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Original Research Article

Relationship between malocclusion, soft tissue profile, and pharyngeal airways: A cephalometric study

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ABSTRACT

Background and objective: The recent years have been marked by a search for new interrelations between the respiratory function and the risk of the development of malocclusions, and algorithms of early diagnostics and treatment have been developed. The aim of the study was to evaluate the relationships between hard and soft tissues and upper airway morphology in patients with normal sagittal occlusion and Angle Class II malocclusion according to gender.

Materials and methods: After the evaluation of clinical and radiological data, 114 pre-orthodontic patients with normal or increased ANB angle, were randomly selected for the study. The cephalometric analysis was done by using the Dolphin Imaging 11.8 computer software.

Results: Comparison of the cephalometric values of soft tissue and airway measurements performed statistically significant negative correlation between the width of the upper pharynx and the ANB angle was found: the ANB angle was decreasing with an increasing width of the upper pharynx. The airways showed a statistically significant negative correlation between the width of the lower pharynx and the distance from the upper and the lower lips to the E line. Logistic regression analysis was performed to evaluate significant factors that could predict airway constriction. The upper pharynx was influenced by the following risk factors: a decrease in the SNB angle, an increase in the nose tip angle, and younger age; while the lower pharynx was influenced by an increase in the distance between the upper lip and the E line and by an increase in the upper lip thickness.

Conclusions: During critical period of growth and development of the maxillofacial system, the patients with oral functional disturbances should be monitored and treated by a multidisciplinary team consisting of a dentist, an orthodontist, a pediatrician, an ENT

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specialist, and an allergologist. Cephalometric analysis applied in our study showed that Angle Class II patients with significantly decreased facial convexity angle, increased nasomental, upper lip-chin, and lower lip-chin angles, and upper and lower lips located more proximally to the E line more frequently had constricted airways.

1. Introduction

The functions of the maxillofacial system affect the growth of the face and jaws as well as tooth eruption [1]. Prolonged mouth breathing is associated with impaired speech, maxillofacial deformities, tooth malposition, abnormal posture, and even cardiovascular, respiratory, or endocrine dysfunctions [2,3]. The discussion on the relationship between maxillofacial morphology and upper airway size and resistance has been continuing over a century. Narrowing of the pharyngeal airway passage caused by various etiological factors – especially in the nasopharyngeal area – results in mouth breathing [2,4]. According to various authors, the main features of upper airway obstruction include: increased excessive anterior face height, narrowed upper dental arch, high palatal vault, steep mandibular plane angle, protruding maxillary teeth, and incompetent lip postures [2,5–7]. Basheer et al. found that the facial profile of patients who had mouth-breathing pattern was more convex than in those who were breathing through the nose [2]. Other authors determined a relationship between the size of the upper airways and the severity of malocclusion [6]. Obstruction of the upper airways is associated with Angle Class II malocclusion and vertical facial growth impairment [6,8]. Some studies have shown that in patients with Angle Class II malocclusion, the width of the upper pharynx is smaller than in those with Angle Class I or III malocclusion. However, other researchers provided contradicting conclusions and did not find any association between the width of the upper or lower pharynx and malocclusion [6,9,10]; some authors associate this with genetic and environmental factors [11].

The importance of lateral cephalometric radiographs in the evaluation of the morphology of soft and skeletal maxillofacial tissues and the diagnostics of airway pathology is unquestionable [1,12–14]. This cephalometric analysis is a simple, cheap, and sufficiently informative diagnostic technique, and the generated 2D images along with evaluation results are sufficiently reliable and may be an alternative to 3D imaging in the evaluation of soft tissue and upper airway morphology [1,15].

The recent years have been marked by a search for new interrelations between the respiratory function and the risk of the development of malocclusions, and algorithms of early diagnostics and treatment have been developed.

The aim of the study was to evaluate the relationships between hard and soft tissues and upper airway morphology in patients with normal sagittal occlusion and Angle Class II malocclusion according to gender.

