology.

MATERIALS AND METHODS

The study was carried out at the Department of Orthodontics, Academy of Medicine of the Lithuanian University of Health Sciences, Kaunas, Lithuania. Sample was obtained from consecutive patients attending for orthodontic treatment at the Department of Orthodontics who agreed to participate in the study. A full explanation of the study aims and procedures was provided to the par-

Table 1. Relationship between the size of ANB angle and the width of the pharyngeal airway

Cephalometric variables	Class I (ANB 1.5°-4°) (n=52)	Class II(ANB>4°) (n=49)	p
SNA°	81.19±5.20	83.22±4.28	0.044*
SNB°	78.97±3.48	77.27±4.09	0.040*
ANB°	2.80±0.75	5.94±1.15	0.000*
SN-MP°	33.38±6.44	33.79±6.54	0.781
Width of nasopharynx (mm)	16.05±3.97	14.64±3.65	0.035*
Width of oropharynx (mm)	10.51±2.47	8.88±2.59	0.002*
Width of hypopharynx (mm)	9.87±2.66	8.28±2.90	0.002*
Width of deep pharynx (mm)	10.26±2.84	8.50±3.00	0.001*

Table 2. Relationship between the size of SN-MP angle and the width of pharyngeal airway

Cephalometric variables	SN-MP<34° (n=54)	SN-MP≥34°) (n=47)	p
SNA°	83.70 ± 5.52	80.43 ± 3.23	0.000*
SNB°	79.86 ± 3.32	76.17 ± 3.50	0.000*
ANB°	4.38 ± 1.92	4.25 ± 1.77	0.775
SN-MP°	28.74 ± 4.01	39.14 ± 3.62	0.000*
Width of nasopharynx (mm)	15.56 ± 3.84	15.14 ± 3.91	0.083
Width of oropharynx (mm)	10.01 ± 2.52	9.38 ± 2.78	0.475
Width of hypopharynx (mm)	9.53 ± 2.90	8.60 ± 2.68	0.103
Width of deep pharynx (mm)	9.94 ± 3.26	8.79 ± 2.65	0.091

ents of each patient and signed consent forms were obtained. The study was approved by the Regional Biomedical Research Ethics Committee (no. BE-2-48). The study group consisted of 101 patients aged from 7 to 17 year. There were 36 males (34.65%) and 65 females (64.35%). Exclusion criteria were: history of facial trauma; previous orthodontic treatment; presence of facial syndromes; missing or poor quality records; Angle Class III patients (ANB<0). Lateral cephalometric radiographs were analyzed using Dolphin software (version 11.0). Parameters used for this study are shown in Figure. The sagittal position of the maxilla (SNA) and mandible (SNB), sagittal jaw relationship (ANB), and the mandible plane angle (SN-MP) were used for the analyses of the facial skull. The upper airway was evaluated when measuring pharyngeal width at different levels using Arnett/Gunson FAB airway analysis (13). The width (mm) of the nasopharyngeal airway (WNP) was measured by drawing a line perpendicular to the true vertical line that passed through point A, and then the distance between the crossing points of the same line with the anterior and the posterior walls of the airway was measured. The width of the oroharyngeal airway (WOP) was measured in a similar way – a line perpendicular to the true vertical line was passed through the occlusal line. The width of the hypopharyngeal airway (WHP) was measured at B point level, and landmarks were put on the front and the back walls of the pharynx. The width of the deep pharyngeal airway (WDP) was measured at the landmark Pog level, between the front and the back walls of the pharynx. In the lateral cephalometric analysis, the error margin was determined by repeating the measurements of the six variables on randomly selected 10 radiographs at 2-week intervals with the same operator; no significant mean differences were found. When evaluating the relationship between sagittal skeletal facial morphology and pharyngeal airway, the sample was divided into two groups, according to the ANB angle:

- group Class I: ANB angle between 1.5° and 4°, considered as Class I. This group consisted of 52 subjects, (mean ANB 2.80°±0.75°), 16 males and 36 females.
- group Class II: ANB angle larger than 4°, considered as Class II. This group consisted of 49 subjects (mean ANB 5.93°±1.15°), 20 males and 29 females.

When evaluating the relationship between vertical skeletal facial morphology and pharyngeal airway, the sample was divided into two groups, according to the SN-MP angle:

- group SN-MP normal: SN-MP angle smaller than 34°, considered as a normal vertical pattern. This group consisted of 54 subjects (mean SN-MP 28.74°±4.01°), 18 males and 36 females.
- group SN-MP increased: SN-MP angle 34° and larger, considered as a high vertical pattern. This group consisted of 47 subjects (mean SN-MP 39.14°±3.62°), 18 males and 29 females.

Statistical analysis was performed by using Statistical Package for Social Sciences 19.0.0 for Windows (SPSS) with unpaired two-sample t-test and Pearson correlation. The corresponding values of the adjusted R Square were reported. T-test and χ^2 test were applied to evaluate the association between ANB, SN-MP angle, and pharyngeal airway width. The difference was considered as statistically significant when $p<0.05$.

