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BONE AND SOFT TISSUE MORPHOLOGICAL MARKERS IN MOUTH-BREATHING CHILDREN USED BY ORTHODONTISTS AND OTOLARYNGOLOGISTS

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Abstract: Several morphological markers are observed in children with nasal breathing disorders. They are often diagnosed during orthodontic analysis in relation to concomitant orthodontic deformities. Mouth breathing leads to muscle activity changes affecting the oral functions - mastication, swallowing and phonation. The muscles involved in the mouth breathing contract at the same time as the muscles in involved in the other oral functions and affect each other.

Aim of the research was to describe a method for simultaneously identifying bone and soft tissue changes in the orofacial region.

In orthodontics, a large field of view (FOV) CBCT covering the entire skull, is obtained. A 3D imaging software is used to evaluate the changes in the bones, the soft tissues and the upper airways.

A single CBCT scan can establish the three-dimensional development of the maxilla and mandible, the level of bone insufficiency, TMJ disorders (TMDs), facial asymmetries, assess bone maturation and determine bone age. It gives the ability to objectively measure airway volume, identify areas of upper airway obstruction, superimpose images of anatomic structures and to track soft tissue changes. It is used in the planning of orthognathic reconstructions and in the digital designing of surgery guides or orthodontic appliances.

Evaluation of Consecutive CBCTs (before and after treatment with maxillary expander) of patients with upper airway obstructions, can be done by both an orthodontist and an otorhinolaryngologist. They can establish the changes in the widths of the bony palate, the maxilla and the interzygomatic space. Additionally, the increase in volume of the nasal, nasopharyngeal and pharyngeal airways can be measured and the areas of obstruction can be identified.

Keywords: *CBCT imaging, mouth breathing, orthodontic deformation, rapid maxillary expansion*
Field: Medical Sciences and Health

1. INTRODUCTION

The nose and the mouth represent two parallel pathways through which air enters and exits the human body. The predominance of one of these pathways is influenced by functional disorders, disease development in children, or by continuing deleterious oral habits. Mouth breathing is one of the most common deleterious oral habits in children and is often accompanied by sleep disordered breathing. Transition to mouth breathing in growing children may arise from upper airways obstructions. Mouth breathing has been shown to lead to various skeletal changes. (Lin et al., 2022) These changes have impact on the soft tissue development and function. Nasal breathing, in conjunction with other oral functions of the craniofacial complex (mastication, swallowing, phonation), influences the direction and magnitude of the craniofacial growth. (Grippaudo et al., 2016; Zheng et al., 2020)

The etiology of mouth breathing is multifactorial. The most common anatomical structure alterations that are responsible for this condition include narrow airways, adenoid hypertrophy, nasal septum deviation, nasal polyps, respiratory allergies, turbinate hypertrophy and poor sleep posture. In addition, establishing the etiology of mouth breathing also helps in predicting the changes in the maxillofacial growth. (Iwasaki et al., 2017)

Mouth breathing leads to functional alteration including changes in tongue position, oral and perioral muscle tonus, changes in head and neck posture, which facilitates mouth breathing by increasing the airflow through the upper airways. (Bakor et al., 2011) In normal breathing patterns the lips are in contact, the tongue is positioned in contact with the palate and the lingual side of upper anterior teeth. Balanced muscle strength from the inner muscle group (the tongue) and the outer muscle group (the lips and cheeks) is critical for the development of a normal upper dental arch. Mouth breathing immediately disrupts this balance. Children with mouth breathing develop upper dental arch (maxillary) compression, which is accompanied by a crossbite in the posterior teeth segments. The mandible is in backwards

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rotation and the distal teeth, due to the lack of occlusal contacts from the permanently open mouth, show a tendency to over erupt, increasing the risk of an open bite. (Harari et al., 2010; Tang et al., 2019) Clinical features may vary depending on the area of action and the magnitude of the etiological factor. (Alhammadi et al., 2021; Festa et al., 2021; Santos Barrera et al., 2024) Morphological changes in the maxillofacial area occur because mouth breathing leads to adaptive changes in the lips, tongue, mandible position, and these changes alter the model of skeletal development through the altered neuromuscular responses. A related result is changes in the patient's soft tissue profile and face. This is due to the fact that the muscles involved in the mouth breathing contract at the same time as the muscles involved in the other oral functions and affect each other.