2. Materials and methods

After the evaluation of clinical and radiological data, 114 pre-orthodontic patients (aged 14–16 years) were randomly recruited for the study from the Clinical Department of Orthodontics, Lithuanian University of Health Sciences. The study was conducted with the permission of the Kaunas Regional Biomedical Research Ethics Committee (February 9, 2015, No. BE-2-12). The inclusion criteria were the following: patients' age, sagittal jaw relationship angle ANB $> 1^\circ$, and no previous maxillofacial trauma or surgery, syndromes, clefts, or orthodontic treatment.

The study included 114 patients: there were 71 girls (62.3%), and 43 boys (37.7%). The subjects' mean age was 14.42 ± 0.58 years. The study sample was divided into two groups according to the ANB angle: the first group consisted of subjects with normal skeletal sagittal jaw relationship (ANB $2^\circ \pm 1^\circ$, Class I), and the second group consisted of patients with sagittal skeletal malocclusion, (ANB $> 4^\circ$, Class II). Group 1 consisted of 57 subjects, namely 37 girls (64.9%) and 20 boys (35.1%); group 2, 57 patients, namely 34 girls (59.6%), and 23 boys (40.4%).

Lateral cephalometric radiography was performed in fixed head position. To minimize radiation doze digital panoramic systems were used and ALARA radiation safety principle was followed. The analysis was done by using the Dolphin Imaging 11.8 (Dolphin Imaging and Management Solution) computer software. Soft tissue analysis was performed manually, using the "Annotations and measurements" function of the Dolphin Imaging software. Cephalometric parameters used for this study are shown in Fig. 1.

For the lateral cephalometric analysis, the error margin was determined by repeating the measurements of the variables on randomly selected 20 radiographic images at 2-week intervals with the same operator; the paired sample *t* test showed no significant mean differences in the two data sets.

2.1. Statistical analysis

Statistical data analysis was performed using the SPSS (IBM SPSS Statistics 22.0) software. Spearman correlation was applied in order to evaluate the strength of the relationship between two quantitative variables that did not meet the conditions of normal distribution. The mean values of quantitative attributes meeting the conditions of normal distribution in two independent sample groups were compared by applying the parametric Student *t* criterion, while the comparison of the medians was performed by applying the

