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Comparative Evaluation of Upper Airway Dimensions With Acoustic Rhinometry and Cone-Beam Computed Tomography

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ABSTRACT

The purpose of this retrospective study was to correlate the narrowest area and volume of nasal cavity assessed by acoustic rhinometry (AR) with the oropharynx area and volume assessed by cone-beam computed tomography (CBCT).
This retrospective study was carried out on CBCT images and AR datas of 45 mouth-breathing individuals (27 male and 18 female) aged between 12-14 years. The examinations assessed: (a) acoustic rhinometry: nasal volume (Vol) and minimum cross-sectional area (MCA) 1 and 2 of nasal cavity; (b) cone-beam computed tomography: oropharyngeal volume and area. The results were evaluated by Pearson correlation analysis. $p<0.05$ was accepted statistically significant.
There was no statistically significant relation among airway volume and nasal cavity parameters (MCA1, MCA2 and nasal volume) ($p>0.05$). There was a low negative correlation among airway area and nasal volume ($r=-0.394$; $p=0.013$).
The highest correlation was found only between the airway area and the nasal volume when the AR results were compared with the data obtained from the CBCT imaging technique.

Keywords: Acoustic rhinometry, Cone-beam computed tomography, Mouth breathing

Introduction

Upper airway is a complicated structure consisting of nose, pharynx, larynx and extrathoracic trachea (1). The nasal cavity starts from the nostrils, continues to the choana and ends in the nasopharynx. The narrowest point of the nose is the nasal valve region, also known as the ostium internum or isthmus nasi, with a total surface area of 55-64 mm² (2,3). The pharynx is located behind the nasal and oral cavity and divided into 3 parts as nasopharynx, oropharynx and hypopharynx. The oropharynx is surrounded by soft palate on the top, tongue base on the bottom, palatoglossal and palatopharyngeal plicas on the lateral sides and lies at the grade of the 2nd and 3rd cervical vertebrae at the back (4). It is the most significant region of the pharynx in upper airway obstructions.

Objective evaluation of the nasal patency, which is one of the most important elements of the respiratory system, is important for both diagnosis and treatment. There are several diagnostic tests like rhinostereometry, radiographic techniques, rhinomanometry and acoustic rhinometry in which airflow is used as a parameter in the assessment of nasal respiratory function (5). These tests should be easy to use, reliable and reproducible in order to help treatment planning (5).

Previous methods for the assessment of nasal airway area and volume included lateral and posterior-anterior cephalometric radiographs (6-8). Although these methods are useful in determining the presence of obstruction in the nasal and pharyngeal regions, they have failed to measure nasal resistance, airflow or nasal cross-sectional area (9).

Modern three-dimensional (3D) imaging procedures, like magnetic resonance imaging (MRI), computed tomography (CT) and cone-beam computed tomography (CBCT) have enabled the volume and area quantification of intracranial structures (10,11). Although CT has the ability to show bone, soft tissue and air at the same time (12), high levels of radiation and high cost of scanning restricted its use in dentistry (13).

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Due to similar signal intensities for bone and air, MRI is less suitable for the evaluation of nasal cavity and paranasal sinuses. CBCT allows three-dimensional volumetric, surface and cross-sectional examination of craniofacial structures (14). Although this method is often used to view mineralized tissues, it also lets clinicians to measure the cross-sectional area and total airway volume of the patients (15-17).

Acoustic rhinometry (AR), is used to evaluate the patency of the nasal passage (18). This method was first used by Hilberg et al. (19) in 1989 to measure the dimensions and geometry of the nasal cavity. The working principle of AR is based on the analysis of sound reflected from the walls of the nasal cavity. With this technique, the topographic map of the nasal airway is obtained by using reflected sound waves in the measurement of nasal cavity area and volume and converting sound waves into area-distance graphs (18). Measurements with AR are simple, noninvasive, rapid, objective, reproducible and requires minimal patient cooperation (18). Thus, AR is an alternative method to CBCT for the evaluation of 3D changes in the nasal cavity. Due to the absence of AR in dental clinics and the difficulty in its supply, CBCT may be substitution.

