Correlation between the upper airway volume and the hyoid bone position, palatal depth, nasal septum deviation, and concha bullosa in different types of malocclusion: A retrospective cone-beam computed tomography study

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Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online)

Dent Med Probl. 2021;58(4):509–514

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Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
The authors would like to thank Dr. Amir Azizi for the statistical analysis and Dr. Farzaneh Dastan for comments that greatly improved the manuscript.

Received on April 7, 2020
Reviewed on July 6, 2020
Accepted on November 4, 2020

Published online on November 30, 2021

Cite as
Dastan F, Ghaffari H, Hamidi Shishvan H, Zareiyan M, Akhlaghian M, Shahab S. Correlation between the upper airway volume and the hyoid bone position, palatal depth, nasal septum deviation, and concha bullosa in different types of malocclusion: A retrospective cone-beam computed tomography study. *Dent Med Probl.* 2021;58(4):509–514. doi:10.17219/dmp/130099

DOI
10.17219/dmp/130099

Abstract

Background. The upper airway volume is among the factors that affect orthodontic treatment plans. Cone-beam computed tomography (CBCT), as an accurate diagnostic modality, can help assess anatomical structures associated with the upper airway volume.

Objectives. This study aimed to use CBCT to determine if there are differences in the upper airway volume between different sagittal and vertical skeletal patterns, considering the hyoid bone position, palatal depth, nasal septum deviation (NSD), and concha bullosa.

Material and methods. From among 105 initial CBCT samples retrieved from the archive of a private radiology clinic in Tehran, Iran, 90 CBCT scans of 27 males and 63 females aged 17–65 years were considered in the study according to the inclusion criteria. The upper airway volume was assessed with regard to Angle's classification (using the A point–nasion–B point angle (ANB)), the vertical skeletal dimension (using the sella–nasion plane to mandibular plane angle (SN–MP)), the hyoid bone position, palatal depth, NSD, and concha bullosa, using CBCT and the NNT® software. The one-way analysis of variance (ANOVA), Levene's test and the *t* test were used to analyze the data with the SPSS Statistics for Windows software, v. 17.0.

Results. The upper airway volume was significantly smaller in long-face cases ($p = 0.037$). There was no significant correlation between the upper airway volume and Angle's classification, the hyoid bone position, palatal depth, NSD, and concha bullosa.

Conclusions. The vertical skeletal dimension was the only parameter that was related to the upper airway volume. The results of this study can be considered while preparing orthodontic treatment plans.

Keywords: upper respiratory tract, pharynx, three-dimensional assessment, jaw relationship

Introduction

The relationship between the airway volume and different types of malocclusion has been researched for many years. The upper airway volume is very important in orthodontics, as it is related to craniofacial growth and development. It may be affected by different positions of the jaws and may determine various treatment plans. Trying to identify and manage the confounding factors with regard to the upper airway volume can be helpful in orthodontic treatment. The upper airway volume may be affected by sagittal (class I, II and III) and vertical (short, normal and long face) dentoskeletal malocclusion as well as facial morphology.[1,2] Also, conditions such as functional anterior shifting,[3] the head posture,[4] maxillary protraction,[5] palatal depth, the hyoid bone position,[6] nasal septum deviation (NSD), and concha bullosa have effects on the airway volume.[7]

The relationship between various types of dentoskeletal malocclusion and the upper airway volume is differently described in different studies.[1,2,8] Sahoo et al. evaluated the hyoid bone position in skeletal class II malocclusion after the advancement of the mandible and realized that the hyoid bone moves forward as the mandible is advanced.[9] Although some studies have evaluated the relationship between maxillary expansion and the upper airway volume,[10] there are few studies on the relationship between palatal depth and the airway volume.

The airway volume has been measured with various imaging techniques, including computed tomography (CT), cone-beam computed tomography (CBCT), cephalometry, fluoroscopy, nasopharyngoscopy, and magnetic resonance imaging (MRI).[11] Most of the previous studies had limitations, because they evaluated the upper airway volume based on patients' lateral cephalograms. A three-dimensional (3D) CBCT system provides more reliable landmark identification of anatomical structures than two-dimensional (2D) cephalometry. Cone-beam computed tomography allows the exact measurement of the airway space and identifies different types of malocclusion in orthodontics. A lower radiation dose, lower costs, shorter scanning time, and overall accuracy have made the CBCT technology a preferred method to evaluate the airway volume.[12]

The aim of this study was to use CBCT to evaluate the upper airway volume in different types of malocclusion with regard to special criteria, such as the hyoid bone position, palatal depth, NSD, and concha bullosa.

