The Analysis of Modified Algorithm to the Assessment of Upper Airway Morphology: A CBCT Study

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Abstract

Upper airway morphology and respiration pattern have been assigned an important role in the development of the craniofacial region. Several studies advocate cone-beam computed tomography to evaluate the upper airway. Although this method has been widely used, there are no clear algorithms and protocols to comprehensively assess the state of the respiratory tract.

The present study aims to describe of a previously developed algorithm for upper airway assessment in children and to identify its significance and effectiveness.

Forty CBCTs of pediatric patients with mouth and nasal breathing were used to perform a 3D evaluation of the upper airway using the developed algorithm. The study group included 20 pediatric patients who suffered from symptoms and signs of nasal obstruction, and the control group included 20 patients who were normal nasal breathers. Group differences were statistically evaluated by independent samples t-test at $p < 0.05$ levels.

Mouth breathers demonstrated considerable narrowing of both nasopharynx and oropharynx areas, increased adenoids and tonsils sizes, a higher A/N ratio. The prevalence of 2 and 3 degree of adenoid hypertrophy was significantly more frequent in the mouth breathers' group (45% and 20%) than nose breathers (25% and 5%). The 3 degree of adenoid hypertrophy was significantly more frequent in the mouth breathers' group (45%) than nose breathers group (25%) (P=05).

In conclusion, a CBCT-based 3D analysis gives a better picture of the anatomical characteristics of the upper airways and therefore can lead to an improvement of the diagnosis.

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Introduction

Physiological nasal breathing is one of the most important components that ensure the normal growth and development of the maxillofacial region.[1,2] The function of nasal breathing is also associated with other functions of the maxillofacial region (swallowing, chewing, speech). In the absence of disharmony, the correct distribution of muscle load on the lips, tongue and chewing muscles is ensured, which in turn contributes to the normal growth and development of bone structures, especially in children.[3] Several authors indicate that impaired nasal breathing is an important etiological factor in the formation of maxillofacial deformities. [4,5,6]

Currently, ear, nose, throat (ENT) diseases occupy one of the leading places in the structure of childhood morbidity and tend to increase.[7,8]. Also, according to epidemiological studies, there is an increase in the number of children with impaired respiratory system functions.[7,9] Adenoid hypertrophy occupies the 1st place in the structure of ENT pathology of the upper airway in children.[9,10]

In orthodontic practice, the assessment of the upper airway (UA) is also important for planning the volume of intervention and ensuring interdisciplinary communication. However, there are no clear descriptions of the upper airway

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assessment algorithm (UAAA) in children according to CBCT data. There are previous studies in which the authors have used cephalometric analysis to compare airway parameters between mouth and nose breathing children.[11,12,13] In recent studies it has been described the used of 3D cephalometric tracings, which allows the evaluation of volumetric measurements of the airway.[14,15] Nevertheless, the authors did not describe complex UA assessment algorithms in any of the mentioned studies. Since today the method of three-dimensional X-ray examination is the most modern and accurate, the development of the upper airway assessment algorithm is relevant.

This article presents a detailed CBCT protocol, which includes not only a classical analysis of the UA size, but also the condition of soft-tissue ENT organs. Previously, this algorithm was developed in the process of scientific work. The present study contains the description of its use in orthodontic practice.

The purpose of the study is to describe a previously developed algorithm for the upper airway assessment in children and to identify its significance and effectiveness.

Materials and methods

The main directions of this work were as follows: description and demonstration of the clinical application of the previously developed algorithm for the UA evaluating by CBCT, assessment of the clinical effectiveness. This retrospective research was performed following the principles of the Declaration of Helsinki. A sample of 40 children was obtained (24 girls and 16 boys) who were aged between 10 and 12 years, with an average age of 11.23 years. 20 children were oral breathers (experimental group) and 20 were nasal breathers (control group). They had attended the private dental clinic, Moscow, Russia. 40 diagnostically acceptable CBCTs of patients with different occlusions at the age from 10 to 12 years (24 girls and 16 boys) were collected. Images were taken from August 2021 to April 2023 and included in this study.

All images were uploaded to the Diagnocat software account (DC, Diagnocat LCC, Moscow, Russia), and the radiologic orthodontic report of each was generated as the basis of automatic evaluation. 3D color visualization of upper airway, total and minimum volume were assessed. The visualization of the CBCT was performed using the RadiAnt Dicom Viewer program.