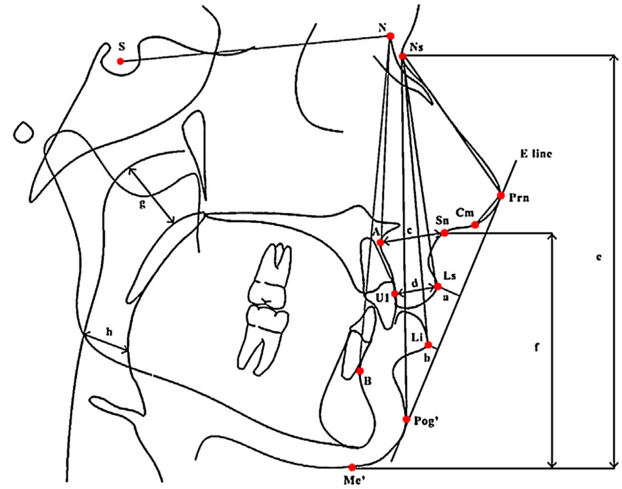

Fig. 1 – Cephalometric landmarks and measurements. *Landmarks:* **(A) the deepest point on the curve of the bone between the anterior nasal spine and dental alveolus; (B) the deepest midline point on the mandible between the infradentale and the pogonion; N (Nasion), the most anterior point of the frontonasal suture in the middle; S (Sella), the center of the sella turcica; U1, the most labial point on the crown of the maxillary central incisor; Cm (Columella), the most anterior point on the columella of the nose; Ns, soft tissue Nasion; Prn (Pronasale), the most protruded point of the nasal apex; Sn (Subnasale), midpoint of the columella base at the apex of the nasolabial angle; Ls (Labiale superius), midpoint of the upper vermilion line; Li (Labiale inferius), midpoint of the lower vermilion line; Pog', soft tissue Pogonion; Me', soft tissue Menton.** Measurements: **SNA, sagittal position of the maxilla; SNB, sagittal position of the mandible; ANB, sagittal jaw relationship; Cm-Prn-Ns, nose tip angle; Ns-Prn-Pog', facial convexity; Prn-Ns-Pog', nasomental angle; Pog'-Ns-Ls, upper lip-chin angle; Pog'-Ns-Li, lower lip-chin angle; Ls-E (a), distance from upper lip (Ls) to the E line (the line formed by connecting the Prn and Pog' points); Li-E (b), distance from the lower lip (Li) to the E line; A-Sn (c), upper lip thickness at point A; U1-Ls (d), upper lip thickness at the maxillary central incisor; TFH (e), facial height; LFH (f), lower facial height; UPW (g), width of the upper pharynx, measured as the distance from the point of the posterior outline of the soft palate to the closest point on the posterior pharyngeal wall; LPW (h), width of the lower pharynx, measured as the distance from the intersection of the posterior border of the tongue and the inferior border of the mandible to the closest point on the posterior pharyngeal wall.**

nonparametric Mann–Whitney *U* test. Correlation analysis of SNA, SNB, and ANB angles as well as the parameters of soft tissues and the airways was performed. The most specific predictors of the decrease in the upper and lower pharyngeal width were assessed using the logistic regression analysis. Differences and interdependence between the attributes were considered to be statistically significant if $P < 0.05$.

3. Results

A comparison of the cephalometric values of soft tissue and airway measurements between Class I and II subjects was performed. It showed that patients with Class II anomalies had a statistically significantly ($P < 0.01$) the upper and the lower lips closer to the E line and a smaller facial convexity angle ($P < 0.001$). They also demonstrated increased nasomental ($P < 0.001$), upper lip-chin ($P < 0.001$), and lower lip-chin ($P < 0.001$) angles, compared to Class I subjects. The upper and lower pharyngeal airways were significantly wider ($P < 0.05$) in Class I than in Class II patients (Table 1). No difference in facial height or the thickness of the upper lip between Class I and II subjects was found.

We evaluated the influence of sex on the soft tissues and the pharyngeal airways. In Class I subjects, differences of soft tissues between males and females were found: girls had a statistically significantly smaller upper lip-chin angle, lower lip-chin angle, the thickness of the upper lip, and lower facial height, compared to boys (Table 2). The comparison of boys to girls in the Class II group showed that in girls, the upper lip was statistically significantly more distal to the E line; they also had smaller facial convexity angles, smaller upper lip-chin angles, and smaller thickness of the upper lip, compared to boys (Table 3).

The differences in the morphology of the soft tissues and the airways between boys and girls in Class I and II groups were evaluated. The comparison of mean values by applying the parametric Student *t* test showed that girls in the Class II group had statistically significantly smaller facial convexity angles ($P < 0.001$), smaller distances from the lower lip to the E line ($P < 0.05$), and increased nasomental ($P < 0.001$), upper lip-chin ($P < 0.001$), and lower lip-chin ($P < 0.001$) angles, compared to girls in the Class I group. The analysis applying the non-parametric Mann–Whitney *U* test showed that girls with Class II anomalies had smaller distances from the upper lip to the E line ($P < 0.05$), compared to girls in the Class I group. Upper pharyngeal width was significantly smaller in Class II girls than in the Class I group ($P < 0.05$). When analyzing boys, the Student *t* test showed that boys with Class II malocclusion had statistically significantly smaller distances from the lower lip to the E line ($P < 0.05$), smaller thickness of the upper lip ($P < 0.05$), and increased upper lip-chin angles ($P < 0.05$), compared to those in the Class I group. No statistically significant differences in other cephalometric measurements were detected between boys of Class I and II groups.