Material and methods

This retrospective cross-sectional study was performed using the CBCT images of 105 patients, randomly selected from the archive of a private radiology clinic in Tehran, Iran. Ninety CBCT scans of 27 males and 63 females aged 17–65 years were included in the study. The inclusion criteria were: complete medical history records; no dentofacial syndromes; and no history of orthodontic treatment, orthopedic maxillary expansion, orthognathic surgery, tonsillectomy, or adenoidectomy. The CBCT scans were excluded if the airway was not clear, the hyoid bone position as well as the nasion (N) and sella (S) points were not obvious, or if there were artifacts.

The CBCT scans and the patients' medical history forms were gathered. All CBCT images were obtained using a NewTom® VG machine (NewTom, Imola, Italy) with the following settings: 2 mA; 110 kVp; 10 s; and a field of view (FoV) of 18 cm × 18 cm. A resolution of 1,024 × 31,024 pixels and 12 bits per pixel (4,096 gray scale) was applied. The images were taken with the teeth in maximum intercuspation, a natural head position, and at the end of the exhalation period, when the patient was not swallowing. Lateral cephalograms were obtained for all patients based on the CBCT data.

According to Angle's classification using the A point–nasion–B point angle (ANB), the samples were divided into 3 groups: class I (–0.5° < ANB < 4.5°) (n = 42); class II (ANB ≥ 4.5°) (n = 34); and class III (ANB ≤ –0.5) (n = 14).[13] The sella–nasion plane to mandibular plane angle (SN–MP) was used to categorize different vertical growth patterns (low angle: <26°; normal angle: 26–38°; and high angle: >38°).[14]

The distance from the most prominent point of the hyoid bone to menton (Me) was measured to evaluate the hyoid bone position sagittally. Also, the distance between the most prominent point of the hyoid bone and the mandibular plane, i.e., the gonion–gnathion line (Go–Gn), was considered as the hyoid bone position in the vertical dimension. The parasagittal view was used for these measurements (Fig. 1).

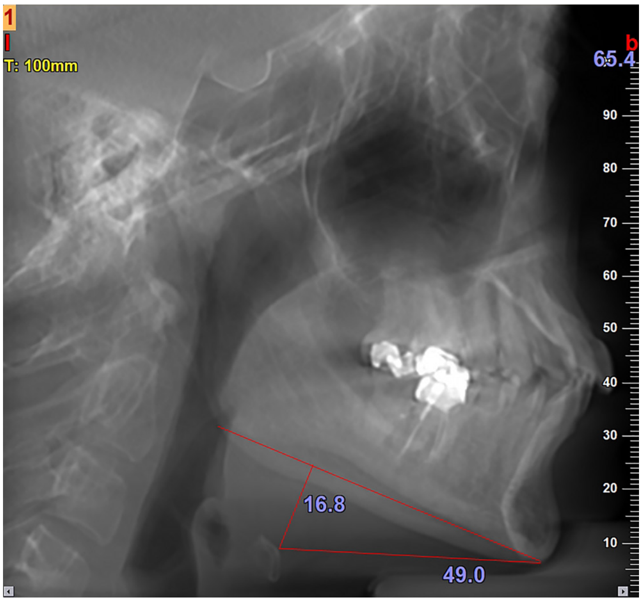

Fig. 1. Evaluation of the hyoid bone position based on menton (Me) and the mandibular plane (Go–Gn)

To assess palatal depth, a transverse line was drawn between the mesiobuccal cusp tips of maxillary first molars in the axial view. Then, the distance between this transverse line and the palatal bone in the midline of the coronal view was considered to be palatal depth (Fig. 2).