Radiological area of upper airway	Parameter	Description	Value
Nasopharynx	sagittal size (UPW)	distance in the anterior-posterior direction from the point on the posterior edge of the anterior-upper third of the soft palate (point U) to the nearest point on the posterior pharyngeal wall	15-20 mm
	linear size of the adenoid	line A is the perpendicular between the outermost point of the convexity of the shadow of the nasopharyngeal tonsil (point A) and line B (the line of the anterior edge of the base skull)	-
	adenoid index (A/N ratio)	ratio of linear measurements A/N	Relative norm ≤ 0.40 1 degree of hypertrophy 0.41- 0.59 2 degree of hypertrophy 0.60- 0.79 3 degree of hypertrophy > 0.80
Oropharynx	sagittal size (LPW)	the distance in the antero-posterior direction from the intersection point of the posterior border of the tongue and the lower border of the mandibular angle (point L) to the nearest point on the posterior pharyngeal wall	11-14 mm
	sagittal size (MPW)	the distance in the antero-posterior direction from tip of uvula (point M) to the nearest point on the posterior pharyngeal wall	-
	palatine tonsil	height – the largest size in the vertical direction (TH); length - the largest size in the sagittal direction (TL); width - the largest size in the transversal direction (TW) Volume – TH* TL* TW	-
	tongue	length (TL) – the distance from the tip of the tongue (TT) to the point of deepening between the edge of the epiglottis and the root of the tongue — vallecula (V) height (TH) – perpendicular from the uppermost point of the back of the tongue (H) to the TL line	-
Hypopharynx	sagittal size (HP)	the distance in the antero-posterior direction from the lower edge of the second cervical vertebra to the nearest point on the posterior pharyngeal wall	-

Table 1. An algorithm for diagnosing the condition of the upper airway using CBCT.

The following requirements for CBCT have been developed, which were considered when including images in previous studies:
1) Minimum FOV is 15*15cm;
2) Natural head position, natural closing occlusion, closed mouth;
3) Breathing through the nose, without swallowing, the tip of the tongue is pressed to the palate behind the upper incisors;
4) Lack of movement;
5) Lack of strong pressure of the chin.

Compliance with these requirements helps to create optimal conditions for scanning, which ensure maximum accuracy of the received data.

The diagnostic protocol for airway assessment included modified cephalometric methods of airway, adenoids, tonsils evaluation. In earlier studies, the UAAA was developed by conducting multiple analyses of CBCT in children (Table 1).

The measurement of volumetric characteristics depends on the type of used program. In this study, we used a Diagnocat which allows to provide the color visualization of the UA volume as when using Invivo Anatomage (Figure 1).

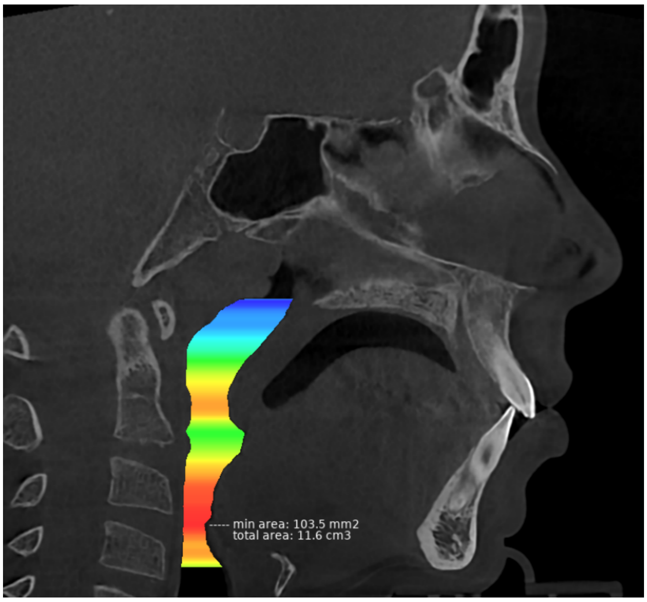

Figure 1. Upper airway volume with color visualization from Diagnocat.

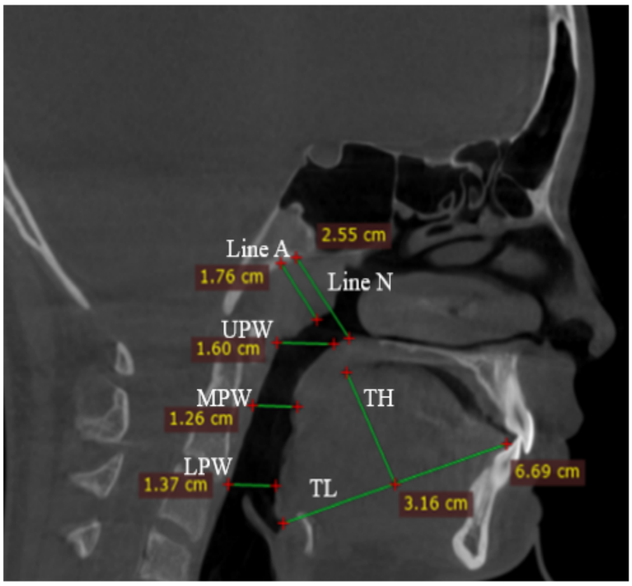

Figure 2. Measurements of upper airway by algorithm.