We performed correlation analysis in order to evaluate the relationship of the sagittal position of the maxilla (SNA), the sagittal position of the mandible (SNB), and the sagittal jaw relationship (ANB) with the width of the airways. A statistically significant positive correlation was found between the width of the upper pharynx and the position of the jaws: with an increasing width of the upper pharynx, the SNA ($r_s = 0.238$, $P < 0.01$) and SNB ($r_s = 0.301$, $P < 0.001$) angles were increasing as well. It was found a negative correlation between the width of the upper pharynx and the ANB angle ($r_s = -0.186$, $P < 0.05$): the ANB angle was decreasing with an increasing width of the upper pharynx (Fig. 2). A statistically significant negative correlation between the width of the lower pharynx and the

Table 1 – Soft tissue and upper airway measurements in Class I and II subjects.

Soft tissue and upper airway measurements	Class I	Class II	P
Upper lip to E line (Ls-E), mm	−5.20 ± 0.51	−3.54 ± 0.50	0.002
Lower lip to E line (Li-E), mm	−3.33 ± 0.43	−1.43 ± 0.43	0.003
Facial convexity (Ns-Prn-Pog'),°	127.41 ± 0.49	124.30 ± 0.42	0.001
Nose tip angle (Cm-Prn-Ns),°	108.55 ± 0.66	107.38 ± 0.68	NS
Nasomental angle (Prn-Ns-Pog'),°	30.77 ± 0.35	32.88 ± 0.36	0.001
Upper lip-chin angle (Pog'-Ns-Ls),°	7.13 ± 0.31	9.06 ± 0.33	0.001
Lower lip-chin angle (Pog'-Ns-Li),°	3.49 ± 0.23	4.71 ± 0.26	0.001
Upper lip thickness at point A (A-Sn), mm	16.16 ± 0.23	15.89 ± 0.23	NS
Upper lip thickness at upper incisor (U1-Ls), mm	12.01 ± 0.23	11.58 ± 0.23	NS
Facial height (TFH), mm	113.15 ± 0.96	113.09 ± 0.82	NS
Lower facial height (LFH), mm	65.59 ± 0.72	66.45 ± 0.94	NS
Upper pharyngeal width, mm	13.02 ± 0.48	11.68 ± 0.53	0.03
Lower pharyngeal width, mm	10.53 ± 0.34	9.37 ± 0.38	0.01

NS, not significant.

Table 2 – Soft tissue and upper airway measurements in Class I, according to gender.

Soft tissue and upper airway measurements	Gender		P
	Male	Female	
Upper lip to E line (Ls-E), mm	−4.87 ± 4.98	−5.13 ± 2.87	NS
Lower lip to E line (Li-E), mm	−3.14 ± 4.06	−3.04 ± 2.83	NS
Facial convexity (Ns-Prn-Pog'),°	126.68 ± 4.88	127.33 ± 2.65	NS
Nose tip angle (Cm-Prn-Ns),°	107.85 ± 5.65	108.65 ± 4.79	NS
Nasomental angle (Prn-Ns-Pog'),°	31.53 ± 3.56	30.65 ± 1.97	NS
Upper lip-chin angle (Pog'-Ns-Ls),°	8.37 ± 2.66	6.60 ± 2.02	0.001
Lower lip-chin angle (Pog'-Ns-Li),°	4.23 ± 1.84	3.17 ± 1.58	0.005
Upper lip thickness at point A (A-Sn), mm	17.14 ± 1.68	15.54 ± 1.61	0.0001
Upper lip thickness at upper incisor (U1-Ls), mm	12.75 ± 1.68	11.42 ± 1.68	0.001
Facial height (TFH), mm	117.80 ± 6.30	110.05 ± 5.63	NS
Lower facial height (LFH), mm	68.74 ± 5.06	64.38 ± 7.23	0.005
Upper pharyngeal width, mm	11.89 ± 3.02	13.06 ± 3.93	NS
Lower pharyngeal width, mm	9.83 ± 2.91	9.20 ± 2.37	NS

NS, not significant.

Table 3 – Soft tissue and upper airway measurements in Class II, according to gender.

