Volumetric changes in pharyngeal airway in Class II division 1 patients treated with Forsus-fixed functional appliance: A three-dimensional cone-beam computed tomography study

Parul Temani, Pradeep Jain, Pooja Rathee, Ruchira Temani

Abstract

Objective: Recent years have witnessed a renewed interest to determine a quantifiable relationship between mandibular advancement performed with an orthodontic appliance and the resulting airway volume. The study was conducted to evaluate the volumetric changes in pharyngeal airway space using cone-beam computed tomography (CBCT) in Class II division 1 patients with retrognathic mandible treated by Forsus-fixed functional appliance and to compare them with their pretreatment findings. **Materials and Methods:** Thirty patients with Class II division 1 malocclusion of age group 10–17 years were selected randomly and evaluated for changes in pharyngeal airway volume with and without Forsus-fixed functional appliance. Patients in each group underwent CBCT scan of head and neck region at pretreatment stage and 6 months after the initial scan. Institutional approval for the project was obtained from the Ethical Committee. Volumetric changes of upper (oropharynx) and lower (hypopharynx) pharyngeal airways were measured on scanogram using computer software and intragroup comparisons were done. **Results:** There was a statistically significant increase in the volume of both hypopharynx and oropharynx and also total airway volume in patients treated with Forsus-fixed functional appliance. Three-dimensional reconstruction of the airway also demonstrates a considerable increase in pharyngeal airway space. **Conclusion:** Forsus-fixed functional appliance can be a promising appliance for improving pharyngeal airway volume in Class II division 1 patients with retrognathic mandible thus preventing obstructive sleep apnea and other respiratory problems in future. However, the long-term implications of this treatment modality need further consideration and a longer period of follow-up.

Keywords: Cone-beam computed tomography, Forsus-fixed functional appliance, pharyngeal airway

Introduction

Class II division 1 malocclusion presents a common challenge to every orthodontist. Almost 60% of the skeletal Class II malocclusions are as a consequence of mandibular retrognathism.[1] Retrognathic mandible has also been found to be a contributing factor in obstructive sleep apnea (OSA) and other respiratory problems with patients having a shorter mandibular body length.[2] In skeletal Class II patients, the problem is likely caused by a posteriorly-oriented mandible that displaces the soft tissues attached to it, impinging on the airway space.[3] This can also lead to the systemic problems such as cardiac and respiratory ailments in such patients.[4] The oral and pharyngeal regions thus maintained in a state of equilibrium have a primary function in maintaining patent airway and the process of deglutition. Functional appliances form the optimum treatment option for mandibular retrognathism in growing children. Functional appliances also increase superior-posterior airway space, allows a larger lumen for air to pass through during inspiration, thereby decreasing the likelihood of an obstructive event. To make the treatment outcome more predictable, several "compliance free" fixed functional appliances have been introduced. The present study was aimed to evaluate the volumetric changes in pharyngeal airway with the help of cone-beam computed tomography (CBCT) in growing patients with retrognathic mandible treated by the Forsus-fixed functional appliance. The ability to perform precise measurements of various cross-sectional areas, three-dimensional (3D) reconstructions and volumetric measurements of the upper airway, and

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low radiation exposure are some of the advantages of CBCT technology when compared with other diagnostic radiological techniques.[5] The null hypothesis was that there was no significant increase in pharyngeal airway in patients treated with Forsus-fixed functional appliance.

Materials and Methods

The present study was conducted with a sample consisting of 30 patients with Class II division 1 malocclusion of age group 10–17 years selected randomly from the patients of North Indian origin to evaluate the changes in pharyngeal airway dimensions with and without fixed functional appliance therapy (Forsus). Approval for the project was obtained from the Ethical Committee of the Institution.

All patients gave their consent as per the forms and regulations decided by the Ethical Committee of the Institute. Each subject filled out the consent form to individually participate in the present study. The subjects were explained about the purpose of the study which covered the points outlined in the information sheet.

