ORIGINAL PAPER

AIRWAY DIMENSIONS AND MANDIBULAR POSITION IN ADULTS WITH DIFFERENT GROWTH PATTERNS: A CONE-BEAM COMPUTED TOMOGRAPHY STUDY

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ABSTRACT

Introduction: Orthodontic treatment modalities depend on individual patient's growth pattern and mandibular position. The airway is an important determinant of treatment. Therefore, a clear correlation between different growth patterns, mandibular positions, and airway would lead to better diagnosis and more specific planning.

Objectives: The aim of this study was to evaluate mandibular position and its' relationship to pharyngeal airway dimensions in patients with different growth patterns using cone-beam computed tomography (CBCT).

Material and methods: CBCT scans of patients were assigned to vertical, average, and horizontal growth pattern types, based on angular (S-N/Go-Me) and linear (S-Go/N-Me) measurements. Data of included patients was used for 3-dimensional reconstruction of the pharyngeal airway to assess parameters, such as total airway volume, airway length, mandibular position, and correlation with different growth patterns. For statistical analysis, one-way ANOVA, post-hoc Tukey test (for pairwise comparisons), and Spearman's correlation with a significance level of 0.05 were applied.

Results: The mandibular distance from the airway was significantly higher in the horizontal growth pattern group ($p = 0.035$). Airway volume was lower in the vertical growth pattern group as compared with the horizontal growth pattern group ($p = 0.043$). A negative correlation was observed between mandibular position and airway length ($p = 0.021$, $r = -0.338$).

Conclusions: Subjects with horizontal growth patterns tend to have shorter and wider airways with their mandibles farther away, as compared to those with vertical growth patterns. To avoid the risk of compromising narrow airway dimensions, clinicians must take into account these findings while planning orthodontic and surgical treatment.

Key words: pharyngeal airway, CBCT, facial types, growth pattern, mandible.

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INTRODUCTION

The association of cranio-facial growth and development with the upper airway has been of specialists interest, including laryngologists, ear, nose, and throat (ENT) specialists, pediatricians, maxillofacial radiologists, oral surgeons, and orthodontists. Airway obstruction may cause changes in the breathing pattern, which may in turn, have an impact on development of cranio-facial structures. Moss famously stated that 'function decides form', and influenced many of the current orthodontic concepts. Solow and Kreiborg in their soft tissue-stretching

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hypothesis explained that soft tissues of the oral cavity and pharynx were influenced by the tongue, jaws, and head posture [1]. Postural changes of the head result in stretching of the muscles, cheeks, and lips causing narrow dental arches and upright incisors, as observed in patients with long faces [1, 2]. An American Association of Orthodontists' (AAO) white paper on obstructive sleep apnea and orthodontics stated that individuals with dolichocephalic cranio-facial morphology and high mandibular plane angles were predisposed to obstructive sleep apnea (OSA). The strength of this association was however not well-established [3].

Several other factors, such as a posteriorly-positioned hyoid bone, retrognathic mandible, bimaxillary retrusion, increased mandibular plane angle, and short mandibular body could cause tongue retrusion and a decrease in the pharyngeal airway space [4, 5]. Ceylan *et al.* noted a negative correlation between A point–nasion–B point angle (ANB) and pharyngeal airway size that was further confirmed by El *et al.* using CBCT imaging [6, 7]. However, the ANB angle, although commonly used in orthodontics, is insufficient to evaluate the relation between airway and mandibular position [8, 9]. Therefore, a new measurement criterion that calculates the distance between the airway and the mandible in the axial plane has been used in this study to directly link the airway with mandibular position.