An example of calculations of the respiratory tract and palatine tonsils is presented below (Figure 2 and Figure 3).

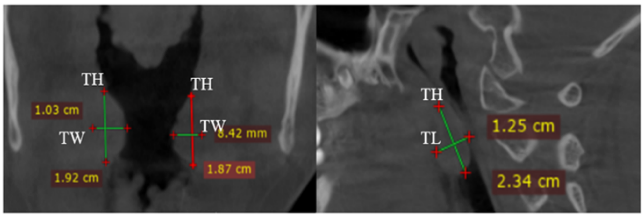

Figure 3. Measurements of tonsils on CBCT in coronary and sagittal sections.

Statistical analysis

The data were analyzed by the statistics Excel program, version Microsoft 2010. For the quantitative variables, the mean values and the standard deviation were calculated. The cephalometric upper airway values between the two groups were com-pared. The t-test for independent samples was used to compare the mean values for each variable, at a 95% confidence level. Statistical significance was set at P < 0.05.

Results

Descriptive statistics and statistical comparisons of volumetric and linear upper airway measurements in patients of both groups according to CBCT data are presented in the table (Table 2). According to the results of the radiological investigation statistically significant differences were found between experimental (MB) and control group (NB) in 6 of 10 measurements.

Airway measurements	Mouth breathing (MB)		Nasal breathing (NB)		Significance
	Mean	SD	Mean	SD	
UPW, mm	11,7	1,9	14,7	2,4	*
MPW, mm	8,62	2,87	10,41	2,72	*
LPW, mm	8,90	2,21	9,56	2,78	N.S
Adenoid size, mm	14.75	2.27	14.75	2.27	*
Nasopharyngeal size, mm	21.6	3.48	22.08	3.1	N.S
A/N ratio	0,65	0,10	0,42	0,15	*
Tonsil volume, mm^3	3185,2	10,34	3185,2	8,62	*
Tongue size, cm^2	29.019	5.473	30.292	3.964	N.S
Minimum area, mm^2	126.56	57.27	172.27	80.61	*
Total area, cm^3	12.45	3.1	14.93	6.27	N.S

Table 2. Descriptive statistics and statistical comparisons of upper airway measurements in mouth breathing and nasal breathing children
Data are reported as means ± SD. *p<0.05; NS: Statistically not significant, SD: Standard deviation.

A statistically significant difference was observed in the nasopharynx and oropharynx areas of MB children compared to NB children.

Adenoids and tonsils sizes, A/N ratio were significantly increased in the MB group. UPW, MPW, nasopharyngeal size, minimum area measurements were found significantly lower in the mouth breathers' group. The statistical analysis indicated that there was a statistically significant difference for tonsil volume (p<0.05). According to statistical analysis, the minimum airway area decreased significantly in MB subjects (p < 0.05). We revealed that there were no significant statistical differences in LPW, nasopharyngeal size, tongue and total airway area measurements.

The association between the degree of adenoid hypertrophy and mode of breathing is shown in table (Table 3). Most of the nose breathers demonstrated normal A/N ratio (45%). However, the 2 and 3 degrees of hypertrophy were significantly more frequent in the mouth breathers group (45% and 20% respectively) than nose breathers group (25% and 5% respectively). However, the 3 degree of adenoid hypertrophy was significantly more frequent in the mouth breathers' group (45%) than nose breathers' group (25%) (P=05). The descriptive analyses showed that adenoid hypertrophy parameters were characterized by a large interindividual difference in MB group.

A/N ratio	Mouth Breathers, n=20 (%)	Nose Breathers, n= 20 (%)	P Value
Relative norm	1 (5)	9 (45)	.05
1 degree of hypertrophy	6 (30)	5 (25)	
2 degree of hypertrophy	9 (45)	5 (25)	
3 degree of hypertrophy	4 (20)	1 (5)	

Table 3. The association between A/N ratio and mode of breathing in the study population.
Note: Data are reported as means and standard deviation (SD). All means showed equal variance and normal distribution independent sample t-test p value.