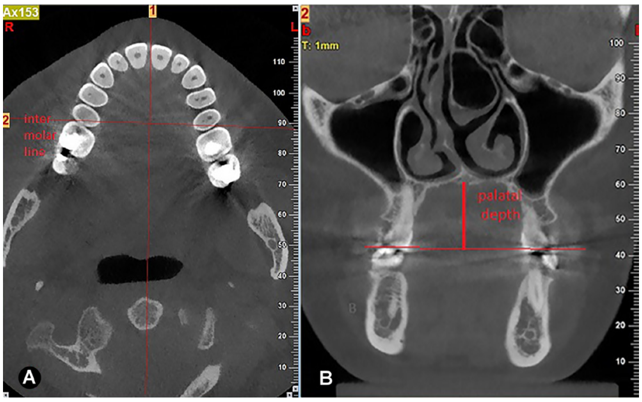

Fig. 2. Evaluation of palatal depth

A – axial view; B – coronal view.

All measurements were obtained by an experienced orthodontist via the export of the CBCT data in the DICOM format and its import into the NNT® viewer, v. 2.21 (NewTom).

The oropharyngeal airway was circumscribed by the palatal plane, i.e., the anterior nasal spine–posterior nasal spine line (ANS–PNS), reaching to the posterior wall of the pharynx, and a line parallel to the palatal plane, extending to the most antero-inferior point of the second cervical vertebra (C2 dens).

The inferior limit of the nasopharynx was ANS–PNS and the superior limit was the last slice before the posterior wall of the pharynx, fusing with the nasal septum. It was observed in the axial view first, and then projected to the sagittal view (Fig. 3). The upper airway volume was calculated with the NNT software (Fig. 4).

Any deviation greater than 4 mm in the midpoint of the nasal septum with regard to the line of symmetry was defined as NSD in the coronal view. Concha bullosa was considered to be the presence of pneumatization of any size within the inferior, middle or superior conchae.[15]

After 2 weeks, the scans of 20 patients were randomly reassessed to determine the reliability of the measurements. Applying Dahlberg's formula (Equation 1) to the 1st and 2nd angular and linear measurements revealed no considerable differences between them.

$$EM = \sqrt{\frac{\sum d^2}{2n}} \qquad (1)$$

where:
EM – error of measurement;
d – difference between the 2 recordings for the individual;
n – number of double recordings.

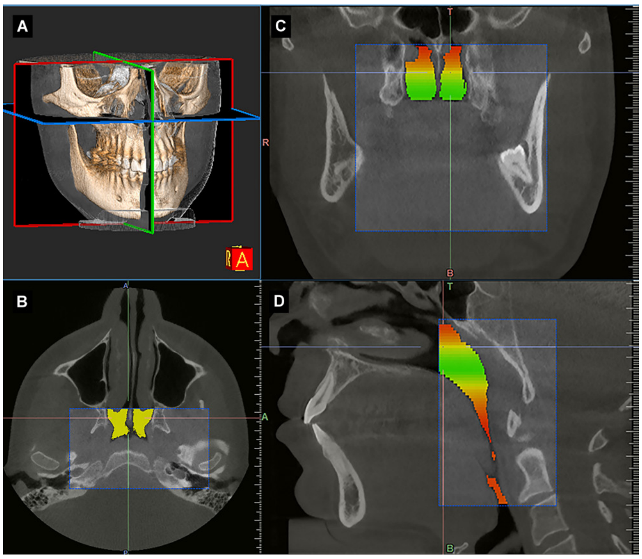

Fig. 3. Measurement of the upper airway volume

A – axial, coronal and sagittal planes; B – the last slice before the posterior wall of the pharynx, fusing with the nasal septum in the axial view; C – coronal view; D – parasagittal view, extending to the most antero-inferior point of the second cervical vertebra (C2 dens)

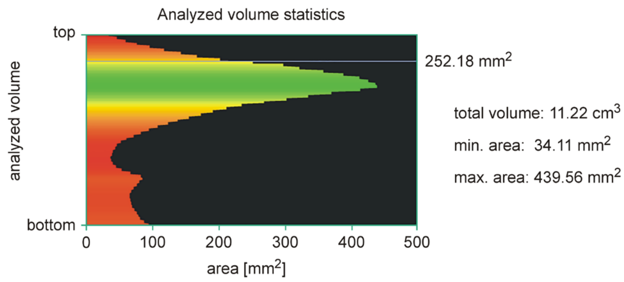

Fig. 4. Calculating the upper airway volume with the NNT software

Statistical analysis

The one-way analysis of variance (ANOVA) was used to assess differences in the total upper airway volume with regard to age and gender among different skeletal classification groups. Levene's test was used to analyze the equality of variances and the *t* test for the equality of means. The SPSS Statistics for Windows software, v. 17.0 (SPSS Inc., Chicago, USA) was used for the statistical analysis. A *p*-value <0.05 was considered statistically significant.

