Pharyngeal Airway Volume in Class II Patients Treated with Herbst and Fixed Mechanotherapy Using Cone Beam Computed Tomography - A Comparative Study from Haryana, India

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ABSTRACT

BACKGROUND

Skeletal malocclusions occur because of the defect in the underlying skeletal structure. Mandibular skeletal retrusion is the most common characteristic of class II malocclusion. The purpose of this study was to evaluate pharyngeal airway dimension in Class II patients treated with Herbst appliance and fixed mechanotherapy using cone beam computed tomography (CBCT).

METHODS

This comparative study was conducted among 30 Class II patients (9 to 15 years of age) selected from the outpatient department of orthopaedics. They were divided into 2 Groups; Group I (15 patients) was treated by Herbst appliance; Group II (15 patients) was treated by fixed mechanotherapy. Pharyngeal airway volume, length and width evaluation were done using CBCT in vivo dental software 5.1 (ANATOMAGE, San Jose, CA). Intergroup comparison was done using independent t tests and level of significance ($P < 0.05$). Correlation of parameters were carried out using Pearson's correlation test.

RESULTS

Significant increase in nasopharyngeal, velopharyngeal, glossopharyngeal, laryngopharyngeal, and total airway volume in Herbst group was observed. Velopharyngeal length, glossopharyngeal length and nasopharyngeal airway width showed significant increase in Herbst group.

CONCLUSIONS

Treatment of Class II patients with Herbst appliance resulted in increase in pharyngeal airway volume. Herbst therapy induced repositioning of tongue resulting in increased length due to posterior fall of uvula, and hence airway volume increased drastically.

KEY WORDS

Airway Volume, Herbst Appliance, Class II Malocclusion, Retrognathic Mandible

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BACKGROUND

Malocclusion is a three-dimensional problem and is only an indication of imbalance between some forces operating inside or outside the mouth, which have caused the abnormality. The skeletal malocclusions occur because of defects in the underlying skeletal structure. It is reported that Class II discrepancies are not self-correcting with growth and therefore intervention to correct the underlying skeletal discrepancy is necessary. Angle showed that Class II division 1 malocclusion is associated with obstruction of the upper pharyngeal airway and mouth breathing.¹ Patients with retrusive mandibles can have breathing problems due to reduced airway volumes.² Skeletal Class II malocclusion has always been an intractable challenge for orthodontic practitioners because it presents with both sagittal and vertical discrepancies, these unfavourable discrepancies could lead to lower hyoid bone position with subsequent reduction of pharyngeal airway space and eventual occurrence of obstructive sleep apnea.³

Pharyngeal airway obstruction is expected to improve with forward jaw movement such as after maxillomandibular advancement surgery or with mandibular advancement oral appliances.⁴ Fairburn et al. reported that maxillomandibular advancement surgery appears to enlarge the lateral and the anteroposterior pharyngeal airway diameters from level of hard palate to hyoid bone.^{5,6} In case of retrognathic mandible, functional appliances should be used to advance the mandible.

Herbst appliance is a rigid fixed functional appliance for treating Class II malocclusion. The original bite jumping mechanism was developed by Herbst, and the banded design of appliance was reintroduced in late 1970s by Pancherz.⁷⁻⁹ Also effect of continuous bite jumping with the Herbst appliance on the occlusion and craniofacial growth were observed.¹⁰ Schultz et al. reported that pharyngeal airway volume increased when Herbst appliance and rapid maxillary expander were used together, resulting in relief of obstructive sleep apnoea symptoms.¹¹ CBCT produces images with high resolution and allows creation of three dimensional (3D) images in sagittal, coronal, and axial planes for volumetric airway evaluation.¹² This study intended to evaluate the effect of Herbst appliance on pharyngeal airway dimension in Class II malocclusion patients and its comparison with fixed mechanotherapy using CBCT.

METHODS

The protocol for this prospective observational study was approved on 15th December 2015 by the ethical committee of institution (SGTU / FDS / 24 / 1 / 717) and informed consent was obtained from patients participating in the study. The study was conducted from March 2016 to November 2016.