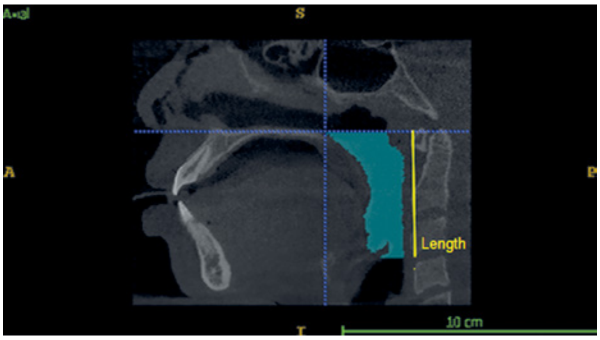

FIGURE 1. Airway length measurement

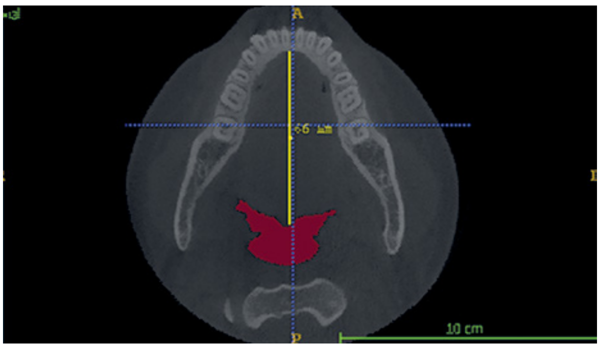

FIGURE 2. Linear distance between genial tubercle of mandible and anterior pharyngeal wall

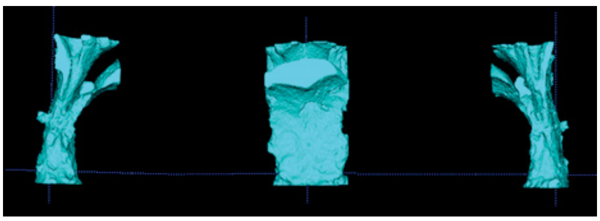

FIGURE 3. Three-dimensional airway reconstruction

Previous studies analyzed airway dimensions on lateral cephalograms and provided relevant data; however, some limitations in the form of anatomical variations, such as constricted transverse dimensions, were evident [10, 11]. To overcome these limitations, three-dimensional (3D) imaging can be used to enable better volume rendering, image reconstruction, and evaluation of the position of the jaws in direct relation to the airway. Although upper airway volume and morphology in patients with different growth patterns has been evaluated three dimensionally, mandibular position with respect to the airway was not considered [12, 13].

OBJECTIVES

The aim of the present study was to evaluate mandibular position and its' relationship to pharyngeal airway dimensions in patients with different growth patterns using CBCT. The results of this study would enable clinicians to better plan mandibular position in subjects with varying growth patterns.

MATERIAL AND METHODS

The present retrospective study was approved by the Institutional Ethics Committee (ACDS/IEC/83/Dec2018). Data was obtained by screening CBCT images in the archives of the Department of Orthodontics. The images were selected between January 2019 and January 2020. A sample size of 46 was estimated using parameters from a previous study with GPower software v. 3.1.9.2 to evaluate the relationship between mandibular position and airway dimensions, with a test power of 80% and a significance level of 0.05 [14].

A total of 46 adult patients' records were examined with the following inclusion criteria: subject aged between 18 to 30 years, no history of previous orthodontic treatment and orthognathic surgery, no cleft lip or palate, and no history of trauma. Patients with a history of tonsillectomy, adenoidectomy, or any other upper airway pathology were excluded.

Subjects were classified into horizontal, average, and vertical growth patterns on the basis of an angular measurement (S-N/Go-Me) and the posterior to anterior facial height ratio (S-Go/N-Me). For S-Go/N-Me, a ratio greater than 69% was considered horizontal, between 61% and 69% average, and less than 61% vertical growth pattern [15]. For the S-N/Go-Me angle, values less than 27° indicated horizontal, between 27° and 37° average, and more than 37° indicated vertical growth patterns [16]. On the basis of these measurements, 15 subjects (5 males and 10 females) were assigned to vertical, 16 subjects (4 males and 12 females) to horizontal, and 15 subjects (6 males and 9 females) to average growth pattern groups. The mean ages of individuals with vertical, horizontal, and average growth pattern were 23.13 ± 2.67, 22.56 ± 3.39, and 25.53 ± 1.89 years, respectively.