To fully understand airway, it is important to comprehend how the changes in nasal cavity correlate with changes in oropharenx. Therefore, the purpose of this study was to correlate the narrowest area and volume of nasal cavity assessed by AR with the oropharynx area and volume assessed by CBCT. Also, the predictability of AR measurements via CBCT measurements was evaluated. The null hypothesis was that volume and area of nasal cavity had no correlation with volume of oropharenx.

Materials and methods

The power analysis were done using G * Power software 3.1.3 (Franz Faul University, Kiel, Germany). The sample size was calculated based on based on 80% power and 5% significance level to determine a correlation coefficient of 0.41 in the narrowest cross-sectional areas (MCA1) of the patients. So, a sample of 45 patients were recruited in the study.

Subjects: This retrospective study was performed on CBCT images and AR records of 45 mouth-breathing individuals (27 male and 18 female) aged between 12-14 years at the Department of Orthodontics, Faculty of Dentistry, ### University. **These selected patients were diagnosed with mouth breathing by the ENT specialist in ### University as a consultation result:** The study was confirmed by the ethics committee of ### University (No: ###). Patients whose CBCT images and AR recordings were suitable in terms of both time and recording quality were included in the study. Other selection criteria were; no systemic disease or syndrome, no clinical evidence of a pathologic condition from the nasopharynx to the larynx, no previous orthognathic surgery and no history of tonsillectomy or adenoidectomy.

Instrumentation and procedure: The AR records were acquired with a 2-microphone acoustic rhinometer (RhinoMetrics, Lynge, Denmark). Each AR test was made by an experienced technician in a standard mode based on the criteria and principles recommended by the AR Standardization Committee (20). Nasal cavity parameters, i.e. minimal Cross Section Area (MCA) 1, MCA2, and volume (Vol) were measured after the application of topical decongestants. The narrowest cross-sectional area between the entrance of the nasal cavity and the 2.2 cm gap was defined as MCA1 and the narrowest cross-sectional area within the cavity from 2.2 cm to 5.4 cm was defined as MCA2. The volume also referred to the total volume of the nasal cavity (5).

Before CBCT records were taken, informed consent was acquired from all patients as a routine protocol. All images were acquired in supine position with a NewTom 5G CBCT machine (QR srl, Verona, Italy) with 110 kVp, 1-20 mA with 15x12 field of view (FOV) and standard resolution mode (0.2 mm voxel size). CBCT images were evaluated in sagittal plane by using Dolphin 3D software (Dolphin Imaging & Management Solutions, Chatsworth,CA, USA) (Figure 1). For determining the area, the sagittal image of the airway that allows the most obvious visualization of the posterior nasal spine and the second cervical vertebra was chosen. For each patient, the oropharyngeal airway area was defined by placing seed points in the boundaries on the selected figure. The software creates a segmented region based on seed points (yellow dots) placed. (Figure 1). In all measurements, the superior border of the oropharyngeal airway was defined as a plane parallel to the Frankfort plane and passing through the most distal part of the posterior nasal spine and the lower border was detected as a plane parallel to the Frankfort plane and drawn along the anterior inferior point of the second cervical vertebrae (21). In all measurements, airway