Soft tissue and upper airway measurements	Gender		P
	Male	Female	
Upper lip to E line (Ls-E), mm	−2.27 ± 3.59	−4.16 ± 4.27	0.05
Lower lip to E line (Li-E), mm	−0.62 ± 3.48	−1.80 ± 2.86	NS
Facial convexity (Ns-Prn-Pog'),°	124.79 ± 2.97	123.04 ± 3.03	0.03
Nose tip angle (Cm-Prn-Ns),°	107.77 ± 4.54	106.90 ± 5.69	NS
Nasomental angle (Prn-Ns-Pog'),°	33.05 ± 2.46	33.37 ± 3.05	NS
Upper lip-chin angle (Pog'-Ns-Ls),°	10.19 ± 2.41	9.02 ± 2.15	0.05
Lower lip-chin angle (Pog'-Ns-Li),°	5.37 ± 2.09	4.71 ± 1.74	NS
Upper lip thickness at point A (A-Sn), mm	16.57 ± 1.57	15.44 ± 1.88	0.01
Upper lip thickness at upper incisor (U1-Ls), mm	11.62 ± 1.78	11.74 ± 1.81	NS
Facial height (TFH), mm	115.16 ± 6.57	112.92 ± 6.34	NS
Lower facial height (LFH), mm	67.78 ± 5.67	65.13 ± 4.84	NS
Upper pharyngeal width, mm	11.45 ± 4.42	12.14 ± 4.06	NS
Lower pharyngeal width, mm	9.09 ± 2.80	10.08 ± 3.25	NS

NS, not significant.

distance from the upper ($r_s = -0.204$; $P < 0.05$) and the lower ($r_s = -0.243$, $P < 0.005$) lips to the E line ($r_s = -0.203$, $P < 0.05$) (Fig. 3) was found. The distance from the upper and the lower lips to the E line was increasing with a decreasing width of the lower pharynx.

Logistic regression analysis was performed to evaluate significant factors that could predict airway constriction. The most significant risk factors affecting the reduction in the width of the upper and the lower pharynx in all subjects and separately in males and females are presented in Table 4. The

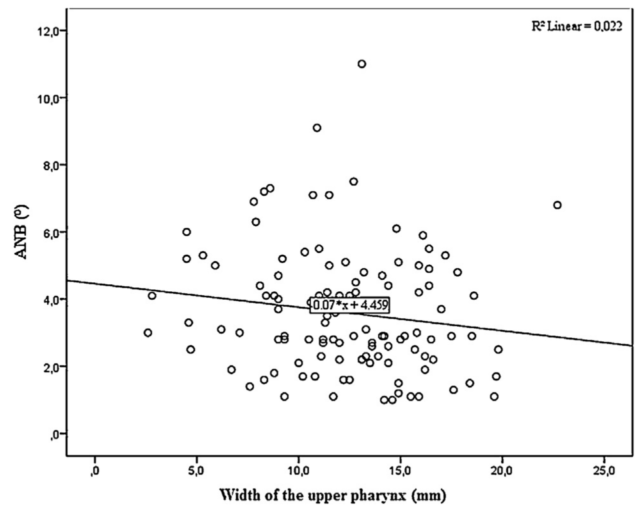

Fig. 2 – Linear relationship between the size of the ANB angle and the width of the upper pharynx ($P < 0.05$).

reduction in the width of the upper pharynx was influenced by the following risk factors: a decrease in the SNB angle, an increase in the nose tip (Cm-Prn-Ns) angle. A decrease of the SNB angle by 1 degree increased the risk of a 1-mm reduction in the width of the upper pharynx by 17%, an increase of the Cm-Prn-Ns angle by 1 degree increased this risk by 14%. The reduction in the width of the lower pharynx was influenced by an increase in the distance between the upper lip and the E line and increased upper lip thickness. An increased distance between the upper lip and the E line by 1 mm increased the risk of a 1-mm reduction in the width of the lower pharynx by 15%, and an increase in the thickness of the upper lip by 1 mm increased this risk by 26%.