CBCT images were obtained in the form of digital imaging and communications in medicine (DICOM) files, and airway measurements were performed using ITK Snap (version 3.8.0, Cognitica; Philadelphia, Pa, USA) software.

Superior reference line was defined from the anterior nasal spine (ANS) through the posterior nasal spine (PNS), extending onto the posterior pharyngeal wall, while the inferior reference line was defined by a plane tangent to the most caudal projection of the third cervical vertebra, as described by Celikoglu *et al.* (Figure 1) [12].

To measure linear distance of the mandible to the pharyngeal airway and the length of the airway, image annotation mode in ITK SNAP software was used. Mandibular position was measured as the linear distance from the anterior pharyngeal wall to the genial tubercle in axial sections (Figure 2).

For volumetric airway measurements, the area of interest was delineated in the software, followed by segmentation and 3D modeling (Figure 3). For segmentation, images were oriented along Frankfurt horizontal plane (FH). Sagittal reference plane, perpendicular to FH plane was passing through nasion. Axial plane was constructed from nasion, perpendicular to both sagittal and horizontal planes (Figure 4) [12].

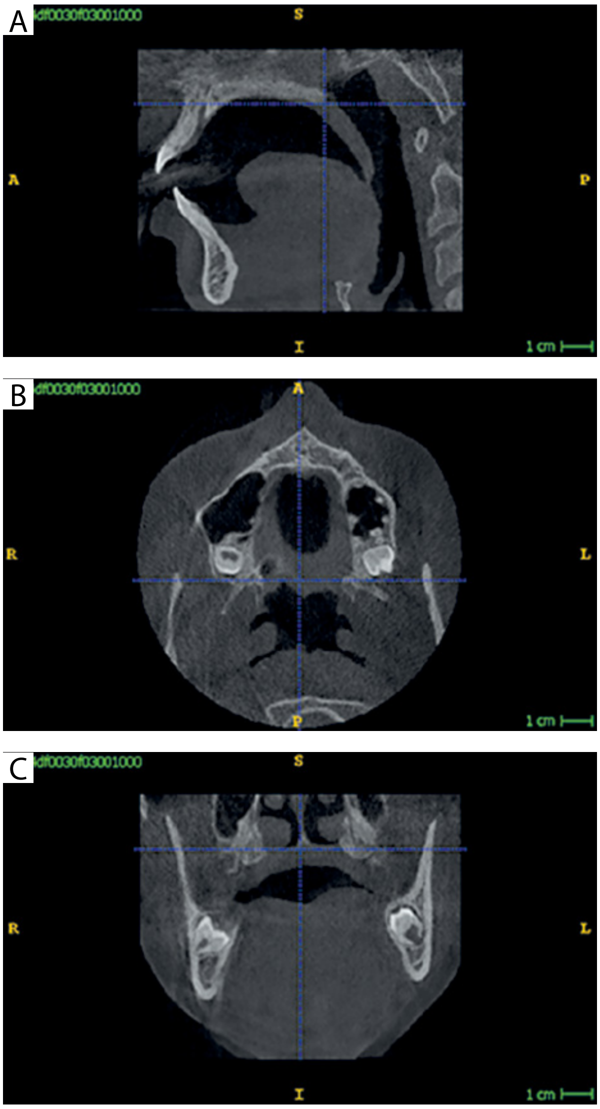

FIGURE 4. Image orientation for segmentation and 3D modeling

STATISTICAL ANALYSIS

Statistical calculations were carried out using Statistical Package for Social Sciences (SPSS) software for Windows version 22.0. Data was normally distributed and was verified using Kolmogorov-Smirnov test. In addition to descriptive statistics, in groups with normal distribution, one-way analysis of variance was used for inter-group comparison, and post-hoc Tukey test was used for pairwise comparisons. One-way ANOVA was performed to test if there were any significant differences for several variables among different groups. Correlations among different variables and pharyngeal airway measurements were analyzed using Spearman correlation coefficient test. For all statistical tests, the level of significance was set at $p < 0.05$.

