Original Article

Radiographic Assessment of Upper Airway Size in Skeletal Sagittal and Vertical Jaw Discrepancies

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Received: 8 June 2013
Accepted: 22 August 2013

Abstract

Background and Aim: An important factor in the process of diagnosis and orthodontic treatment planning is patient's respiratory function that has a direct correlation with the upper airway size. The aim of this study was to measure and compare nasopharyngeal, oropharyngeal and hypopharyngeal airway volumes in Iranian subjects with sagittal (Class I, II and III) and vertical (normodivergent, hyperdivergent and hypodivergent) jaw discrepancies using standard cephalometric radiographs.

Materials and Methods: In this descriptive cross-sectional study, 100 pre-treatment lateral cephalograms of orthodontic patients were evaluated to assess the size of upper airway space including the nasopharynx, oropharynx and hypopharynx. In order to assess airway dimensions in patients with sagittal and vertical discrepancies, subjects were divided into two large groups of normal sagittal and normal vertical patterns. Airway size was measured in sagittal plane in 50 subjects with normal vertical patterns and in vertical plane in 50 subjects with normal sagittal patterns. Linear variables i.e. the size of nasopharyngeal space (PNS-UPW), oropharyngeal space (U-MPW) and hypopharyngeal space (V-LPW) were measured by cephalometric tracing. Data were analyzed using SPSS version 15 software and chi-square, ANOVA and Tukey's HSD tests.

Results: Understudy subjects had normal age and gender distribution pattern. In patients with normal sagittal pattern, by an increase in vertical dimension, size of nasopharynx (PNS-UPW), oropharynx (U-MPW) and hypopharynx (V-LPW) decreased and the mentioned volumes were significantly smaller in subjects with hyperdivergent facial patterns compared to hypodivergents. In subjects with normal vertical pattern, by an increase in ANB angle, size of oropharynx (U-MPW) and hypopharynx (V-LPW) decreased and the mentioned volumes in CL II patients were significantly smaller than in CL III subjects; whereas, the largest nasopharynx (PNS-UPW) was observed in CL I subjects.

Conclusion: Sagittal and vertical discrepancies affect upper and lower airway dimensions and by an increase in facial height, the mentioned volumes decrease. Smaller ANB angle results in larger airway dimensions.

Key Words: Cephalometry, Upper airway, Sagittal, Vertical, Discrepancy

Journal of Islamic Dental Association of IRAN (JIDAI) Spring 2014 ;26, (2)

Introduction

Patient's respiratory function is an important factor to be considered in the process of diagnosis and orthodontic treatment planning. The size of upper airway spaces including the nasopharynx, oropharynx and hypopharynx is among the most important factors involved in respiration and deglutition [1]. There is still controversy regarding the correla-

tion of respiratory pattern and type of malocclusion. A reduction in size of pharyngeal spaces leads to an imbalance in craniofacial structures during growth and development and results in a tendency to an increase in facial height [2]. It has been demonstrated that subjects with anomalies such as maxillary and mandibular retrognathism, short mandibular body length and downward-backward mandibular rotation have small airway dimensions. There is a close association between the size of airway spaces and facial morphology. Airway dimensions are also affected by the anterior functional shift, head position, anterior-posterior relations, and vertical growth pattern [3]. Memon et al, in their study in 2010 reported that the upper pharyngeal width was significantly narrower in hyperdivergent subjects; whereas, this was not the case in sagittal malocclusions [4]. Kirjavainen et al, in 2006 observed narrower upper airways in subjects with Class II division 1 malocclusion compared to Class I patients [5]. Another study by De Freitas et al, in 2006, demonstrated significantly narrower upper pharyngeal airways in Class I and Class II malocclusion patients with vertical growth patterns in comparison to Class I and Class II subjects with normal growth patterns. Furthermore, the growth pattern did not affect the width of lower pharyngeal airway [6].
Various complex and costly methods such as the Magnetic Resonance Imaging (MRI), computerized tomography, fluoroscopy and fiberoptic pharyngoscopy have been applied in different studies for evaluation of upper airway. Lateral cephalometric radiography has long been used in orthodontic therapy for the assessment of growth and development of craniofacial structures, skeletal and dental anomalies and soft tissue [7]. Lateral cephalograms can provide us with valuable, credible and reproducible data regarding the airways while reducing the costs and radiation dose of patients. Studies have indicated that although cephalometric measurements offer two-dimensional data, cephalometry is a reliable method for airway evaluation and estimation of adenoid size [7-9].
The aim of this study was to assess the nasopharyngeal, oropharyngeal and hypopharyngeal airway dimensions on standard cephalometric radiographs in Iranian subjects with different sagittal (Class I, II and III) and vertical (normodivergent, hyperdivergent, hypodivergent) jaw discrepancies.