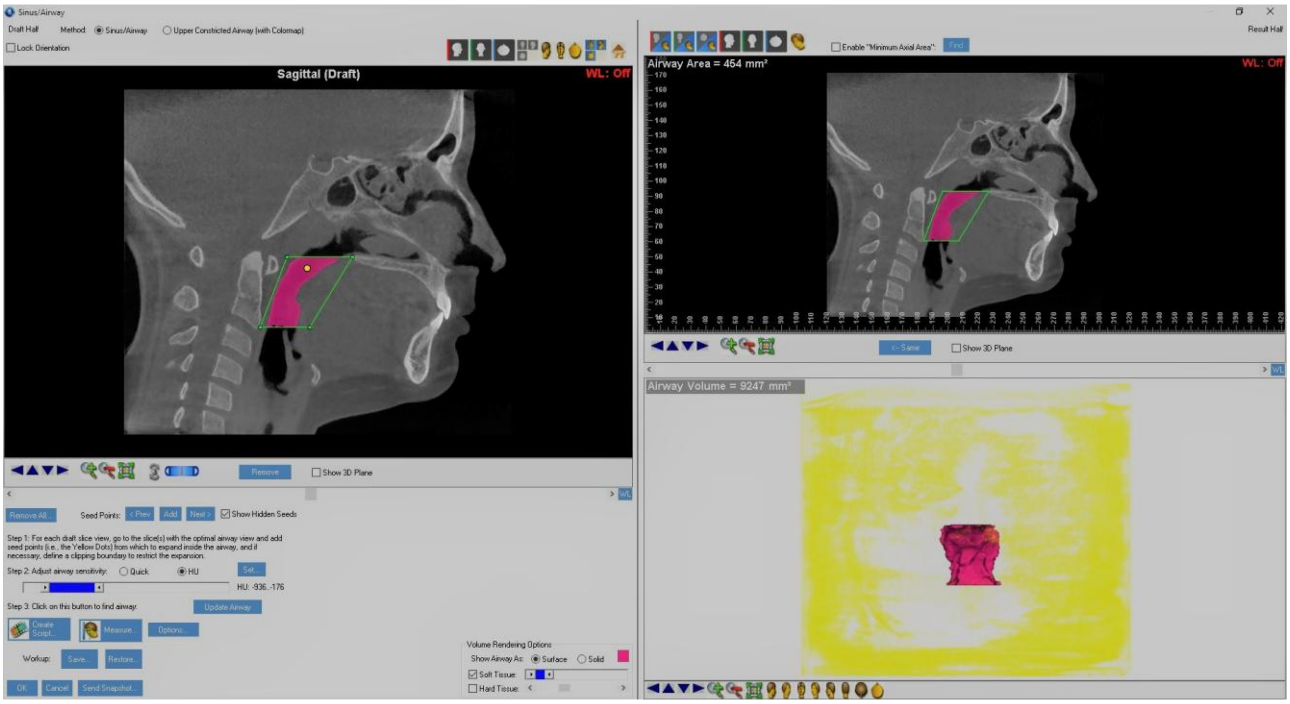

Fig. 1. Airway Area and Volume Measurement With Dolphin 3d Software

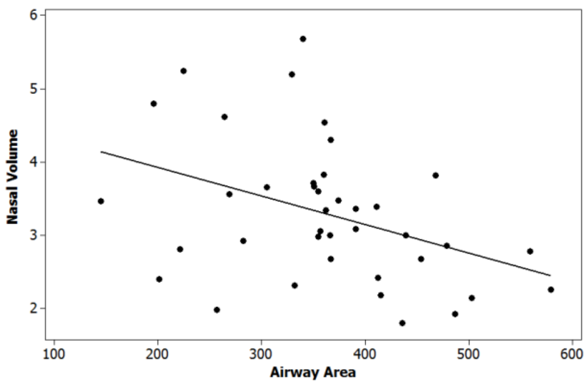

Fig. 2. Scatter Plot of Correlation Between Airway Area And Nasal Volume

sensitivity was adjusted at the same Hounsfield (HU) levels. After selecting the relevant area, the oropharyngeal volume was calculated automatically by software the in cubic millimeters (mm^3), while the airway area was calculated in millimeters square (mm^2). Also, the predictability of AR measurements via CBCT measurements was evaluated.

15 CBCT images were redigitized by the same researcher (xx) 3 weeks after the initial measurements were performed. For the evaluation of method error, the Dahlberg formula (22) was employed. Intraexaminer reliability was measured using the intraclass correlation coefficient (ICC).

Statistical Analysis: The data were analyzed by IBM SPSS Statistics Standard Concurrent User V 25 (IBM Corp., Armonk, New York, USA). The normal distribution of the numerical variables was assessed by the Shapiro Wilk normality test and Q-Q graphs. The relationships between numerical variables were evaluated by Pearson correlation analysis. The volume estimation performance of airway area was evaluated by linear regression analysis. $p<0.05$ value was accepted to be statistically significant.