The upper pharynx in girls was influenced by the following risk factors: an increase in the ANB angle, an increase in the nose tip (Cm-Prn-Ns) angle. An increase of the ANB angle by 1 degree increased the risk of a 1-mm reduction in the width of the upper pharynx by 86%, an increase of the Cm-Prn-Ns angle by 1 degree increased this risk by 19%. The upper pharynx in boys was influenced by a decrease in the SNB angle and an increase in the nose tip angle (Cm-Prn-Ns). A decrease of the SNB angle by 1 degree increased the risk of a 1-mm reduction in the width of the upper pharynx by 47%, and an increase of the Cm-Prn-Ns angle by 1 degree increased this risk by 23%. The lower pharynx in boys was influenced by an increase in the upper lip-chin angle. An increase of this angle by 1 degree increased the risk of a 1-mm reduction in the width of the lower pharynx by 54%.

4. Discussion

There is widespread and growing interest in facial esthetics and its attractiveness, and it has become one of the goals of the contemporary orthodontic treatment. Scientific research on the quantitative measurable bases of facial esthetics is still in progress, and various analyses of the soft tissues are performed, evaluating facial morphology and helping to plan orthodontic treatment [16–19]. When analyzing human face, maxillofacial surgeons, plastic surgeons, and orthodontists always try to set certain principles that would help in maxillofacial reconstruction or the treatment of orthodontic malocclusion [17,19–21]. Most frequently, the analysis of the soft tissue profile and the evaluation of the relationships of the nose, lips, and chin are performed [22]. Literature data suggest that the features of the nose and other facial structures depend on a person's race and ethnic group, and a number of analyses have been proposed to evaluate them [16,20]. Various techniques are used for the analysis of the soft tissue profile, including lateral cephalometric radiographs [20], digital photography [22], 3D photography [23,24], and magnetic resonance imaging [25]. Most frequently, the analysis of the soft tissues is performed by evaluating facial profile images or cephalometric analysis. Zhang et al. compared the data of facial profile analysis obtained via cephalometric radiographs or digital photography, and did not find any significant

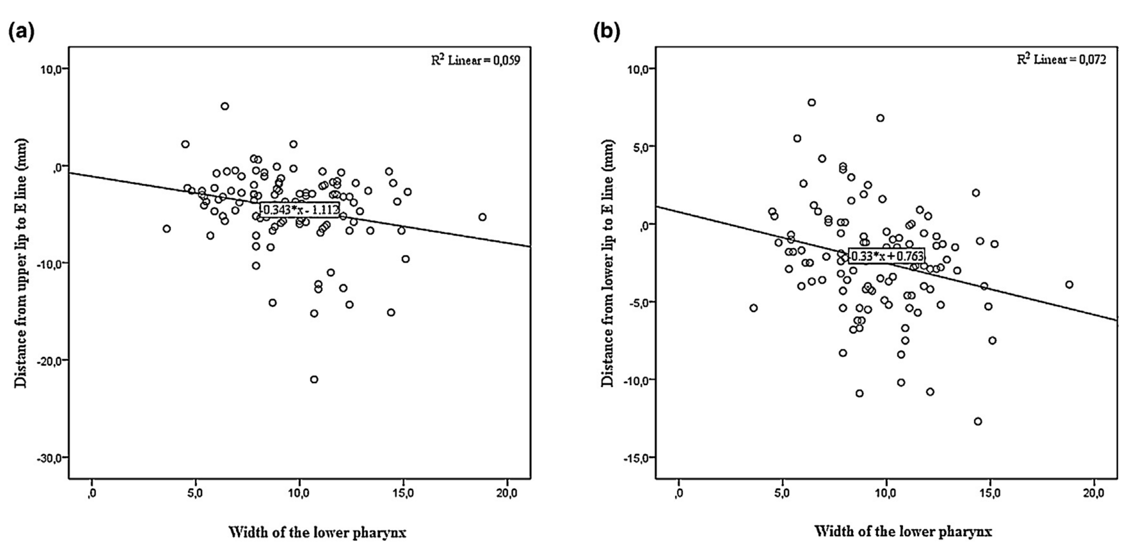

Fig. 3 – Linear relationship between the distance from the upper (a, $P < 0.05$), and the lower (b, $P < 0.01$) lips to the E line and the width of the lower pharynx.