Materials and Methods

In this descriptive cross-sectional study we evaluated 100 pretreatment standard digital lateral cephalograms of orthodontic patients (54 females and 46 males with a mean age of 18.4±3.3 yrs.) presenting to an oral and maxillofacial radiology clinic in Tehran. Understudy subjects did not have history of mouth breathing, snoring, head or facial trauma, TMJ disorders, tonsils and adenoid problems, upper airway diseases, or any syndromes. They had not undergone any orthodontic treatment or maxillofacial surgery either. Radiographs were obtained with CRANEX D (Soredex, Helsinki, Finland) machine under standard conditions (lips at rest, teeth in occlusion and head in natural head position or NHP). Patient's head was positioned in the machine in a way that the sagittal plane was parallel to the film plane. In order to fix the head during the exposure time, ear rods were used that had a mild contact with the external auditory meatus. All cephalometric radiographs were performed by an expert technician. The exposure conditions for all patients included 81 kVp and10 mA for 5-8 seconds. The magnification factor of the device (1.15) was also considered in linear measurements. Cephalometric tracings were done by an orthodontic resident and linear variables were drawn parallel to the Frankfurt plane and measured (Figure 1).

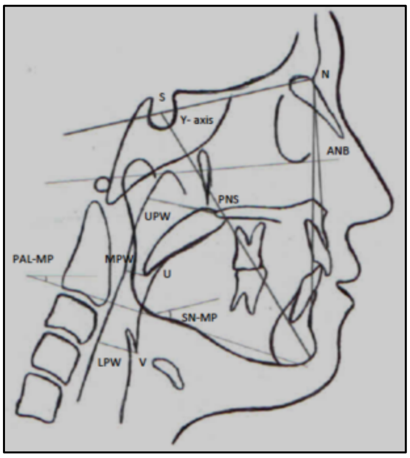

Figure 1. understudy landmarks and variables

Linear variables included nasopharyngeal width from the posterior nasal spine to upper pharyngeal wall (PNS-UPW), oropharyngeal width from the uvula to middle pharyngeal wall (U-MPW), and hypopharyngeal width from vallecula to lower pharyngeal wall (V-LPW) (Table 1) [10]. Since the anterior-posterior (sagittal) and vertical dimensions have a mutual effect on one another, the effect of vertical discrepancies on upper airway dimensions was evaluated in patients with normal sagittal patterns. By doing so, the potential errors were eliminated. On the other hand, in order to assess the influence of sagittal discrepancies on the mentioned dimensions subjects with normal vertical patterns were selected. Thus, patients were divided into two main groups (sagitally normal and vertically normal subjects). Subjects with normal vertical patterns were divided into 3 subgroups of CL I, CL II and CL III based on the ANB angle. Subjects with 1<ANB<4 were categorized as CL I, ANB>1 as CL II and ANB<0 as CL III. Subjects with normal sagittal patterns were divided into 3 subgroups of normal, high angle and low angle based on the Y-axis, palatal plane/mandibular plane (PP/MP) and SN/mandibular plane (SN/MP). The average value of these angles was considered as 66, 25 and 32 degrees, respectively. Higher than average values were indicative of vertical growth and lower than average values were indicative of horizontal growth. Accordingly, all three malocclusions were divided into three subgroups of deep bite, open bite and normal bite. Data were analyzed using SPSS version 15 software and chi square, ANOVA and Tukey's HSD test. For the assessment of measurement error in the understudy variables, 15 radiographs were randomly selected and traced by the same person 6 weeks later and linear and angular measurements were repeated as well. T-test failed to find a significant difference between measurements at the two time points.