Selection criteria

Inclusion criteria

- Skeletal Class II division 1 malocclusion (ANB > 4°) with a clinically diagnosed retrognathic mandible
- Class II division 1 dental malocclusion
- Mandibular plane angle (Go-Me to FH plane) of 25 ± 5°
- Overjet >5 mm
- Age group: 10–17 years with significant growth potential at the beginning of treatment period.

Exclusion criteria

- No sex difference taken into account
- No prior orthodontic treatment and no permanent teeth extracted before and during Forsus-fixed functional appliance treatment
- Patients having no congenital anomalies or facial asymmetries
- Patients with no history of any serious trauma or surgery of orofacial region.

Methods

The maxillary and mandibular teeth were bonded with preadjusted edgewise appliance (roth prescription −0.022" × 0.028" slot). Leveling and alignment was completed with NiTi archwires and stabilized with 0.019" × 0.025" stainless steel archwires in both maxillary and mandibular arches. Forsus-fixed functional appliance was attached in the lower jaw onto a continuous 0.019" × 0.025" stainless steel archwire [Figures 1 and 2]. Prior to attachment of Forsus-fixed fuctional appliance, the lower arch was consolidated as one using the figure of "8" stainless steel ligature (0.009") from 1st mandibular molar on one side to the other. The lower archwire was given a labial root torque of 10° and cinched back distal to first mandibular molar. The appliance was checked every 1 month and adjusted if necessary with a total time of 4–6 months for Forsus-fixed functional appliance therapy.

Installation of Forsus – Fatigue-resistant device

Once the correct size was selected, the appliance was inserted through the molar headgear tube from distal to mesial, push rod was inserted into the telescoping spring, and the mesial hook was looped over the mandibular archwire and crimped shut.

The records that were collected included a detailed clinical history, photographs, and CBCT scans at the beginning of the treatment and after completion of Class II correction with Forsus-fixed functional appliance therapy (within a week of appliance removal).

Cone-beam computed tomography scans

The CBCT scans used in the present study were obtained with Carestream CS9300 machine, which has a broad range of CBCT applications – such as paranasal sinus, temporal bone, dental implantology, trauma, and oral surgery. Ultrahigh CBCT resolution (0.09 mm) delivers superior fine bony structure visualization of temporal bone and radicular structures. Each compact disc having CBCT scan with digital imaging and communications in medicine images were loaded into 3D-Doctor Imaging Software (Able Software Corporation, USA) TM, which is an advanced 3D modeling,

Figure 1: Forsus-fixed functional appliance-frontal view

Figure 2: Forsus-fixed functional appliance-lateral view

image processing, and measurement software for magnetic resonance imaging (MRI), computed tomography (CT), positron emission tomography (PET), microscopy, and scientific and industrial imaging applications. To build 3D models of the airways for the subjects, the CBCT data were loaded into 3D-Doctor software to allow semi-automatic segmentation of the airway in the sagittal view.

Oropharyngeal airway segmentation and volume measurement

The airway was visualized and then digitally excised by defining training area. The software was used to define the volume of the entire airway by first "segmenting" the regional space of interest by drawing a boundary in orthogonal planes. Because the airspace exhibits a significantly greater negative CT value than the more dense surrounding soft tissue, the sharp distinct high contrast border produces a clean segmentation of the airway.

Upper and lower landmarks for oropharynx were taken as the posterior most tip of the hard palate and tip of epiglottis, respectively. Hypopharynx was taken from the epiglottis to the lower border of sixth cervical vertebra [Figure 3]. After finishing the markings, volume viewer of the software measures the entire volume of the segmented region of the oropharynx and hypopharynx [Figure 4].

Statistical analysis

Mean, standard deviation, and standard error were calculated, with the *t*-test used to determine the level of significance.

Results

The changes in volume measurements of upper and lower pharyngeal airway in the sample have been summarized in Table 1 and Figure 5.