Error of the Method: Standard errors were calculated for all measurements, all of which were found to be within acceptable limits. High degree of intraexaminer reliability was achieved for all variables (ICC= 0.958-0.989).

Results

The results of Pearson correlation coefficients were shown in Table 1. According to Pearson correlation analysis, there was no statistically significant relation among airway volume and nasal cavity parameters (MCA1, MCA2 and nasal volume). Also no statistically significant relationship was found between the airway area and MCA1 and MCA2. There was a weak negative correlation between airway area and nasal volume ($r=-0.394$; $p=0.013$) (Figure 2).

The test statistics obtained from the regression model were given in Table 2. Linear regression analysis model for volume estimation using airway value was found to be statistically significant ($F=6.811$; $p=0.013$). According to the R^2 value obtained as a result of the model, the airway area was defined as 15.5% of the airway volume.

Table 1. The Results of Pearson Correlation Coefficients

	MCA1 (cm^2)	MCA 2 (cm^2)	VOL (cm^3)
Airway Volume (mm^3)			
r	0,077	0,267	0,020
p	0,640	0,100	0,903
Airway Area (mm^2)			
r	-0,157	-0,122	-0,394
p	0,341	0,461	0,013

R indicates pearson correlation coefficient; MCA1, Minimum cross-sectional area 1; MCA2 Minimum cross-sectional area 1; VOL Volume

Table 2. Linear Regression Analysis Results For Volume Value

	β	se of β	t	p
Constant	4,705	0,558	8,432	<0,001
Airway	-0,004	0,001	2,610	0,013

se: Standard error

Based on these findings, the null hypothesis was rejected.

Discussion

Nasal obstruction is one of the most common complaints in patients applying to the ear-nose-throat (ENT) clinics (23). Nasal obstruction may cause mouth breathing in people and increase pharyngeal resistance and collapsibility of the pharyngeal airway (24). Oral breathing is effective in the growing and development of orofacial structures, and may lead to narrow maxilla, decreased lower jaw development, malocclusion and dry mouth (25). It can also effect pharyngeal airway contraction and resistance (24,26). In case of any obstruction in the nasal or nasopharyngeal tracts, nasal breathing pattern may change to mouth breathing pattern to compensate for decreased nasal flow and let adequate breathing (27). Therefore, evaluation of nasal and nasopharyngeal airway dimensions and the presence of obstruction is important and necessary in orthodontic treatment.

Nasal and pharyngeal airway dimensions and obstruction can easily be determined by the use of objective diagnostic methods such as lateral cephalometric radiographs, CBCT, magnetic resonance imaging, AR (28-31).

AR is a newer objective method that can be used reliably to examine the patency of the nasal cavity with measuring nasal air flow and pressure simultaneously (31). Since it requires minimum co-operation from the subject, it is a preferable method, especially in the pediatric population (31).

One of the radiographic methods CBCT is used to objective evaluation of pharyngeal airway dimensions and has a very important place thanks to the possibility of three-dimensional imaging and providing detailed information in diagnosis and treatment (32). Upper airway morphology and soft tissues can be evaluated in more detail and more accurate airway measurements can be made by CBCT (32). The main disadvantage of tomography that allows three-dimensional imaging of tissues is the high dose of radiation. Kawamata et al. (29) reported that images obtained by CBCT were satisfactory in evaluating morphological airway changes. Athanasios (33) argued that the dimensions of oropharynx and hypopharynx can be measured more clearly by CBCT.

Accuracy of upper airway measurements plays a significant role in the diagnosis of patients with respiratory or sleep disorders (34). It is important to understand how changes in the nasal cavity relate to changes in the oropharynx. Most dental clinics does not routinely have AR device. In this study, we evaluated to correlation between the narrowest area and volume of nasal cavity by AR and area and volume of oropharynx by CBCT. Since the study was a retrospective, no additional radiation dose was given to the patients and CBCT images and AR measurements obtained for different purposes were evaluated.