The upper airways can be divided into four sections: nasal cavity, nasopharynx, oropharynx and laryngopharynx. (Chen et al., 2015; Lin et al., 2022) Airway obstructions can be present in any section, but the most common is the posterior nasopharyngeal obstruction. (Chung Leng Muñoz & Beltri Orta, 2014) It is due to the pathological adenoid hypertrophy, which orthodontists associate with distal bite formation and hyperdivergent vertical growth.

Growing patients affected by pathological tonsillar hypertrophy obstructing the lower part of the upper airway medialize their lower jaw to increase the width of the oropharyngeal airway.

They develop an anterior crossbite which can progress to medial occlusion. (Grippaudo et al., 2016) Therefore, orthodontists identify two distinct facial profiles of patients who have mouth breathing, depending on the type of obstruction - progenic in tonsillar hypertrophy and prognathic in adenoid hypertrophy. (Iwasaki et al., 2017) The development of different skeletal-facial profiles as a consequence of impaired nasal breathing necessitates orthodontists to seek clarification of the etiological factor and diagnosis by an otolaryngologist. (Zhao et al., 2022; Zheng et al., 2020)

These skeletal patterns can affect the shape and size of the upper airways, but at the same time they change the bone and soft tissue facial profile and are predictors of obstructive sleep apnea (OSA) (Vu et al., 2024).

A high palatal vault is one of the most common features in patients who are mouth breathers. Tang et al. reported that the height of the palate at the first molar site was 11% higher in children who are mouth breathers than in those who breath through the nose. (Tang et al., 2019)

Studies of the described morphological changes have been done until recently on 2D images (lateral and frontal cephalograms), which provide information about the development of the facial skeleton. In the last decade, CBCT imaging has entered the orthodontic field, providing detailed, high-resolution images. They have lower radiation dose than traditional CT scans. From the captured slices, the software does a 3D reconstruction and a 3D model (volume) of the scanned area. The large volume (large field of view) CBCT scan used in the study include the calvaria. From this noninvasive examination, orthodontists obtain information about the size and position of the facial bones in the three dimensions; the relationships between them; the presence of facial asymmetries; teeth positions; temporomandibular joint conditions; the volume and position of the soft tissues. From the same examination, ENT specialists assess the volume, position and pathologies of the sinuses, nasal passages, airway volume and other parts of the head and neck. CBCT machines provide isotropy of the voxels in all three dimensions, as opposed to their anisotropy in conventional computed tomography. This results in better visualization of the head and neck bony structures in CBCT cross sections. A resolution of up to 0.09 mm is used in this study, allowing high accuracy. Otorhinolaryngologists identify the size and volume of the airways and sinuses using the CBCT examination. (Lata et al., 2018; Patil et al., 2022; Piotrowska-Seweryn et al., 2019) CBCT imaging is particularly useful in the assessment of the paranasal sinuses to evaluate their anatomy; to diagnose sinusitis, nasal polyps, and other diseases. The study is of great significance for the evaluation of airway obstructions. It helps in diagnosing conditions such as obstructive sleep apnea. It has a particular application in assessing disorders affecting the temporal bone, such as chronic otitis media or cholesteatoma, offering clear visualization of the complex structures of the ear. The information in the literature about CBCT and its use in treating ENT diseases shows that the potential of CBCT in this medical field is not yet fully known.

In summary there are multiple morphological markers indicating the impaired nasal breathing. They are often detected when developing treatment plans as part of the orthodontic analysis in order to correct the orthodontic malocclusion. In order to reduce the patient's radiation exposure during examinations by different specialists (orthodontists, ENT, pediatricians), it is important to be up-to-date with imaging methods that can provide information on hard, soft and airway structures simultaneously.

Aim: To describe a method for simultaneously identifying bone and soft tissue changes in the orofacial region.

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2. MATERIAL AND METHODS

Ethics Statement

Patients were diagnosed, treated and included in the study after the explicit informed consent of their parents. During the course of treatment, all rules and standards for good orthodontic practice applicable in the country were observed. In order to process and present the result of their treatment, approval was obtained from the Ethics Committee of KENIMUS, Approval Code: 7995/07.10.2024. The development is related to a study under the Grant project D-176/04.06.2025.