It was seen that there was a significant increase ($P < 0.001$) in upper pharyngeal, lower pharyngeal, and total airway volume in treated cases after 6 months of Forsus-fixed functional appliance therapy [Figures 6 and 7].

Discussion

The pharyngeal airway has always been an area of interest for orthodontists because of the role played in the growth and development of the craniofacial and orodental complex and their primary functions in maintaining patent airway. Many previous studies have shown a possible relationship among pharyngeal airway and skeletal structures, soft tissues, and musculature.[6,7] McNamara[1] stated that 60% of the skeletal

Table 1: Comparison of pre- and post-treatment values w.r.t. volume

	n	Mean	SD	*P**
Upper pharyngeal				
Pre	30	7.8530	2.94477	<0.001
Post	30	9.4539	2.37231	
Lower pharyngeal				
Pre	30	8.9800	2.61622	<0.001
Post	30	10.4599	2.70918	
Total				
Pre	30	15.9263	4.56017	<0.001
Post	30	19.9885	4.43702	

*Paired *t*-test. SD: Standard deviation

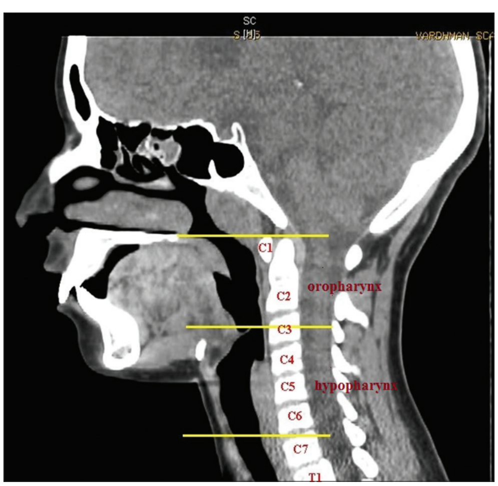

Figure 3: Segmentation of pharyngeal airway

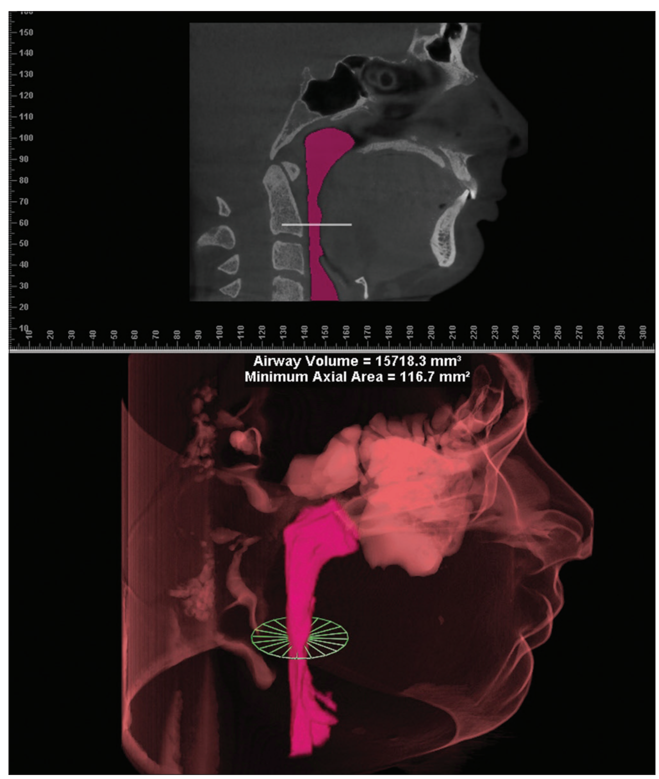

Figure 4: Three-dimensional volumetric measurement of pharyngeal airway

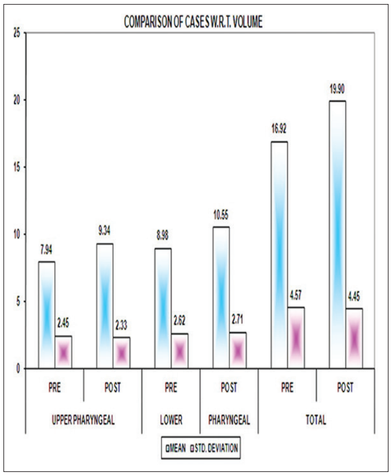

Figure 5: Graph depicting volumetric changes pre- and post-treatment

Figure 6: Pretreatment three-dimensional volumetric construction of airway. Volume: 748.32 mm^3