RESULTS

The means and standard deviations of total airway dimensions in the subjects with vertical, average, and horizontal growth patterns are summarized in Table 1. One-way ANOVA found statistically significant differences between individuals with vertical, average, and horizontal growth patterns in terms of mandibular distance from the pharyngeal airway ($p = 0.035$). The mandibular distance from the airway was greatest in subjects with horizontal growth patterns (63.05 ± 2.65), followed by average and vertical growth patterns (60.83 ± 4.40 and 59.45 ± 4.04, respectively).

When airway length was evaluated, patients with vertical growth patterns had higher values (57.07 ± 5.73) as compared with patients with horizontal and average growth patterns (53.02 ± 7.26 and 54.69 ± 6.13), though differences were not statistically significant.

Volumetric data was obtained from a 3D airway modeling in subjects with different growth patterns (Table 2). The preliminary bivariate analysis showed that total airway volumes in horizontal growth pattern

TABLE 1. Comparison of airway volume, airway length, and mandibular distance (MD)

Variable	VGP (*n* = 15)	HGP (*n* = 16)	AGP (*n* = 15)	*F*-value	*p*-value
Volume	11,058.27 ± 5,159.36	17,480.50 ± 6,470.34	13,716.13 ± 9,267.45	3.159	0.052 (N.S.)
Length	57.07 ± 5.73	53.02 ± 7.26	54.69 ± 6.13	1.551	0.224 (N.S.)
TMD	59.45 ± 4.04	63.05 ± 2.65	60.83 ± 4.40	3.643	0.035*

*One-way ANOVA test. *Significant difference at p ≤ 0.05*

AGP – average growth pattern, HGP – horizontal growth pattern, VGP – vertical growth pattern, N.S. – non-significant, MD – mandibular distance

TABLE 2. Pairwise comparison

Variable	VGP vs. HGP	VGP vs. AGP	HGP vs. AGP
Volume	0.043*	0.570 (N.S.)	0.318 (N.S.)
Length	0.197 (N.S.)	0.570 (N.S.)	0.752 (N.S.)
TMD	0.028*	0.576 (N.S.)	0.238 (N.S.)

*Post-hoc Tukey test. *Significant difference at p ≤ 0.05*

AGP – average growth pattern; HGP – horizontal growth pattern; VGP – vertical growth pattern; N.S. – non-significant; MD – mandibular distance

TABLE 3. Correlation coefficient between mandibular position and airway dimensions

TMD	*r*-value	*p*-value
Volume	–0.011	0.943 (N.S.)
Length	–0.3 38	0.021*

*Spearman correlation test. *Significant difference at p ≤ 0.05*

AGP – average growth pattern, HGP – horizontal growth pattern, VGP – vertical growth pattern, N.S. – non-significant, MD – mandibular distance

subjects (17,480.50 ± 6,470.34) were significantly higher than in subjects with vertical growth patterns (11,058.27 ± 5,159.36).

Correlations between the pharyngeal airway volume, length, and mandibular distance from the anterior pharyngeal wall were evaluated using Spearman correlation coefficient, as shown in Table 3. The position of the mandible in relation to the airway showed a significant negative correlation with that of airway length ($r = –0.338$, $p = 0.021$), but not with airway volume ($r = –0.011$, $p = 0.943$).

DISCUSSION

Different skeletal growth patterns may develop as a result of factors, such as growth of the maxilla and mandible, dento-alveolar processes, eruption of the teeth, and tongue function. Most subjects with vertical growth patterns are known to have concomitant pharyngeal airway obstruction, with associated snoring, daytime sleepiness, and mouth breathing [17, 18]. Hence, the relationship between growth patterns and airway must be assessed for better orthodontic treatment planning.

Many studies in literature have used lateral cephalometry to correlate airway dimensions with skeletal growth patterns. However, two-dimensional analysis of a three-dimensional structure failed to provide adequate accuracy. Furthermore, a systematic review by Indriksone *et al.* reported that evidence was insufficient to conclude that airway dimensions vary in different sagittal growth patterns [19]. Therefore, CBCT imaging was used in this study to correlate airway dimensions and mandibular position in various growth patterns to obtain a clearer picture.