Sample size was calculated using the findings of Lombardo et al.¹³ keeping $\alpha = 0.05$ and power of the study as 99 % sample size of 12 subjects in each group was required. This number was inflated to 15 subjects in each group making total sample of 30 patients. Thirty Class II growing patients who reported to the Department of Orthodontics for routine fixed mechanotherapy treatment. Inclusion criteria was patients with Class II malocclusion having retrognathic mandible, Cervical vertebral

maturation index (CVMI) stages 2, 3, 4, age 9 - 12 years, horizontal or average growth pattern, minimum crowding in dental arches. In CVMI method, CVMI 2 indicates that peak in mandibular growth will occur 1 year after this stage, CVMI 3 indicates that peak in mandibular growth will occur during the year after this stage and CVMI 4 indicates that peak in mandibular growth occurs within a year before this stage.¹⁴ Exclusion criterion was CVMI stage ≥ 5 , ANB ≤ 4 , moderate or severe crowding, missing first permanent molar or any systemic disease.

Treatment options available for treating these type of growing Class II patients include removable functional appliances like twin block and fixed functional appliances like Powerscope, Advansync, Herbst appliance. Herbst appliance was selected as it is a fixed functional appliance with greater compliance of the patient as compared to the removable functional appliances. Also, Herbst appliance produces greater skeletal changes than other fixed functional appliances. Group I patients were treated by Herbst appliance and Group II by fixed mechanotherapy. Pre- and post-treatment CBCT scans were taken before treatment and at the end of 8 months (when the appliance was removed). Group II data was selected from department databank which suitably matched with regards to CVMI status.

Collection of Records

Pre-treatment records for both the groups included intraoral and extra oral photographs, study casts, and CBCT scans (i - CAT Classic, imaging sciences international, Hatfield, Pa). Each volumetric data set was acquired with a 20 seconds scan time with 16 (diameter) and 22 (height) cm field of view and at a resolution of 0.25 mm voxels. Herbst appliance design used was splint type appliance and was used during a fixed time period of 8 months + 2 weeks (Figure 1). Patients in Group II were treated by fixed mechanotherapy (MBT prescription 0.022" slot). CBCT scans were analysed in Group I and Group II to determine the changes in airway volume dimensions using in vivo dental software 5.1 (ANATOMAGE, San Jose, CA).

Airway Evaluation

For evaluation of airway volume, the DICOM images of subjects were imported into in Vivo Dental 5.1 where it was possible to orient all three planes, the intersection of these axes appeared at same X, Y and Z coordinates when viewed on respective axial, sagittal and coronal sections (Figure 2). This intersection was utilized to orient and identify from axial to coronal or sagittal views and localize airway volumes. This facilitated multi planar reconstruction for each subject and once precise airway boundaries were established; region of interest was automatically reconstructed, and calculations were done by the software. For this study, the airway evaluation was done for total airway volume and at nasopharynx, velopharynx, glossopharynx and laryngopharynx level (Figure 2). Total airway length was measured as greatest distance in anteroposterior direction of airway dimension and width was measured as the horizontal distance passing through midpoint of airway in axial view at nasopharyngeal, velopharyngeal, glossopharyngeal and laryngopharyngeal levels (Figure 3).

Figure 1. (a) Intraoral Frontal Photograph of a Patient with Herbst Appliance; (b) Intraoral left Lateral Photograph of a Patient with Herbst Appliance; (c) Intraoral Right Lateral Photograph of a Patient with Herbst Appliance

Figure 2. (a) Orientation of Patient's Skull along Lower Borders of Orbitale in Midsagittal View; (b) Orientation of Patient's Skull on Right Side along Frankfurt Horizontal Plane; (c) Orientation of Patient's Skull along Frankfurt Plane on Left Side; (d) Orientation of Patient's Skull along Crista Gali and Opisthion in Axial View; (e) Boundaries Marked in the Volume Rendered Image for Nasopharyngeal, Velopharyngeal, Glossopharyngeal, Laryngopharyngeal Airway

Figure 3. (a) Length and Width of Nasopharynx in Axial View; (b) Length and Width of Velopharynx in Axial View; (c) Length and Width of Glossopharynx in Axial View; (d) Length and Width of Laryngopharynx in Axial View Respectively

Statistical Analysis

The software used for statistical analysis was SPSS (Statistical package for social sciences) version 21.0 and Epi - info version 3.0. All the parameters of three groups were listed in a tabular manner in MS Excel Spreadsheet (Version 2013) with their mean, standard deviation and analysed statistically. Intergroup comparison of airway volumes, airway length and width were done using independent t tests and level of significance (p value). Correlation of Airway volume with Airway length and width parameters in Group I and Group II were carried out using Pearson's correlation test.