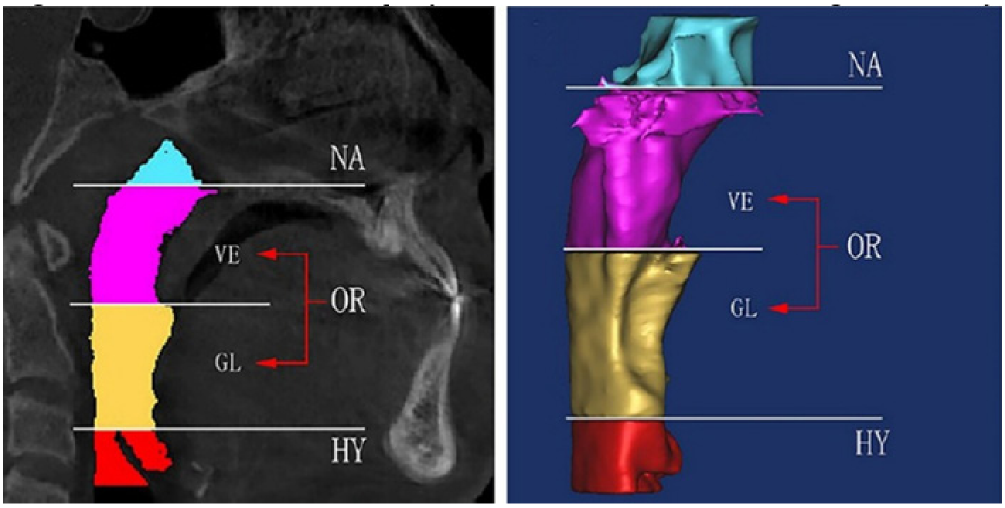
Diagnostic and Clinical Considerations

The orthodontic analysis includes large field of view CBCT including the calvaria and software that is capable of segmenting hard (bones), soft tissues and airway structures. Because for patients with impaired nasal breathing, it is necessary that the scope of the study includes more structures and anatomical landmarks. The information is stored in DICOM format, which is a standard. With appropriate software, individual bone, tooth and soft tissues are segmented in order to make measurements of deviations and plan the various treatment changes. The capabilities of the software used by the team allow for measuring airway volume at different levels; assessing asymmetry in bones and soft tissues; planning and designing the treatment expander; planning orthognathic surgery; locating impacted teeth and other abnormalities.

The methodology for determining upper airway volume requires the use of reference points and planes. With CBCT, the cross-sectional area of the upper airways is evaluated and determined. (Fonseca et al., 2023) Modern software allows for measuring volume in the three segments of the trachea. Such measurements are described by Chen et al., 2015and also from Yanev et al., 2024.

For the purpose of the study, the upper respiratory tract is divided into 3 parts: nasopharynx (NA); oropharynx (OR); hypopharynx (HY). For more complete detail, the oropharynx can be further divided into 2 parts: velopharynx (VE) and glossopharynx (GL) (Fig. 1).

Figure 1: The three divisions of the pharynx visualized on a CBCT slice and segmented airway.



Source: Authors' research

After segmenting the airway sections, the volume (V) and height (h) of the airway are automatically determined by the software. The average cross-sectional area is calculated as the V/h ratio. Thus, the percentage of narrowing can be determined by otorhinolaryngologists and the percentage change after orthodontic therapy (usually rapid palatal expansion) can be determined by orthodontists.

The presented case is of a 13-year-old girl with impaired nasal breathing due to oropharyngeal obstruction. Clinical examination revealed a bilateral posterior crossbite more severe in the right posterior segment, a high palatal vault, maxillary compression, minimal incisor coverage, and a short upper labial frenulum (Fig. 2). X-rays are needed to make a complete orthodontic diagnosis. Consultation with an ENT specialist is also needed, where paraclinical examinations will also be necessary. Therefore, the orthodontist prescribed a large field CBCT.

Figure 2: Intraoral status of the patient before orthodontic treatment.