The measurements with AR method of nasal volume and MCA in the anterior region of the nasal cavity has been confirmed by many *in vivo* studies (19,35,36). Hilberg et al. (35) used CT to approve the accuracy of AR measurements and found a considerable correlation among CT and AR results when images perpendicular to the acoustic wave direction were obtained. Min et al. (37) evaluated the accuracy of the AR test and compared MCA values with CT images. Researchers have reported that AR gives more accurate and reliable results in the anterior part of the nasal cavity. Prasun et al. (38) reported that CT and AR volume measurements obtained in the posterior part of the nasal cavity showed statistically poor correlations. Cakmak et al. (39) reported that AR is as valuable and valid as CT. Gilain et al. (40) compared the measurements of MCA obtained with AR and CT and concluded that AR was suitable for the evaluation of the anterior nasal cavity. Terheyden et al. (41) examined six healthy subjects with AR and CT to compare the data. In conclusion, they suggested for intra- and inter-individual comparison of measurements made with AR in the anterior nasal region. In the light of these data, the correlation between anterior parts of the nasal cavity dimensions from obtained AR recordings were evaluated in this study.

El and Palomo (42) evaluated changes of oropharyngeal airway and nasal passage volume that come about after RME by using CBCT. Researchers reported a significant increase in nasal passage airway volume, but did not observe a significant change in oropharyngeal airway volume. In the current study, a significant correlation was realized between the value of orofaringeal area and nasal volume. However, no statistically significant relationship was found between airway volume, MCA1, MCA2 and nasal volume.

Kamal (43) reported that the AR technique is reliable and therefore it can be used to evaluate pharyngeal cross-sectional areas. They found the pharyngeal MCA measured with AR and CBCT to be similar with a difference of only 3 mm^2 and defended the accuracy of CBCT. D'Urzo et al. (44) reported that the MCA measured with both AR and CT showed less than 4.3% difference between them and a high correlation of 0.92. Tsolakis et al. (45) investigated the differences between AR and CBCT in measurement a total of 59 subjects airway volumes and areas. The researchers reported that both techniques showed a difference of less than 4% for the same pharyngeal MCA, by a high correlation of 0.94 between them. They observed that CBCT is an proper technique for evaluating anterior nasal volume, nasal MCA, pharyngeal volume and area.

The different results obtained from the literature may be due to some limitation of our study. The limitation of this study was based on a relatively small sample size.

The presence of correlations between AR and CBCT indicates the significance of a team of orthodontists and otolaryngologists in the interdisciplinary evaluation and treatment of patients with mouth breathing.The highest correlation was found only between the airway area and the nasal volume when the AR results were compared with the data obtained from the CBCT imaging technique. Although both methods provide information about the upper airway, we think that it may be diagnostically appropriate to use both methods separately for a more detailed evaluation. More research may be needed to confirm this results.

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Ethical approval: The study has been confirmed by the ethics committee of Izmir Katip Celebi University (license number 499) and carried out with the consent of each author. For this type of study, formal consent is not required. In view of the retrospective nature of the study, all the procedures being performed were a part of the routine care.

References

1. Isono S, Remmers JE, Tanaka A, Sho Y, Sato J, Nishino T. Anatomy of pharynx in patients with obstructive sleep apnea and in normal subjects. J Appl Physiol 1997; 82: 1319- 1326.
2. Bridger GP. Physiology of the nasal valve. Arch Otolaryngol 1970; 92: 543- 553.
3. Cakmak O. Value of acoustic rhinometry for measuring nasal valve area. Laryngoscope 2003;113: 295- 302.
4. Bosma JF, Donner MW, Tanaka E, Robertson D. Anatomy of the pharynx, pertinent to swallowing. Dysphagia 1986; 1: 23- 33.
5. Ballenger JJ, Snow JB. Ballenger's otorhinolaryngology: head and neck surgery. Pmph-usa;2003.
6. Ricketts RM. Respiratory obstruction syndrome. Am J Orthod 1968; 54: 495–507.
7. Handelman CS, Osborne G. Growth of the nasopharynx and adenoid development from one to eighteen years. Angle Orthod 1976; 46: 243- 259.