RESULTS

Parameters	Group I (Herbst Group)		Group II (Mechanotherapy Group)		t - Test	P - Value
	Pre - Post Change					
	Mean Difference	S.D	Mean Difference	S.D		
Nasopharynx	0.93	1.18	0.18	0.94	1.68	0.107
Velopharynx	3.20	2.38	2.75	1.91	0.50	0.622
Glossopharynx	2.81	2.97	0.82	1.50	1.95	0.064
Laryngopharynx	1.15	1.84	0.48	1.61	0.94	0.357
Total airway volume	8.09	5.14	4.23	1.87	2.26	0.03*
Table 1. Comparison between Group I and Group II for Effective Airway Volume (c.c.) Changes						
P > 0.05 – Non-Significant (N.S); P ≤ 0.05 – Significant (*)						

Parameters	Group I (Herbst Group)		Group II (Mechanotherapy GROUP)		t - Test	P - Value
	Pre - Post Change					
	Mean Difference	S.D	Mean Difference	S.D.		
L1Nasopharyngeal Airway (along palatal plane) (mm)	1.56	3.50	2.27	3.58	0.493	0.627
L2 Velopharyngeal length (mm)	4.38	4.99	1.82	2.49	1.493	0.149
L3 Glossopharyngeal length (mm)	2.60	4.31	0.07	3.83	1.502	0.147
L4 Laryngopharyngeal length (mm)	0.67	4.15	- 0.92	2.15	1.114	0.277
L5Nasopharyngeal length (along PNS to cranial base) (mm)	1.12	3.26	- 0.12	3.07	0.953	0.350
Table 2. Comparison between Group I and Group II for Effective Airway Length (mm) Changes						
P > 0.05 – Non-Significant (N.S): P ≤ 0.05 – Significant (*)						

Parameters	Group I (Herbst Group)		Group II (Mechano - Therapy Group)		t - Test	P - Value
	Pre - Post Change					
	Mean Difference	S.D	Mean Difference	S.D.		
W1Nasopharyngeal Airway (along palatal plane) (mm)	1.45	2.19	2.00	2.95	- 0.539	0.595
W2 Velopharyngeal length (mm)	1.00	5.62	4.17	4.09	- 1.530	0.140
W3 Glossopharyngeal length (mm)	1.04	6.38	- 1.29	2.55	0.117	0.908
W4 Laryngopharyngeal length (mm)	1.29	3.51	1.04	3.56	0.171	0.866
W5Nasopharyngeal length (along PNS to cranial base) (mm)	- 0.16	1.50	- 0.40	1.61	0.381	0.707
Table 3. Comparison between Group I and Group II for Effective Airway Width (mm) Changes						
P > 0.05 – Non-Significant (N.S); P ≤ 0.05 – Significant (*)						

Group I	Nasopharynx Airway Volume (in cc)		Velopharynx Airway Volume (in cc)		Glossopharynx Airway Volume (in cc)		Laryngopharynx Airway Volume (in cc)		Total Airway Volume (in cc)	
	r Value	P Value	r Value	P Value	r Value	P Value	r Value	P Value	r Value	P Value
Airway length										
L1 Nasopharyngeal length (along palatal plane) (in mm)	.689	.004*	.337	.220	.242	.386	-.170	.544	.392	.149
L2 Velopharyngeal length (in mm)	.150	.593	.067	.812	.893	.001*	-.089	.751	.549	.034
L3 Glossopharyngeal length (in mm)	.233	.402	.223	.424	.768	.001*	.533	.175	.827	.001*
L4 Laryngopharyngeal length (in mm)	.344	.210	.486	.066	.658	.008*	.633	.011**	.746	.001*
L5 Nasopharyngeal length (along PNS to cranial base) (in mm)	.000	.999	-.507	.054	.161	.566	-.422	.117	-.293	.290
Airway width										
W1 Nasopharyngeal width (along palatal plane) (mm)	.736	.002*	.467	.079	.535	.040*	.185	.510	.760	.001*
W2 Velopharyngeal width (mm)	.377	.166	.452	.091	.556	.031*	.268	.334	.712	.003*
W3 Glossopharyngeal width (mm)	.354	.196	.148	.599	.455	.088	.452	.091	.574	.025*
W4 Laryngopharyngeal width (mm)	.005	.987	-.339	.217	-.241	.388	-.291	.293	-.399	.141
W5 Nasopharyngeal width (along PNS to cranial base) (mm)	-.337	.219	-.072	.799	-.321	.243	-.284	.306	-.397	.143