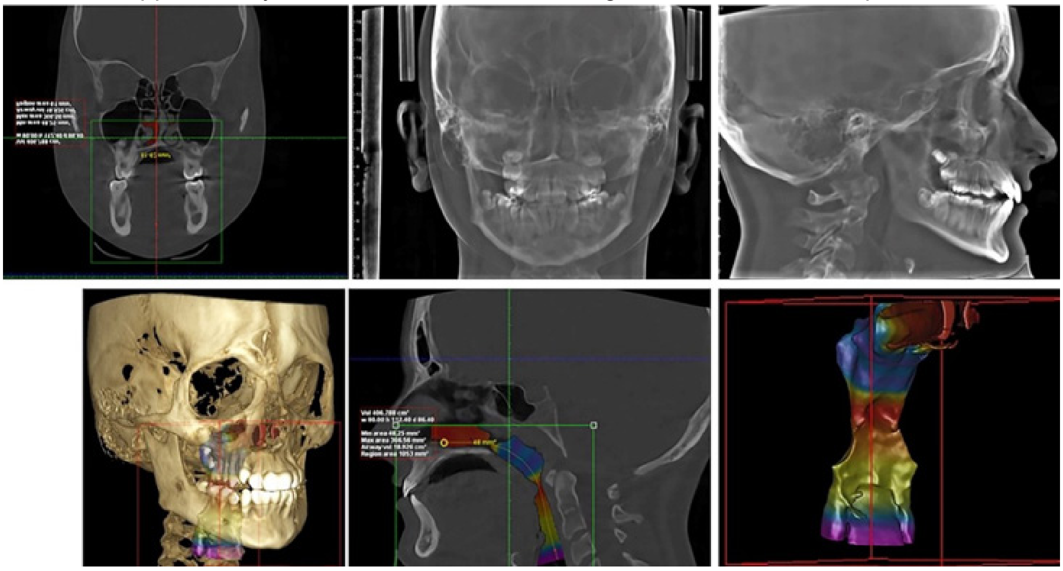
Source: Authors' research

The patient underwent orthodontic treatment after thorough diagnostics and analysis. The treatment consists of two stages - rapid palatal expansion and alignment of both dental arches and adjustment of the occlusal relationships with fixed technique - braces.

3. RESULTS

The three-dimensional development of the maxilla and mandible upper jaw and lower jaw; the level of upper jaw bone insufficiency in mouth breathers; the presence of facial asymmetries and the digital design of orthodontic treatment appliances were evaluated with one study. Airway volumes can be measured objectively, areas of nasopharyngeal obstructions are identified, superimposition of anatomical structures can be done, soft tissue changes are tracked, bone maturation is assessed and bone age is determined. (Fig. 3).

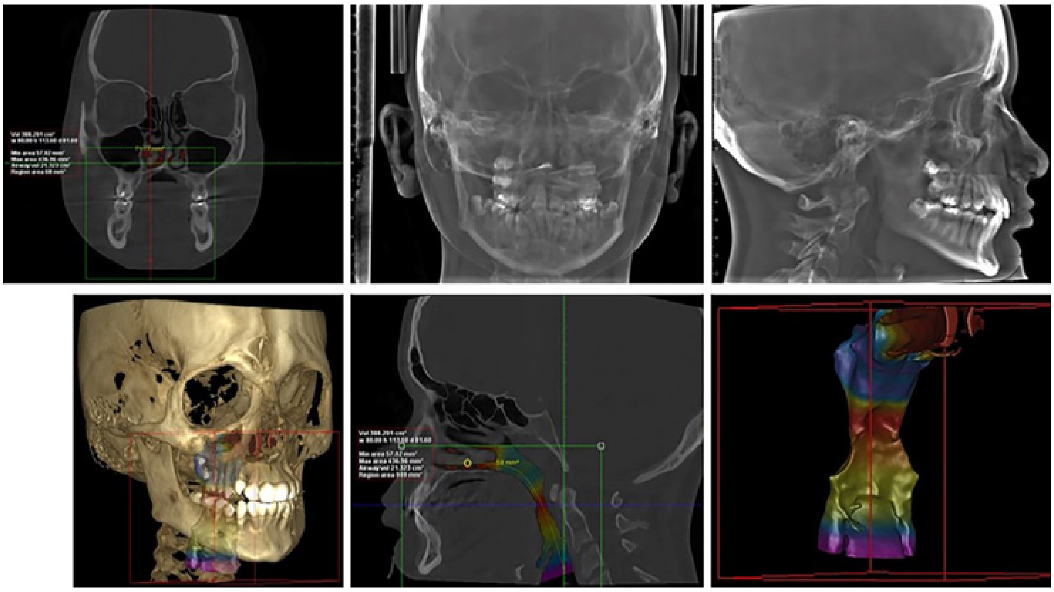
Figure 3: Figure 3: Assessment of bone and soft tissue parameters, airway volume, and sites of upper airway obstruction tracked as change from initial to finish phase