In the present study, mandibular position was evaluated by measuring linear distance from the anterior pharyngeal wall to the genial tubercle in the axial section. The mandibular distance from the airway was greatest in subjects with horizontal, followed by average and vertical growth patterns. This could be due to the upward and forward rotation of the mandible in horizontal growers, increasing the distance between the airway and mandible. Assessment of this distance is particularly important since surgical mandibular reversal in such patients could negatively affect their airways. A similar study measured mandibular position from the airway in class I and II subjects of Chinese origin in the sagittal section [14]. The measurement was done from the tip of the uvula (U-point) posteriorly to the genial tubercle anteriorly. The limitation of this method was that the U-point used as a landmark to measure the distance between the airway and the mandible, was not a stable, immobile bony landmark.

Airway length is influenced by mandibular position and the type of skeletal malocclusion, as reported by several researchers [20-23]. However, most of these studies were conducted in subjects with different sagittal malocclusions, with limited evidence for vertical dimensions [24, 25]. In the present study, it was noted that airway length was highest in the vertical and least in horizontal growth patterns. This is in concordance with a previous study performed using lateral cephalometry, which found that vertical airway length was significantly shorter in hypo-divergent group [26].

Upon comparison of mandibular position with respect to the airway, significant negative correlation with that of airway length was noted. This phenomenon can be explained by the Moss functional matrix theory. A longer airway may induce vertical growth of the jaws, likewise shorter airway length in normo-divergent or hypo-divergent growth patterns may stimulate the growth of mandible in a more forward direction, rather than in the vertical direction [27]. The findings of the present study are in accordance with that theory, where mandibular distance from the airway is lesser in cases with a longer airway, as in vertical growers.

It was also observed that the average airway volume in horizontal growth pattern subjects was significantly greater than in those with vertical growth patterns, which is similar to findings by Nejaim *et al.* [28]. Decreased airway volume in vertical growth patterns could be due to downward and backward mandibular rotation and posterior tongue displacement. However, Salehi *et al.* found no significant relationship between airway volume and vertical facial types [29]. These variations in findings can be a result of differences in methodologies, including software used, sample size, and imaging modality.

Obstructive sleep apnea (OSA) is a rising concern, and orthodontic treatment has an important role to play in its' treatment. Comprehensive orthodontic treatment should include a correct evaluation of the airway as well as growth patterns. Vertical growers are prone to suffer from OSA and lower airway volume, hence clinicians must endeavor to preserve or enhance the airway dimensions in such patients. When possible, treatment, such as mandibular advancement using growth modification or surgery, must be attempted. If the airway dimensions are at risk of worsening after mandibular setback, it must be avoided.

One of the limitations of this study is that, although subjects with previous history of upper airway pathology, tonsillectomy, and adenoidectomy were excluded, a few asymptomatic subjects could have been included in the sample unknowingly. However, this has no influence on respiratory function when airway dimensions are recorded, as reported by Laine-Alava *et al.* [30]. Another limitation is that the airway, which is a dynamic structure in constant motion, cannot be as appropriately measured three-dimensionally when compared to 4D measurement techniques, which can also calculate airway pressure and resistance. Therefore, observations from this study could be used as a clinical guide during diagnosis and treatment planning, especially in cases with different dento-facial patterns requiring mandibular repositioning sagitally or vertically.

CONCLUSIONS

Based on the results of this study, it can be concluded that the mandibular distance relative to the airway is lesser in patients with vertical growth patterns. This is of importance, since surgical mandibular set back in such patients may negatively affect their airway. Furthermore, vertical growth patterns show significantly lower airway volumes. Therefore, in clinical scenarios, further downward and backward mandibular rotation should be avoided to prevent further reduction of the airway volume. Also, the pharyngeal airway length is greater in vertical growth patterns, although the results were not statistically significant.

CONFLICT OF INTEREST

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

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