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Comparative analysis of upper airway volume with lateral cephalograms and cone-beam computed tomography

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Introduction: In this study, we aimed to evaluate the adenoidal nasopharyngeal ratio (ANR) on lateral cephalograms by assessing upper airway volumes using cone-beam computed tomography (CBCT) images as the validation method. **Methods:** Fifty-five patients were included in the study, and it was essential that the lateral cephalograms and CBCT images taken at their examinations were not more than 1 week apart. There were 32 subjects in group A (age ≤15 years) and 23 subjects in group B (age >15 years). The ANR was measured on the lateral cephalograms. The area and volumetric measurements of the nasopharynx and the total upper airway were obtained from CBCT images. Repeated measurements of the ANR and airway volume were performed on 10 subjects by 2 observers. **Results:** Group A had a higher correlation ($r = -0.78$) between the ANR and the nasopharynx volume than did group B ($r = -0.57$). The ANR had a weak correlation with the total upper airway volume (group A, $r = -0.48$; group B, $r = -0.32$). Both measurements made on lateral cephalograms and CBCT were highly reproducible in terms of intraobserver and interobserver agreement. **Conclusions:** Based on our results, the measurement of the ANR on lateral cephalograms can be used as an initial screening method to estimate the nasopharynx volumes of younger patients (age ≤15 years). (Am J Orthod Dentofacial Orthop 2015;147:197-204)

Obstruction of the airway often alters normal breathing, which has a significant impact on the development of craniofacial structures,[1,2] such as incompetent lips, lower or anterior tongue position, narrow maxillary arch, long face height, crossbites, and posteroinferior rotation of the mandible.[3] The most common reason for obstruction of the airway is adenoid hypertrophy. Adenoids are a collection of lymphoid tissues in the posterior nasopharyngeal wall; they are small at birth but progressively enlarge as a result of increased immunologic activity.[4] Repeated adenoidal infection and inflammation or genetic factors may lead to pharyngeal obstruction, causing mouth breathing, which can in turn result in altered craniofacial development.[5]

Before planning orthodontic treatment, orthodontists should view and analyze the airway region on a lateral cephalogram. If an obstruction is observed, the patient might be referred to an otolaryngologist for further treatment. A diagnostic method that can accurately provide data on the severity of nasopharyngeal obstruction is important for both dentists and medical specialists. Several methods may be used for evaluating the size of adenoidal tissues, including conventional lateral cephalogram, nasal endoscopy, acoustic rhinometry, rhinomanometry, computed tomography, and magnetic resonance imaging. Among these methods, the conventional lateral cephalogram was reported to be the most cost effective, reproducible, and easy to interpret in assessing the size of adenoidal tissues.[6-8] A lateral cephalogram is useful for analyzing adenoidal tissues and the nasopharyngeal airway; however, it is a 2-dimensional imaging modality that has limitations to represent 3-dimensional (3D) structures. Several studies have reported that computed tomography and magnetic resonance imaging may provide more clinically useful

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data to supplement the information from the 2-dimensional images.[9,10] Recently, with the introduction of cone-beam computed tomography (CBCT), 3D images of patients became more available in dentistry, with reduced radiation doses compared with multidetector computed tomography and lower costs than magnetic resonance imaging.[11-13] A study by Ludlow and Walker[14] reported that the effective dose of radiation of CBCT for a cephalometric scan with low-dose settings may be reduced to the level of a panoramic examination at the expense of lower image quality expressed in the signal:noise ratio. However, the image quality of low-dose protocols in relation to diagnostic tasks needs to be further studied before CBCT can be recommended as a routine radiographic method for orthodontic patients.

Interest in using CBCT to measure airway volume on craniofacial growth and airway changes after orthognathic surgery and rapid maxillary expansion is growing.[15-19] However, during the orthodontic treatment period, more lateral cephalograms are readily available than CBCT images. Previous studies have tried to find correlations between measurements performed on lateral cephalograms and CBCT images. Sears et al[20] measured the nasopharynx (NP), oropharynx, and hypopharynx airways, using both cephalograms and CBCT, but the correlations between linear measurements and volumes were weak. In another study, a moderately high correlation was found between the NP area on lateral cephalograms and the NP volume on CBCT images.[21] There is no consensus concerning whether the measurements on lateral cephalograms can estimate the airway volume calculated on CBCT images.

It has been generally accepted that despite many limitations, lateral cephalograms serve as radiographic standards for airway assessment. When lateral cephalograms are used, the adenoidal nasopharyngeal ratio (ANR) is a helpful diagnostic parameter for assessing nasopharyngeal obstruction. The ANR is a classic method for assessing adenoid size in clinical diagnosis and treatment. In 1979, Fujilka et al[22] obtained the ANR by simple linear measurements on the lateral radiographs of 1398 infants and children. They concluded that the ANR reliably expressed adenoidal size and patency of the nasopharyngeal airway. After that study, several reports confirmed the positive correlations between the ANR and surgical findings,[23] nasal endoscopic examinations,[24] and clinical symptomatology.[25]

The size of the adenoids has an important role in the evaluation of airway volume. The adenoids develop progressively, with their growth peak reached by 4 to 5 years of age, followed by another peak between 9 and 10 years; then the size diminishes progressively until 14 to 15 years.[22] Our hypothesis was that instead of linear measurement of the adenoids, the ANR on lateral cephalograms might be an applicable method to assess airway volume for younger patients.

Fig 1. Linear measurements used to calculate the ANR on lateral cephalograms: *A*, perpendicular distance between the point of maximum convexity of the adenoid shadow to the anterior margin of the basiocciput; *N*, distance between the posterosuperior edge of the hard palate and the anteroinferior edge of the spheno-occipital synchondrosis.

The aim of this study was to evaluate whether the ANR on lateral cephalograms can be used to estimate the airway volume, using CBCT as the validation method. Since lateral cephalograms are routinely used in orthodontic diagnosis and treatment planning, these results will provide essential information on the value of lateral cephalograms for the assessment of airway volume.

MATERIAL AND METHODS

This study was approved by the ethics committee of the Stomatological Hospital in Dalian, China (protocol number DLKQLL201302).

This was a retrospective study; we used the image database available at the Department of Orthodontics, Stomatological Hospital, Dalian, China. The database was searched systematically between 2010 and 2012 at the Department of Oral Radiology for patients who had both lateral cephalograms and CBCT images taken not more than 1 week apart. The field of view of the CBCT images should cover the whole upper airway with the superior border above sella turcica and the