Source: Authors' research

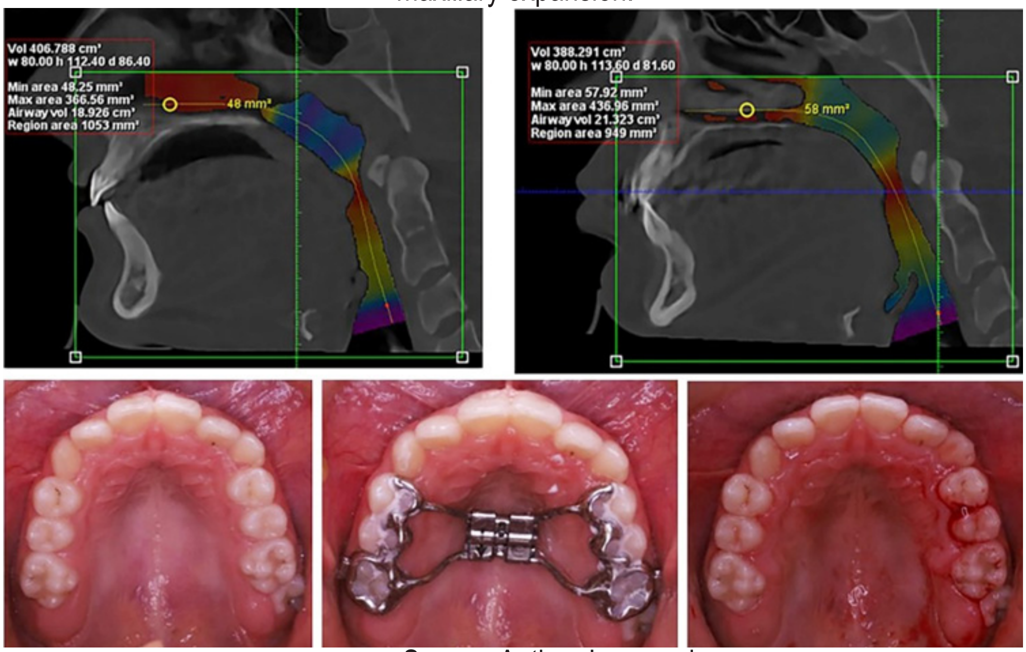
The orthodontic treatment involved maxillary expansion with a digitally designed and metal-printed expander. The increased maxillary transversal width resulted in normalization of occlusal relationships and also altered the airway volume as seen in Figures 4 and 5.

Figure 4: Assessment of bone and soft tissue parameters, airway volume and obstruction sites along the upper airways with one study after the orthodontic treatment.



Source: Authors' research

Figure 5: Comparison of maxillary transversal widths and airway volumes before and after rapid maxillary expansion.



Source: Authors' research

Orthodontic treatment starts immediately after completion of the conservative or surgical otolaryngologic therapy. Orthodontic treatment is aimed at achieving a new maxillary bone size that underlies the nasal passages and maintains their width. The transversal width of the hard palate is one of the three-dimensional parameters used to assess the volume of the upper airways. Therefore, an increase of this width will favorably increase the volume of the airways. Assessment of these parameters and their changes are possible with a single imaging study (CBCT) that allows measurements in all three planes.

4. DISCUSSION

Measurements of three-dimensional structures in the orofacial region and their adjacent tissues on two dimensional images are not accurate because there is overlapping of the structures, especially when there is facial asymmetry. It is known and other authors (Aboudara et al., 2009) confirm it that lateral cephalography measures changes in the upper airway only vertically and sagittal, but the main changes after expansion are in the transverse direction. CBCT has its advantages due to its lower radiation dose and higher spatial resolution as claimed by Chen et al., 2015. Another advantage is its high resolution, which allows for the use of many more landmarks and visible bone structures. By using the stable structures at the base of the skull as markers, it is possible to register pre- and post-treatment 3D patterns. CBCT provides a new standard for volumetric measurements, airway cross-sectional area analysis and making more accurate diagnosis.

In the presented clinical case, the airway volume increased from 18.926 cm3 to 21.323 cm3.. It was found that the expansion of the maxilla is directly proportional to the increase in volume in the nasopharynx and oropharynx. Spontaneous medial displacement of the mandible, hyoid bone is observed, which also affects the surrounding soft tissues. When treating patients with maxillary expander, the orthopedic forces that are used, stimulate cellular activity in the palatal suture where growth occurs. After treatment with a rapid maxillary expander, the expanded maxilla provides more space for the tongue. Due to this fact, the mandible shifts and adapts in relation to the upper jaw. The mandible shift is observed as backwards (clockwise) rotation. These observations confirm the relationship between the skeletal structures of the craniofacial complex and the upper airways.

5. CONCLUSION

CBCT is a reliable method and has a number of advantages over other methods for volumetric airway analysis. At the same time, CBCT provides data relevant for orthodontic evaluation of the skeletal components of malocclusions that occur in mouth breathing patients. Therefore, it is recommended that a single protocol to be established when diagnostic tests are prescribed by different specialists, who are involved in the management of patients with mouth breathing. This protocol recommends this diagnostic test to be large field CBCT.

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