Results

From among 105 initial CBCT samples, 90 CBCT scans of 27 males and 63 females aged 17–65 years were analyzed in the study. According to the multiple linear regression analysis, the upper airway volume was significantly different for various vertical skeletal dimensions. A smaller airway volume was detected in long-face cases ($p = 0.037$).

The upper airway volume was significantly increased in older subjects ($p = 0.042$) and it was significantly increased in females ($p = 0.036$). There was no significant relationship between the upper airway volume and malocclusion in terms of Angle's classification ($p = 0.541$). There was no correlation between the upper airway volume and the hyoid–menton distance (H–Me), the hyoid–mandibular plane distance (H–MP), palatal depth, and concha bullosa. Pearson's correlation coefficients (r) and p-values for particular parameters with regard to the upper airway volume are presented in Table 1.

According to the t test analysis, there was no statistically significant relationship between NSD and the following parameters: H–Me; H–MP; palatal depth; and the upper airway volume ($p > 0.05$).

There was a statistically significant negative relationship between H–Me and the vertical dimension. The distance H–Me was greater in short-face cases ($p = 0.002$). The distance H–Me was not statistically significantly different with regard to various types of malocclusion according to Angle's classification, age and gender ($p > 0.05$).

There was a statistically significant relationship between H–MP and Angle's classification (class III > class I > class II) ($p = 0.018$). The distance H–MP was statistically significantly greater in males ($p = 0.008$) and in patients with concha bullosa ($p = 0.001$).

Palatal depth was reported to be statistically significantly greater in males ($p < 0.05$).

The mean (M) and standard deviation (SD) values for particular airway parameters with regard to Angle's classification and vertical growth patterns are presented in Table 2.

Table 1. Correlations between the upper airway volume and the parameters studied

Parameter	*r*	*p*-value†
Angle's classification	0.063	0.541
Vertical growth pattern	−0.214	0.037*
Age	0.210	0.042*
Male gender	−0.215	0.036*
H–Me	0.136	0.201
H–MP	−0.117	0.274
Palatal depth	−0.054	0.611

r – Pearson's correlation coefficient; H–Me – hyoid–menton distance; H–MP – hyoid–mandibular plane distance; † – ANOVA; * statistically significant.

Discussion

The upper airway volume is vital in orthodontics, as it is related to craniofacial growth and development.[16] The upper airway volume is associated with different types of malocclusion and various structures, such as NSD, concha bullosa, and the hyoid and palatal bones. Therefore, the aim of this study was to use CBCT to evaluate the upper airway volume in different types of malocclusion and consider the associated structures.

This study found that there was a noticeable relationship between the upper airway volume and the vertical craniofacial dimension. The upper airway volume was increased in short-face cases. Also, it was increased in older subjects. The upper airway volume was greater in females in comparison with males. Angle's classification, the hyoid bone position, palatal depth, NSD, and concha bullosa were not statistically significantly related to the upper airway volume.

Lateral cephalometry provides limited evaluation of the airway, as it is a 2D sagittal projection.[17] In recent years, CBCT has improved the accuracy of the analysis of the airway space and different types of malocclusion in orthodontics.[18] Therefore, CBCT was used for all measurements in this study.

Some researchers claim that there is a correlation between a smaller airway volume and class II malocclusion.[19] On the other hand, Shokri et al. observed a greater airway volume in skeletal class III cases, but the difference between class I and class II was not statistically significant.[2] In the present study, however, there was no significant relationship between different types of malocclusion according to Angle's classification and the airway volume. Differences in the values of the airway volume with respect to Angle's classification may be attributed to the chosen sensitivity values and the ANB ranges, which were different in different studies.