Table 4. Correlation of Airway Volume with Airway Length and Airway Width Parameters in Group I (Herbst Group)

P> 0.05 – Non-Significant (N.S); P≤ 0.05 – Significant (*)

Group II	Nasopharynx Airway Volume (in cc)		Velopharynx Airway Volume (in cc)		Glossopharynx Airway Volume (in cc)		Laryngopharynx Airway Volume (in cc)		Total Airway Volume (in cc)	
	r Value	P Value	r Value	P Value	r Value	P Value	r Value	P Value	r Value	P Value
Airway Length										
L1 Nasopharyngeal length (along palatal plane) (in mm)	.150	.679	.212	.557	-.164	.651	-.408	.242	-.921	.594
L3 Glossopharyngeal length (in mm)	-.074	.839	.029	.937	-.128	.725	.363	.303	.202	.575
L4 Laryngopharyngeal length (in mm)	-.049	.893	-.095	.793	.420	.227	.490	.150	.640	.046*
L5 Nasopharyngeal length (along PNS to cranial base) (in mm)	-.134	.712	.312	.380	.269	.453	.221	.539	.659	.038*
Airway Width										
W1 Nasopharyngeal width (along palatal plane) (mm)	.391	.264	.232	.518	.132	.715	-.528	.117	.085	.815
W2 Velopharyngeal width (mm)	-.019	.958	.287	.422	-.225	.533	-.671	.034*	-.478	.163
W3 Glossopharyngeal width (mm)	.511	.131	.295	.408	-.021	.954	-.238	.509	.336	.342
W4 Laryngopharyngeal width (mm)	-.041	.911	.245	.495	-.622	.055	.077	.832	.342	-.204
W5 Nasopharyngeal width (along PNS to cranial base) (mm)	.284	.426	.031	.932	-.305	.392	-.224	.534	-.204	.462

Table 5. Correlation of Airway Volume with Airway Length and Airway Width Parameters in Group II (Mechanotherapy Group)

P> 0.05 – Non Significant (N.S); P≤ 0.05 – Significant (*)

Table 1, 2 and 3 represents Airway volume, airway length and airway width changes following treatment with Herbst appliance and fixed mechanotherapy. There was significant increase in nasopharyngeal, velopharyngeal, glossopharyngeal, laryngopharyngeal airway volume in Group I whereas there was statistically significant increase in only airway volume, length, width of velopharyngeal in mechanotherapy group (Group II). Statistically significant increase in total airway volume was produced by Herbst appliance when compared to mechanotherapy group. Table 4 shows that in Group 1, significant correlation was found between change in nasopharynx airway volume with nasopharyngeal airway length L1, and nasopharyngeal width W1 and was statistically significant ($P < 0.01$). The glossopharyngeal airway volume changes correlated significantly with changes in length of velopharyngeal (L2) and glossopharyngeal (L3), laryngopharyngeal airway (L4). Also, change in glossopharyngeal airway volume was also significantly correlated with change in width of nasopharyngeal (W1) and velopharyngeal airway (W2). There was a strong correlation between change in total airway volume and change in airway length and width.

Table 5 shows that in Group II; Change in laryngopharyngeal airway volume showed significant correlation with change in velopharyngeal airway width W2. Also, there was a significant correlation between changes in total airway volume with change in glossopharyngeal airway length L3, laryngopharyngeal airway length L4.

DISCUSSION

Significant increase in nasopharyngeal airway volume was observed which correlates with findings of Schutz et al.¹¹ who examined modification in sleep pattern and craniofacial morphology of adolescents with mandibular retrognathia using Herbst appliance. Restrepo et al.¹⁵ reported a significant increase in nasopharyngeal airway using bionator appliance. However, the findings showed disagreement with that of Jena et al. who conducted a three-dimensional study and found no significant change in the dimensions of nasopharynx among Class II subjects.¹⁶ Han et al.¹⁷ reported an increase in the airway volume but no significant difference in nasopharyngeal region from pre to post - treatment stage was observed between two groups. This could be probably because of the nasopharyngeal region is directly influenced by the size of adenoids and adenoids reach their greatest size at age of 10 years and mean age of subjects in his study was 10.1 years. Whereas in the present study, mean age was 12 - 13 years, hence significant increase in airway volume was observed.