RESULTS

The study sample consisted of 101 patients. The relationship between sagittal skeletal morphology of the facial skeleton and the width of the upper and lower airway was evaluated. The evaluation showed a significant correlation between an increase in the size of ANB angle and a decrease in the width of the upper and lower pharynx (Table 1). The differences between group Class I and group Class II were tested by using an independent t-test. Kolmogorov–Smirnov's test confirmed a normal sample distribution, and $p<0.05$ was considered as statistically significant. Pearson's correlation coefficient was used in order to find any relationship between the measurements of ANB angle and airway width. The results of the study showed a negative correlation between the ANB angle and airway width ($p<0.05$): ρ=-0.216 nasopharyngeal width, ρ=-0.314, ρ=-0.276 oropharyngeal airway width. When the ANB angle was increasing, airway dimensions were decreasing. The evaluation of the relationship between vertical morphology of the facial skeleton and the width of the upper and lower airway is presented in Table 2. No statistically significant relationship was found between vertical morphology of the facial skeleton and the width of the upper and lower airway – even though the width of the airways was decreased, but this difference was not statistically reliable. Differences between group SN-MP normal and group SN-MP increased were tested by using an independent t-test. Pearson's correlation coefficient test was used to find any relationship between the measurements of the SN-MP angle and airway width. Although no statistically significant relationship was found between mean values of airway width, Pearson correlation coefficient showed a negative, weak, statistically significant dependence between the width of nasopharyngeal airway and oropharyngeal airway, and the SN-MP angle, i.e. it showed that when angle SN-MP was increasing, the nasopharyngeal and oropharyngeal airway width was decreasing. SN-MP with nasopharyngeal airway width $\rho=-0.204$, and SN-MP angle with oropharyngeal airway width $\rho=-0.201$, $p<0.05$

DISCUSSION

Abnormal development of the upper airway is related to airway constriction, and the relevance of the relationship between reduced respiratory function and craniofacial growth has long been of interest to orthodontist (3). Our study was based on the premise that sagittal and vertical facial skeletal morphology and the upper and lower pharyngeal airway morphology are inter-dependant. Our study group consisted of 7-17 year-old patients. In the previous studies it was found, that the pharyngeal structures continue to grow rapidly until 13 years of age, while between 14 and 18 years, a quiescent period follows. Long-term follow-up studies have established that between 20 and 50 years of age, the soft palate becomes longer and thicker, and the pharyngeal region gets narrower. According to these data, the most stable time period to evaluate the mature oropharyngeal region seems to be between 14 and 18 years of age (14). In our study, growing and stable subjects were evaluated, and no significant correlation between the subjects' age, sex, and pharyngeal airway morphology was found. According to the results found by Oh *et al.* in their study, no significant differences between sex, age, and pharyngeal airway were detected (3) – a finding similar to that found in our study. Meanwhile, in a study by Daniel *et al.*, and study by Chaturvedi *et al.* differences between sexes and pharyngeal airway dimensions were found (15, 16). An airflow test, nasoendoscope examination, nasal resistance measurements, lateral cephalometric examination, three-dimensional cone beam computed tomography, and magnetic resonance scans can be used for the evaluation of pharyngeal airway dimensions and capacity. Cephalometric analysis of airways permits precise measurements in a sagittal plane at anatomically well-defined homologous locations (17, 18). Traditionally, the pharyngeal airway space has been evaluated using cephalometric radiographs, but this method results in superimposition of all bilateral structures of the craniofacial complex, and only provides a two-dimensional (2D) antero-posterior linear dimension (19-21). This technique reveals a variety of soft and hard tissue abnormalities that may indicate patients with narrow and collapsible upper airways (22). The present study was performed using two-dimensional cephalometric films to evaluate pharyngeal airway and craniofacial morphology. The evaluation of the relationship between sagittal craniofacial morphology and pharyngeal airway morphology showed a statistically significant correlation between an increase in the ANB angle and a decrease in the width of the pharyngeal airway. In the studies performed by Alves *et al.* and Muto *et al.*, seven linear measurements were used to evaluate the airway space, and only the pharyngeal airway space between the uvula and the posterior pharyngeal wall showed statistically significant differences between Class I and II (7, 19). Kim *et al.* stated that retrognathic patients tended to have a smaller airway volume compared with patients with a normal anteroposterior skeletal relationship (23). In our study, we found that more retruded mandibular position negatively influenced airway space. However, in some studies relationship between decrese of the width of upper airway and retrognatic position of the mandible was not detected (27), these results can be explained due to the large inter-individual variation (28).

Literature indicates a relationship between high vertical facial pattern and a narrow pharyngeal airway. In our study negative correlation between an increased SN-MP angle and narrowed nasopharyngeal and oropharyngeal airway width was found. Studies performed by Alves *et al.* (7) and by Ansar *et al.* (24) and by Wang *et al.*, who also used 3D measurements (25) also stated that there is correlation between airway width and vertical skeletal angle. However in Memon *et al.* study no association between the lower pharyngeal airway and different vertical growth patterns was detected (6). In some studies it was found that high-angle Class II patients had significantly narrower upper airway than low-angle or neutral-angle Class II patients (26), and it was stated that vertical growth pattern has an effect on pharyngeal airway space (1).

A narrow pharyngeal airway space is one of the predisposing factors for mouth breathing and obstructive sleep apnea (1). The growth and function of the nasal cavities, the nasopharynx, and the oropharynx are associated with the growth of the skull and the dentofacial complex. When diagnosing and treating pre-adolescent children with malocclusion, an orthodontist should recognize pharyngeal airway morphologies that might be predisposing factors for undesirable craniofacial development in order to provide good and stable treatment results.

CONCLUSION

The evaluation of the relationship between the sagittal morphology of the facial skeleton and the width of the upper and lower airway revealed a significant correlation between an increase in the size of the ANB angle (more than 4°) and a decrease in the width of the upper and lower pharynx. When evaluating the relationship between the vertical morphology of the facial skeleton and the width of the upper and lower airway, no significant correlation was found. Nasopharyngeal airway and oropharyngeal airways had a statistically significant negative correlation with the size of the SN-MP angle: an increase in the SN-MP angle influenced a decrease in the nasopharyngeal and oropharyngeal airway width.

STATEMENT OF CONFLICT OF INTEREST

The authors state no conflict of interest.

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