In contrast to the present study, some researchers have shown that the airway volume is not statistically significantly different with respect to the vertical craniofacial dimension.[1] Conversely, in a study similar to the present one, Alhammadi et al. determined that the airway volume was decreased in long-face cases.[20] The contradicting results might be due to the different age ranges of the study groups.

The hyoid bone plays an important role in the maintenance of the upper airway space and its position changes according to the different positions of the mandible.

Table 2. Comparison of the airway parameters with regard to Angle's classification and vertical growth patterns

Airway parameter	Angle's classification			Vertical growth pattern		
	class I	class II	class III	short face	normal face	long face
Upper airway volume	17.523 ±6.646	21.730 ±5.725	20.013 ±6.323	21.936 ±6.146	18.988 ±6.663	18.249 ±6.222
H–Me	46.291 ±4.963	49.679 ±7.399	47.983 ±5.142	50.532 ±7.101	47.842 ±4.987	45.655 ±4.389
H–MP	14.674 ±5.190	11.264 ±4.564	14.835 ±4.438	13.737 ±4.953	13.734 ±4.770	15.015 ±5.158
Palatal depth	21.006 ±3.533	19.614 ±2.600	19.421 ±2.571	19.216 ±2.850	20.171 ±3.163	20.391 ±2.996

Data presented as mean ± standard deviation ($M \pm SD$).

Based on our measurements, there was a highly significant relationship between H–MP and Angle's classification (class III > class I > class II). There was no statistically significant relationship between the hyoid bone position and the upper airway volume. Similarly, in a long-term study, the hyoid bone moved significantly forward after mandibular advancement operations on class II cases, but the airway volume remained almost unchanged.[21] In contrast, in a study of class III patients, the hyoid position did not change after mandibular setback surgery in the long term, but the nasopharynx volume increased significantly.[22] The conflicting results of these studies may be due to the different landmarks in the assessment of the anatomical position of the hyoid bone. In the present study, in order to increase the accuracy of measurements, the hyoid bone position was determined based on Me (as the sagittal position) and MP (as the vertical position). In other studies, the distance between the hyoid bone and retrognathion (RGn) (the most prominent point of the posterior border of the mandibular symphysis) was considered to determine the hyoid bone position.[23] Also, the conflicting results may be due to the chosen radiological modality. Some researchers have stated that the hyoid triangle method was applicable to lateral cephalometry, but not to 3D CBCT; therefore, CBCT showed a lesser correlation between the hyoid bone position and the airway volume.[6] Furthermore, the tone of the hyoid muscular suspension apparatus is different in the upright and supine positions. In the present study, the examination was performed with a NewTom VG CBCT unit in the upright position. Therefore, the results of various studies may differ due to the different positions of patients during examination.

The relationship between palatal depth and the upper airway volume was not noticeable in the present study. Similarly, many investigations have shown that there is no statistically significant relationship between these two items.[24] This is in contrast with a recent study showing that a smaller palatal depth was correlated with the airway obstruction in children.[25] The cause of such conflicting results may be the different age ranges of patients.

Since the nasal septum is a relevant structure in the airway, we evaluated the relationship between NSD and the upper airway volume. The present assessment showed no correlation between NSD and the upper airway volume. Wanzeler et al. reported that NSD influenced the oropharynx volume.[7] They showed that the oropharynx volume was increased in NSD patients, although the presence of NSD was not associated with facial types.[7] The section of the scan in which NSD was evaluated is the probable reason for the differences between the studies.

Concha bullosa is a common anatomical problem that may accompany NSD. The present study did not find any statistically significant relationship between concha bullosa and the upper airway volume. This is similar to the research conducted by Balikci et al.[15] The authors of the present study predicted that the pneumatization of the conchae might decrease the nasopharyngeal space volume; however, the results of the study did not support this assumption.

The tongue dimension as a possible factor influencing the upper airway volume cannot be assessed accurately by means of CBCT. Thus, further studies are recommended with the use of other modalities, such as MRI.

Conclusions

In conclusion, the upper airway volume was greater in short-face subjects, and especially in older females. There was no correlation between the upper airway volume and the anatomical and morphological variations, such as malocclusion according to Angle's classification, the hyoid bone position and palatal depth.

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