Figure 7: Posttreatment three-dimensional volumetric construction of airway. Volume: 1012.83 mm^3

Class II malocclusions are a consequence of mandibular retrognathism. Over the years, mandibular advancement appliances in the form of functional appliances are used in the dentofacial orthopedic treatment of growing children with hypoplastic and/or retrognathic mandible.[8]

Through this study, it was intended to evaluate the volumetric changes in pharyngeal airway space in Class II division 1 patients with retrognathic mandible treated by Forsus-fixed functional appliance and to compare them with their pretreatment values. The importance of the third dimension and the use of CT have been emphasized as early as 1979, highlighting important limitations of two-dimensional airway studies.[9]

The ability to perform precise measurements of various cross-sectional areas, 3D reconstructions and volumetric measurements of the upper airway are some of the advantages of CT technology when compared with cephalometric techniques. Following the introduction of CBCT, the main disadvantages of conventional CT devices, such as high radiation dose and longer exposure times, were eliminated.[10] CBCTs have led to a better understanding of upper airway anatomy and physiology. In addition, Aboudara *et al*. stated that CBCT is a simple and effective method for the evaluation of the upper airway.[9] This study used 3D-Doctor Imaging Software (Able Software Corporation, USA), which is an advanced 3D modeling, image processing, and measurement software for MRI, CT, PET, microscopy, and other imaging applications.

The purpose of this study was to try to understand the effect of fixed functional appliances; specifically Forsus in Class II division 1 patients on airway volume (oropharynx [upper pharynx] and hypopharynx [lower pharynx]) by 3D imaging and their efficacy in reducing obstructive respiratory problems in future. It was seen that there was a significant increase ($P < 0.001$) in upper pharyngeal, lower pharyngeal, and total airway volume in treated cases after Forsus-fixed functional appliance therapy.

These findings match with those observed by Haskell *et al*.[11] in their study on the effects of mandibular advancement device (MAD) on airway dimensions. They reported an average oropharyngeal volume increase of approximately 2800 mm^3 with MAD therapy.

Previous other authors have also suggested the improvement in volume in the oropharynx with MAD.[12-14]

Dolce[15] compared one phase versus two phase treatment effects in their study and showed that the skeletal effects of phase1treatment disappear by the end of fixed appliance treatment. This explains the rising trend toward a one phase treatment (combination of fixed functional appliance with fixed mechanotherapy) enabling simultaneous skeletal and dental correction. Moreover, the usage of fixed functional appliances has eliminated the onus of patient compliance factor from dictating treatment outcome, thus making the treatment more predictable and also quicker.[16-18]

Hence, Forsus-fixed functional appliance therapy is suitable for skeletal correction of Class II malocclusion by forward movement of mandibular bony base in younger age group which in turn leads to increase in pharyngeal airway volume thus preventing OSA and other respiratory problems in future.

This study was concerned with the immediate treatment effects of the Forsus-fixed functional appliance on pharyngeal airway. The long-term implications of this treatment method need further consideration.

Conclusions

- The null hypothesis was rejected
- There was a statistically significant increase in the volume of both hypopharynx and oropharynx in patients treated with Forsus-fixed functional appliance.

Hence, it can be concluded that Forsus-fixed functional appliance can be a promising appliance for improving pharyngeal airway space in Class II division 1 patients with retrognathic mandible.

This study was concerned with the immediate treatment effects of the Forsus-fixed functional appliance on pharyngeal airway. The long-term implications of this treatment method need further consideration.

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Conflicts of interest
There are no conflicts of interest.

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