Results

In Patients with normal sagittal patterns, the largest nasopharyngeal space was observed in low angle subjects (3.38± 27.4 mm), normal bite subjects (24.6±4.05 mm) and high angle subjects (21.3 ± 3.78 mm), in a descending fashion. The largest oropharyngeal space was found to be in low angle patients (10.9±3.6 mm), normal bite subjects (10.5±3.13 mm) and high angle subjects (9.6± 3.13 mm) in a decreasing order. The largest hypopharyngeal space was observed in low angle subjects (18.5± 3.9 mm) followed by high angle (17.1± 4.02 mm) and normal bite (16.8± 2.61 mm) subjects. ANOVA found significant differences between the understudy groups in the size of nasopharynx (PNS-UPW), oropharynx (U-MPW) and hypopharynx (V-LPW) (p< 0.001). Tukey's HSD test was applied to assess the inter-group differences in terms of nasopharyngeal dimensions, which indicated that nasopharyngeal and oropharyngeal dimensions in high angle subjects were significantly smaller than in normal bite and low angle patients. Furthermore, this value in normal bite subjects was smaller than in low angle patients (p<0.001). On the other hand, hypopharyngeal dimensions in low angle subjects were significantly larger than in the other two groups. However, in contrast to the nasopharyngeal and oropharyngeal dimensions, hypopharyngeal volume in high angle subjects was greater than in normal bite patients (p< 0.001) (Table 2).

In Patients with normal vertical pattern, the largest nasopharyngeal space was observed in CL I malocclusion (24.1± 4.14 mm) followed by CL II (23.3± 3.72 mm) and CL III (22.1 ± 3.62 mm) subjects. The largest oropharyngeal space was observed in CL III malocclusion (13.8± 3.29 mm) followed by CL I (10.5± 3.62 mm) and CL II (8.7± 3.03 mm) patients. The largest hypopharyngeal space was found to be in CL III malocclusion (18.9± 3.74 mm) followed by CL I (17.1 ± 3.62 mm) and CL II (14.3± 3.18 mm) malocclusion patients. ANOVA was applied to compare these dimensions in different subgroups. Results revealed significant differences between different subgroups in terms of the size of nasopharyngeal, oropharyngeal and hypopharyngeal space (p< 0.001). Tukey's HSD test showed that the oropharyngeal and hypopharyngeal space in CL III subjects was significantly larger than in CL II and CL I patients (p< 0.001). In CL I subjects the mentioned volumes were greater than in CL II patients (Table 3). However, the nasopharyngeal space in CL I patients was significantly larger than in CL II or CL III patients (p< 0.001).

Table 1. Understudy landmarks and their definitions

Landmark	Definition
PNS	Posterior nasal spine
UPW	Point of intersection of posterior pharyngeal wall and perpendicular line drawn from PNS
U	Prong of the uvula
MPW	Point of intersection of posterior pharyngeal wall and perpendicular line drawn from U
V	The most posterior point on the base of tongue
LPW	Point of intersection of posterior pharyngeal wall and perpendicular line drawn from V
ANB	The angle between the lines drawn from N to A and B points
SN/MP	The angle between anterior skull base (SN) and mandibular plane
Yaxis	The angle between the line drawn from S to Gnathion and SN
PP/MP	The angle between the palatal plane and mandibular plane

Table 2. Comparision of cephalometric variables in subjects with normal sagittal pattern

-	Normal	Low angle	High angle
Nasopharynx	24/6±4/05	27/4±3/38	21/3±3/78
Oropharynx	10/5±3/13	10/9±3/6	9/6±3/13
Hypopharynx	16/8±2/61	18/5±3/9	17/1±4/02

Table 3. Comparision of cephalometric variables in subjects with normal vertical pattern

-	Cl I	Cl II	Cl III
Nasopharynx	24/1±4/14	23/3±3/72	22/1±3/62
Oropharynx	10/5±3/62	8/7±3/03	13/8±3/29
Hypopharynx	17/1±3/62	14/3±3/18	18/9±3/74

Discussion

Evaluation of airway, its influence on facial morphology and the reverse correlation between the two are among the controversial and conflicting orthodontic topics. Numerous studies have investigated these subjects using different techniques. Parkkinen et al, in 2011 believed lateral cephalometric radiography to be a reliable technique for the measurement of nasopharyngeal and retropharyngeal dimensions [8]. Malkoc et al, in 2005 also confirmed the very high reproducibility of lateral cephalometric radiographs obtained at NHP for the assessment of airway dimensions, position of the tongue and hyoid bone [11].