Furthermore, glossopharyngeal region was the narrowest part of cross-section in Class II patients and was considered clinically important in terms of airway flow and oxygen saturation. Glossopharyngeal airway region has been reported to increase by 0.5 mm during growth.¹⁸ Glossopharyngeal and laryngopharyngeal airway volume increased significantly in our study in Herbst group and supported by findings of Kaoy et al.¹⁹ and Zhao et al.²⁰ in their study.

Kannan et al.²¹ reported significant increase in nasopharynx, oropharynx and hypopharynx airway following

treatment with various removable functional appliances whereas decrease or insignificant change was observed with FMA, MPA IV, and Herbst appliances which was in contrast to present study findings. Anusuya et al.²² concluded in systematic review that correction of mandibular deficiency by functional appliances has minimum effect on nasopharynx and significant effect on the improvement of oropharyngeal airway whereas Vompi et al.²³ found significant improvement in pharyngeal airway length, width and depth following functional appliance therapy. Moro et al.²⁴ concluded that rigid fixed functional appliances provided better skeletal results than flexible and hybrid ones.

Because of peculiar anatomy of nasopharyngeal airway amongst complete pharyngeal complex; nasopharyngeal length and width was measured in two planes; plane PNS to Cranial base as nasopharyngeal length (L1, W1) and plane along the extension of PNS to posterior pharyngeal wall as nasopharyngeal length (L5, W5). Nasopharyngeal airway length showed insignificant increase at both levels. And in fixed mechanotherapy group, the nasopharyngeal airway length (L5) was decreased by 0.12 mm. The skeletal changes of palatal plane could be responsible for decrease in nasopharyngeal airway length (L5). Nasopharyngeal length was found to be highly correlated with change in nasopharyngeal airway volume. Herbst therapy induces the repositioning of tongue resulting in increased length due to posterior fall of uvula, hence airway volume increases drastically. Increased nasopharyngeal width (W1) also showed a strong correlation with nasopharyngeal and total airway volume in the present study.

The mandibular advancement appliance appears to enlarge pharyngeal airway width to a greater degree than length at velopharyngeal and glossopharyngeal levels. Han et al.¹⁷ concluded that increase in upper oropharyngeal length was 0.8 mm in skeletal Class I subjects, while bionator showed an increase which was as large as 2 mm during the same period in Class II subjects. Fixed mechanotherapy patients also showed significant improvement in velopharyngeal airway length (L2) in this study. Mesial movement of molars as mentioned by Germac - Cakan et al. could be responsible for velopharyngeal airway dimension change.¹⁸

Glossopharyngeal length and glossopharyngeal and total airway volume were strongly correlated and were responsible for improvement in tongue position, resulting in enhanced airway passage. Ryan et al.²⁵ reported that when the mandible is advanced with a mandibular advancement oral appliance, most of velopharyngeal airway enlargement is in the lateral dimension, which is in contrast with the present study findings. Valiathan et al.²⁶ reported a positive correlation between the pharyngeal airway and length and position of mandible in fixed orthodontic patients.

Advancement in the mandibular position and repositioning of tongue, resulted in immense change in glossopharyngeal airway space. Glossopharyngeal width showed positive correlation with change in total airway volume, the laryngopharyngeal width showed an insignificant correlation with nasopharyngeal airway volume changes. Drosan et al.²⁷ assessed long-term effects of Class II malocclusion treatment with the Herbst appliance and found significant post-treatment increase of pharyngeal airway

width, possibly due to an increased lower posterior facial height development compared to untreated individuals.

However, further studies with increase in number of sample size and comparison with untreated subjects are encouraged to find outgrowth changes in mandible.

CONCLUSIONS

Herbst appliance therapy resulted in significant increase in the pharyngeal airway volume in nasopharyngeal, velopharyngeal, glossopharyngeal and laryngopharyngeal airway levels. Significant change in the length and widths of nasopharyngeal, velopharyngeal, glossopharyngeal and laryngopharyngeal airway was observed using Herbst appliance. Herbst therapy resulted in the change in position of hyoid bone which in turn caused modulation of pharyngeal muscles, leading to increase in the airway volume.

Future Scope

Further studies with a larger sample size must be conducted in future. Also, the stability of volumetric changes produced by Herbst appliance in Class II patients must be evaluated in the long term.

Data sharing statement provided by the authors is available with the full text of this article at jemds.com.

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