Table 4 – Factors affecting the risk of the reduction in the width of the upper and the lower pharynx, adjusted for age.

Factor	OR	95% CI	P
Reduction in the width of the upper pharynx			
Sagittal position of the mandible (SNB)	0.83	0.73–0.96	0.009
Nose tip angle (Cm-Prn-Ns)	1.14	1.04–1.26	0.005
Reduction in the width of the lower pharynx			
Distance between the upper lip and the E line	1.15	1.02–1.29	0.024
Upper lip thickness	1.26	1.00–1.59	0.052
Reduction in the width of the upper pharynx in females			
Sagittal jaw relationship (ANB)	1.86	1.16–2.98	0.010
Nose tip angle (Cm-Prn-Ns)	1.19	1.04–1.35	0.011
Reduction in the width of the lower pharynx in females			
Nose tip angle (Cm-Prn-Ns)	0.91	0.83–1.01	0.066
Upper lip thickness	1.38	1.01–1.88	0.042
Reduction in the width of the upper pharynx in males			
Sagittal position of the mandible (SNB)	0.68	0.52–0.90	0.006
Nose tip angle (Cm-Prn-Ns)	1.236	1.04–1.52	0.017
Reduction in the width of the lower pharynx in males			
Upper lip-chin angle (Pog'-Ns-Ls)	1.54	1.13–2.11	0.007

OR, odds ratio; CI, confidence interval.

differences between these techniques [26]. The methods used for the evaluation of upper airway patency include fluoroscopy [8], nasal endoscopy [8,27], cephalometric radiographs [1,12–14], 3D computed tomography [8,28], cone beam computed tomography [15], and magnetic resonance imaging [13]. The greatest accuracy may be achieved when analyzing 3D images [8], yet the disadvantages of this technique are high radiation exposure and high costs, and therefore cephalography is used as an alternative technique for the planning of orthodontic treatment [29]. Studies comparing cephalometry with magnetic resonance imaging (MRI) suggest evaluating nasopharynx and laryngopharynx on cephalograms, refraining from evaluating the oropharynx due to overlapping structures [13]. Scientific literature indicates that cephalography allows for performing high-quality simultaneous evaluations of the airways and skeletal and soft tissues [11,30], and suggests using cephalography as a simple and sufficiently informative technique [10,31]. In our study, we chose cephalometric radiography images for the evaluation of soft and skeletal tissues and the airways. During this analysis, we evaluated the measurements of skeletal structures in the sagittal plane, the soft tissues of the lips, nose, and chin, and the structure of the airways in the upper and the lower parts of the pharynx.

A patient's respiratory function is an important factor in diagnostics and orthodontic treatment planning, and it has a direct correlation with the size of the upper airways [32,33]. In our study, subjects with Angle Class II malocclusion had a significantly more convex facial profile, compared to Class I patients. The increased convexity of the facial profile was associated with the position of the upper and the lower lips closer to the E line, a decreased convexity angle, an increased nasomental angle, and increased upper lip-chin and lower lip-chin angles. Angle Class II patients were found to have significantly narrower upper airways. Researchers analyzing the soft tissue profile state that facial convexity is one of the parameters that have a statistically reliable relationship with pharyngeal airway pathology. Adequate treatment of orthodontic anomalies at a young age may prevent or alleviate pathological changes of the airways [5]. According to Basheer et al., individuals who breathe through the mouth have more convex faces and protruding incisors, compared to those who breathe through the nose [2]. Gulsen et al. stated that the convexity of facial soft tissues is related to the position of the jaws [20]. The findings of this study confirm the aforementioned statements – a greater facial convexity and narrower pharyngeal airways were detected in Angle Class II subjects. The correlation analysis conducted in our study showed that an increasing width of the upper pharynx was associated with an increasing sagittal mandibular angle (SNB) and a decreasing sagittal maxillo-mandibular angle (ANB). This indicates that Angle class II subjects had narrower upper airways.