In the present descriptive cross-sectional study, 100 pretreatment lateral cephalograms of orthodontic patients were used for the assessment of the size of upper airways including nasopharynx, oropharynx and hypopharynx. In order to assess the size of airway in patients with sagittal and vertical malocclusions, samples were divided into two large groups (sagittally normal and vertically normal) and the respective parameters were separately evaluated for each group. Patients had normal age and sex distribution. In patients with normal sagittal patterns, by an increase in vertical dimension, volume of different parts of airway decreased as the largest nasopharyngeal, oropharyngeal and hypopharyngeal spaces were observed in low angle subjects. Batool et al, in their study in 2010 applied McNamara airway analysis and demonstrated that CL II patients with vertical growth pattern had a narrower upper and lower airways compared to CL II patients with horizontal growth pattern [12]. Ucar et al, in 2011 studied airway dimensions in CL I patients with different vertical growth patterns using lateral cephalometric radiographs. They found that nasopharyngeal airway space and upper posterior airway space measurements in low angle patients were larger than in high angle subjects [3]. Memon et al, in 2012 stated that the dimensions of upper airways were not influenced by the sagittal malocclusions but vertical discrepancies may have an impact as the mentioned dimensions were significantly smaller in hyperdivergent subjects compared to normodivergent and hypodivergent cases [4]. Freitas in 2006 reported that CL I and CL II malocclusion subjects with vertical growth patterns had smaller upper airway width compared to normal subjects [6]. Joseph in 1998 revealed narrower anteroposterior pharyngeal dimensions in the nasopharynx and oropharynx of hyperdivergent subjects compared to normodivergents. Furthermore, the hyperdivergent patients had a thinner posterior pharyngeal wall, which might be a compensatory mechanism [13]. In his study, subjects were selected regardless of the sagittal relationship of the jaws. Considering the fact that sagittal and vertical planes have mutual effects on one another, in the present study, CL I subjects were selected for the evaluation of the effect of vertical discrepancies. On the other hand, based on the available literature, patients with upper airway obstruction suffer from excessive vertical development and subsequently have a long face appearance [14, 15]. In our study, the influence of sagittal malocclusion on upper airway dimensions was also evaluated. The obtained results revealed a reduction in dimensions of oropharynx and hypopharynx by an increase in ANB angle as in CL III subjects these dimensions were significantly larger than in CL II patients.

Kirjavainen et al, in 2006 demonstrated that the nasopharyngeal space in CL II subjects was equal in size or even wider than that in control group (CL I) but the oropharyngeal and hypopharyngeal spaces were significantly smaller [5]. Muto et al, in 2008 also indicated that the pharyngeal airway diameter was the largest in patients with mandibular prognathism and the smallest in those with mandibular retrognathism [16].

Jena et al, in 2010 showed that the soft palate length was significantly smaller in patients with mandibular prognathism compared to those with mandibular retrognathism. They also stated that the sagittal mandibular development had no influence on the nasopharyngeal or hypopharyngeal dimensions but the oropharyngeal space was significantly larger in subjects with mandibular prognathism compared to those with normal or retrognathic mandible [17]. In the present study, the nasopharyngeal space in CL I subjects was larger than in CL II and CL III patients. Kerr in 1985 reported smaller nasopharyngeal space in CL II malocclusion patients compared to CL I subjects [18].

However, in his study, the vertical facial dimension had not been considered. Sosa et al, in 1982 could not find a distinct association between the size of nasopharyngeal space and CL I or CL II div 1 malocclusions using lateral cephalograms [19]. Zhong et al, in 2010 also showed that the sagittal and vertical skeletal patterns can affect the dimensions of the inferior and superior parts of the upper airways, respectively [20].

Conclusion

1.The nasopharyngeal, oropharyngeal and hypopharyngeal airway dimensions are correlated with vertical malocclusion and the mentioned volumes decrease by an increase in vertical facial height (except for hypopharynx which was larger in high angle patients compared to normal bite subjects).

2.The oropharyngeal and hypopharyngeal airway dimensions are correlated with sagittal malocclusions as the mentioned spaces decrease in size by an increase in ANB angle.

3.The nasopharyngeal airway dimensions are correlated with sagittal malocclusions as the mentioned space is larger in CL I malocclusion subjects.

Since the cause and effect correlation between the size of upper and lower airways and malocclusion type has yet to be confirmed, it is recommended that the sagittal and vertical skeletal discrepancies be interventionally corrected during the growth ages and approximate the normal state as much as possible.

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