8. Behfelt K , Linder-Aronson S , Neander P. Posture of the head, the hyoid bone, and the tongue in children with and without enlarged tonsils. Eur J Orthod 1990; 12: 458- 467.
9. Doruk C, Sökücü O, Bıcakcı AA, Yılmaz U, Tas F. Comparison of nasal volume changes during rapid maxillary expansion using acoustic rhinometry and computed tomography. Eur J Orthod 2007; 29: 251- 255.
10. Koudstaal MJ, Poort LJ, van der Wal KG, Wolvius EB, Prahl-Andersen B, Schulten AJM. Surgically assisted rapid maxillary expansion (SARME): A review of the literature. Int J Oral Maxillofac Surg 2005; 34: 709- 714.
11. Lagravére MO, Major PW, Flores-Mir C. Dental and skeletal changes following surgically assisted rapid maxillary expansion. Int J Oral Maxillofac Surg 2006; 35: 481- 487.
12. Jackler RK, Dillon WP, Schindler RA. Computed tomography in suppurative ear disease: a correlation of surgical and radiographic findings. Laryngoscope 1984; 94(6): 746- 752.
13. Silva MAG, Wolf U, Heinicke F, Bumann A, Visser H, Hirsch E. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. Am J Orthod Dentofacial Orthop 2008; 133(5): 640-e1.
14. Kapila SD, Nervina JM. CBCT in orthodontics: assessment of treatment outcomes and indications for its use. Dentomaxillofac Radiol 2015; 44: 20140282.
15. Mattos CT, Cruz CV, da Matta TC, Pereira Lde A, Solon-deMello Pde A, Ruellas AC, Sant'Anna FE. Reliability of upper airway linear, area, and volumetric measurements in cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2014; 145: 188-197.
16. Haskell JA, Haskell BS, Spoon ME, Feng C. The relationship of vertical skeletofacial morphology to oropharyngeal airway shape using cone beam computed tomography: possible implications for airway restriction. Angle Orthod 2014; 84: 548- 554.
17. Schendel SA, Hatcher D. Automated 3-dimensional airway analysis from cone-beam computed tomography data. J Oral Maxillofac Surg 2010; 68: 696- 701.
18. Corey JP, Houser SM, Ng BA. Nasal congestion: A review of its etiology, evaluation and treatment. Ear Nose Throat J 2000; 79: 690- 702.
19. Hilberg O, Jackson AC, Swift DL, Pedersen OF. Acoustic rhinometry: evaluation of nasal cavity geometry by acoustic reflection. J Appl Physiol 1989; 66: 295- 303.
20. Clement PAR. Committee report on standardization of rhinomanometry. Rhinology 1984; 22: 151-155.
21. Enciso R, Nguyen M, Shigeta Y, Ogawa T, Clark GT. Comparison of cone-beam CT parameters and sleep questionnaires in sleep apnea patients and control subjects. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010; 109: 285- 293.
22. Dahlberg G. Statistical methods for medical and biological students. Interscience Publications, NY; 1940.
23. Mladina R, Čujić E, Šubarić M, Vuković K. Nasal septal deformities in ear, nose, and throat patients: an international study. Am J Otolaryngol 2008; 29(2): 75- 82.
24. Fitzpatrick MF, McLean H, Urton AM, Tan A, O'Donnell D, Driver HS. Effect of nasal or oral breathing route on upper airway resistance during sleep. Eur Respir J 2003; 22: 827- 832.
25. Bresolin D, Shapiro PA, Shapiro GG, Chapko MK, Dassel S. Mouth breathing in allergic children: its relationship to dentofacial development. Am J Orthod 1983; 83: 334-340.
26. Isono S, Tanaka A, Tagaito Y, Ishikawa T, Nishino T. Influences of head positions and bite opening on collapsibility of the passive pharynx. J Appl Physiol 2004; 97: 339- 346.
27. Harvold EP, Tomer BS, Vargervik K, Chierici G. Primate experiments on oral respiration. Am J Orthod 1981; 79: 359- 372.
28. Mislik B, Hänggi MP, Signorelli L, Peltomäki TA, Patcas R. Pharyngeal airway dimensions: a cephalometric, growth-study-based analysis of physiological variations in children aged 6–17. Eur J Orthod 2013; 36(3): 331- 339.
29. Kawamata A, Fujishita M, Ariji Y, Ariji E. Three dimensional computed tomographic evaluation of morphologic airway changes after mandibular setback osteotomy for prognatism. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000; 89: 278- 287.
30. Meisami T, Musa M, Keller MA, Cooper R, Clokie CM, Sandor GK. Magnetic resonance imaging assessment of airway status after orthognathic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 103: 458- 463.
31. Al Ahmari M, Wedzicha J, Hurst J. Intersession repeatability of acoustic rhinometry measurements in healthy volunteers. Clin Exp Otorhinolaryngol 2012; 5(3): 156- 160.
32. Lam B, Ooi CG, Peh WC, Lauder I, Tsang KW, Lam WK, Ip MS. Computed tomographic evaluation of the role of craniofacial and upper airway morphology in