Discussion

Correct and complete diagnosis in orthodontics is the shortest way to drawing up an optimal individual treatment plan and obtaining the planned result. Currently, the method of 3D diagnostics and visualization is actively gaining popularity, and much attention is also paid to the interdisciplinary approach in the treatment of orthodontic patients with respiratory problems.[16,17,18] There are many modern studies describing ways to evaluate the upper airway according to CBCT data.[15,19,20]

In the literature available to us, it was not possible to find a comprehensive protocol that allows us to assess the state of upper airway using CBCT. The available data are fragmented and require generalization to reduce the time for processing diagnostic information. This article describes the analysis of CBCT using cone-beam computed tomography and modified UAAA. The protocol described above is a combination of several methods of interpretation of X-ray images. It includes diagnostics of linear and volumetric parameters, assessment of soft tissues (size and position of adenoids, palatine tonsils, tongue).

Our study demonstrates not only that there are cephalometric differences between mouth breathing and nasal breathing children, but also demonstrates the key role of ENT pathology in the etiology and development of oral breathing in children.

According to the study, a high prevalence of adenoid hypertrophy was revealed in children with oral breathing. Also, the degree of hypertrophy is more pronounced in the experimental group compared to the control group. We believe that hypertrophy of lymphoid tissue, especially adenoids and tonsils, plays an important role in the pathophysiology of the nasal obstruction syndrome. It is our main target in orthodontic management to treat malocclusion and to restore a normal breathing pattern since there are published studies which suggests that adenotonsillar hypertrophy causes upper airway narrowing in children also have been associated with maxillofacial deformities and dental anomalies.[21,22] Our results reveal that there are significant differences when comparing upper airway measurements between nasal breathing children and mouth breathing children, and that the latter have radiological signs of airway obstruction due to hypertrophy of lymphoid tissues.

The advantage of this algorithm is that the UA organs and dimensions are evaluated by simple and objective parameters. In contrast to the subjective assessment, which creates difficulties in accurate diagnosis due to the large variation depending on the experience of the doctor, this CBCT analysis by precise anatomical landmarks makes the diagnostic process simpler, better, and less time-consuming.

Analysis of the patients' CBCT data using this algorithm revealed a cause of oral breathing, localization of Ent pathology, possible relapses after surgical treatment performed earlier, narrowing of the upper airway. Therefore, the use of the developed algorithm helps orthodontists to quickly diagnose, using an interdisciplinary approach in planning the treatment of patients considering the UA morphology. This helps to improve cooperation between otorhinolaryngologists and orthodontists. The integration of this method into programs that use artificial intelligence techniques to perform automatic calculations will greatly simplify the diagnosis of the upper airway.

This protocol allows you to supplement the classical analysis of CBCT, which makes it possible to obtain a more complete amount of information and increase the productivity of the orthodontist. The inclusion of this protocol in the diagnosis allows you to choose the most correct treatment plan. A comprehensive assessment of the images of the elements of the respiratory tract obtained using the method of cone-beam computed tomography allows us to estimate the volumetric and linear parameters of the respiratory spaces, the size of soft tissues in various sections. This analysis is especially necessary in the presence of relevant anamnestic information and objective data of the patient indicating a violation of the respiratory pattern.

Conclusions

The findings confirm that the CBCT is a valid and reliable method for measuring dimensions of upper airway dimensions and soft tissue structures. Nasal respiratory obstruction with mouth breathing during critical growth periods in children has a higher influence for normal facial and dental growth and development. In children with mouth breathing, the parameters of the upper airway differ significantly, and ENT pathology is more often detected. Using CBCT, it is possible to identify problems in time and refer the child to a specialist for correct treatment. Since CBCT provides accurate information about the localization of ENT pathology, this type of X-ray examination will be useful not only for orthodontists but also for otorhinolaryngologists, including for planning surgery. Measuring the parameters of the respiratory tract allows the dentist to take a more comprehensive approach to diagnosis and treatment. An orthodontist is one of the few doctors who can not only improve the quality of a person's life, but also increase its duration by conducting a screening examination of nasal obstruction.

Combining several methods of interpretation of CBCT in a single protocol will allow doctors to obtain a more complete amount of information for drawing up a full-fledged comprehensive treatment plan. Of course, this analysis requires further development and is only an addition to the standard methods of cephalometric studies.

The data obtained using the UAAA cannot be interpreted separately without anamnesis and clinical situation in each individual patient. it must be considered in a comprehensive assessment, considering the parameters of the jaws, teeth, etc.

Clinical relevance

Description and demonstration of the developed algorithm for upper airway assessment in children were carried out. Its significance and effectiveness were identified and proved in children with mouth breathing to reveal the causes of nasal obstruction. These findings have a significant impact on the assessment of the pathogenesis and treatment of obstructive conditions localizing the eventual obstacle to a normal breathing pattern or evaluating the relationship between craniofacial morphology and nasorespiratory function.

Declaration of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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