The evaluation of the changes with respect to sex showed that girls with Angle Class II malocclusion had convex facial profiles: smaller facial convexity angles, smaller distances from the upper and the lower lips to the E line, and greater nasomental, upper lip-chin, and lower lip-chin angles, compared to girls in the Class I group. In boys with Class II malocclusion, increased facial convexity was related to a smaller distance from the lower lip to the E line, a decreased upper lip thickness, and an increased upper lip-chin angle. The evaluation of the influence of sex on the soft tissues showed that in girls with Class I malocclusion, upper lip-chin angles, lower lip-chin angles, the width of the upper and the lower parts of the upper lip, and lower facial height were smaller, compared to boys of the same group. Girls with Angle Class II malocclusion had greater distances between the upper lip and the E line, smaller facial convexity angles, smaller upper lip-chin angles, and smaller upper lip thickness, compared to boys of the same group. There was no difference in airway measurements between the sexes.

The retrognathic position of the mandible may cause pharyngeal airway constriction in patients with a convex facial profile. Facial profile convexity may be one of the risk factors of sleep apnea. A study conducted by Ikävalko et al. showed that of all healthcare specialists working with children, orthodontists can perform the most exact evaluations of facial convexity because other specialists lack knowledge about the importance of the facial profile in the diagnostics of airway pathology [5]. The results of studies conducted by Dimaggio et al. [22] and Souki et al. [4] suggest that the nasolabial angle in patients with Angle Class I is statistically significantly greater than in those with Angle Class II malocclusion. A small nasolabial angle may be detected in patients who breathe through the mouth [4]. The data of our study confirm these results as we found in Class II subjects more protruded upper lips, increased upper lip-chin angle, decreased distance to the E line, comparing to Class I. This is due to the protrusion of the upper incisors and the upper lip, which in turn is caused by imbalance of the linguolabial positioning.

The growth and development of the maxillofacial system should be closely monitored during the critical pre-puberty period in order to prevent future nose breathing disorders – especially in patients with possible nasal breathing disorders. The condition of these patients should be followed by a team of specialists consisting of a dentist, an orthodontist, a pediatrician, an ENT specialist, and an allergist, who should ensure timely correction of nose breathing disorders during the period of the active growth and development of the maxillofacial system. The results of the present study show that upper airway obstruction and malocclusion are inter-related and cause changes in the facial profile. Since the cause-and-effect correlation between the size of the upper and the lower airways and the type of malocclusion has yet to be confirmed, sagittal and vertical skeletal discrepancies should be corrected interventionally during the period of growth and development, maximally approximating them to the normal status [33]. The function of the airway is of considerable importance in orthodontics and cannot be overlooked during treatment planning.

5. Conclusions

During critical period of growth and development of the maxillofacial system, the patients with oral functional disturbances should be monitored and treated by a multidisciplinary team consisting of a dentist, an orthodontist, a pediatrician, an ENT specialist, and an allergologist. The aim of this team is timely diagnostics of disorders, adequate early treatment, and optimal recommendations for primary and secondary prevention, as well as patient monitoring throughout this growth period.

Cephalometric radiographs producing 2D images are a sufficiently informative, simple, and inexpensive diagnostic modality, which could be recommended for use in daily clinical practice when diagnosing respiratory system disorders and the disorders of the morphology of skeletal and soft maxillofacial tissues.

Cephalometric analysis applied in our study showed that Angle Class II patients with significantly decreased facial convexity angle, increased nasomental, upper lip-chin, and lower lip-chin angles, and upper and lower lips located more proximally to the E line more frequently had constricted airways.

Conflict of interest

The authors state that they have no conflicts of interest to declare.

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