obstructive sleep apnea in Chinese. Respir Med 2004; 98: 301- 307.

33. Athanasios AE. Assessment of the pharyngeal airway space after mandibular setback surgery. J Oral Maxillofac Surg 2000; 3(58): 285- 287.
34. Schwab RJ, Gupta KB, Gefter WB, Metzger LJ, Hoffman EA, Pack AI. Upper airway and soft tissue anatomy in normal subjects and patients with sleep-disordered breathing. Significance of the lateral pharyngeal walls. Am J Respir Crit Care Med 1995; 152: 1673-1689.
35. Hilberg O, Pedersen OF. Acoustic Rhinometry: recommendations for technical specifications and Standard operating procedures. Rinology Suppl 2000; 16: 3- 17.
36. O'Flynn P. Posture and nasal geometry. Acta Otolaryngol 1993; 113: 530- 532.
37. Min YG, Jan YJ. Measurements of cross-sectional area of the nasal cavity by acoustic rhinometry and CT scanning. Laryngoscope 1995; 105: 757- 759.
38. Prasun D, Jura N, Tomi H, Pertti R, Markus R, Erkki L. Nasal airway volumetric measurement using segmented HRCT images and acoustic rhinometry. Am J Rhinology 1999; 13: 97- 103.
39. Cakmak O, Coskun M, Celik H, Büyüklü F, Ozluoglu LN. Value of acoustic rhinometry for measuring nasal valve area. Laryngoscope 2003; 113: 295- 302.
40. Gilain L, Coste A, Ricolfi F, Dahan E, Marliac D, Peynegre R, Louis B. Nasal cavity geometry measured by acoustic rhinometry and computed tomography. Arch Otolaryngol Head Neck Surg 1997; 123: 401- 405.
41. Terheyden H, Maune S, Mertens J, Hilberg O. Acoustic rhinometry: validation by three-dimensionally reconstructed computer tomographic scans. J Appl Physiol 2000; 89: 1013- 1021.
42. El H, Palomo JM. Three-dimensional evaluation of upper airway following rapid maxillary expansion: a CBCT study. The Angle Orthod 2013; 84: 265- 273.
43. Kamal I. Test-retest validity of acoustic pharyngometry. Otolaryngol Head Neck Surg 2004; 130: 223- 228.
44. D'Urzo AD, Lawson VG, Vassal KP, Rebuck AS, Slutsky AS, Hoffstein V. Airway area by acoustic response measurements and computerized tomography. Am Rev Respir Dis 1987; 135: 392-395.
45. Tsolakis IA, Venkat D, Hans MG, Alonso A, Palomo JM. When static meets dynamic: Comparing cone-beam computed tomography and acoustic reflection for upper airway analysis. Am J Orthod Dentofacial Orthop 2016; 150: 643- 650.