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Evaluation of Changes in Pharyngeal Space and Hyoid Bone Position in Skeletal Class II with Mandibular Advancement- A Prospective Clinical Study

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ABSTRACT:
Introduction: Pharyngeal airway and hyoid position are highly influenced by its surrounding anatomical structures. Mandibular advancement appliances are one of the common options for an adult patient not willing to undergo mandibular advancement surgery. No prospective study with 3D imaging and pharyngeal airway volumetric analysis has been carried out in skeletal class II adult patients treated with mandibular advancement. Aim: To evaluate changes in pharyngeal airway space and hyoid bone position in adults with Skeletal Class II malocclusion with mandibular advancement.
Material and methodology: A prospective clinical trial was carried out in 20 adult patients. Sample consisted of adult patients with skeletal class II requiring mandibular advancement. Patients underwent mandibular advancement with either removable or fixed functional appliances. Pre treatment and post treatment full head CBCT scans were taken and change in the hyoid position and change in pharyngeal airway volume were recorded.
Results: Paired t- test was performed for evaluation of pre-treatment and post-treatment data using GraphPad Prism 10 for statistical analysis. Significant change was observed in airway parameters and hyoid bone position post treatment. There was significant improvement in nasopharynx, palatopharynx, glossopharynx and hypopharyngeal volume with ($p < 0.001$). There was significant decrease in H-HRP and H-RGn whereas increase in H-VRP and H-3vai indicating upward and forward movement of the hyoid bone.
Conclusion: Patients showed significant improvement in pharyngeal airway volume with upward and forward position of the hyoid bone.

INTRODUCTION

The upper airway is a complex 3-dimensional (3D) structure, key apparatus made up of hard

and soft tissue that is responsible for a critical human function: breathing.
Anatomically, the pharyngeal airway has been divided into three parts: the nasopharynx, oropharynx, and hypopharynx which has been shown to be affected by different craniofacial skeletal patterns[1]. Accurate pharyngeal airway can be evaluated using 3D measurement of the minimum cross sectional area (MCA) and airway volume[2]. The minimal cross sectional area is the anatomical site that is perpendicular to the direction of airflow as visualised in the axial plane, and the degree of its constriction defines the resistance to airflow.

Skeletal class II Malocclusions are corrected using Functional appliances either fixed or removable by adapting the mandible and the dentition[3]. There are significant amount of studies about the effects of these appliances; however, the method by which they cause skeletal change and the amount of skeletal change that can be related to their use remains highly debated.[4]
Craniofacial morphology is one of the factors that can influence the upper airway. The effects of functional appliances on the airway have been previously studied. Studies have shown that maladjustment of the maxillofacial anatomy can lead to stenosis of the bony upper airway, resulting in obstruction symptoms.[5,6]. Suffering from airway stenosis is common in patients with short body length, retrusion, or clockwise rotation of the mandible.[7] Subjects with retrognathic mandibles frequently experience narrowing of the pharyngeal airway passage (PAP) and soft palate adaptations.[8] In people with sleep disordered breathing (SDB), the mandible is frequently retrognathic in relation to the cranial base.[9]As a result, the space between the cervical column and the mandibular corpus shrinks, which contributes to a posteriorly postured tongue and soft palate, increasing the chances of impaired respiratory function during the day and potentially causing nocturnal problems like snoring, upper airway resistance syndrome, and obstructive sleep apnea (OSA) syndrome.[10]
The use of functional appliances for retrognathic mandibles is fairly widespread in orthodontics. Adults with mild to moderate OSA are also commonly treated with similar appliances. Many prior research have shown that functional appliance therapy in children and oral appliance therapy in adults improves PAP dimensions. However, the majority of research employ two-dimensional analysis with cephalometric radiographs.[11,12,13] This has substantial limits since the airway is a complex three-dimensional structure in which the airway volume and minimum cross-sectional area (MCA) cannot be correctly evaluated with two-dimensional imaging[14]. The use of cone-beam computed tomography (CBCT) systems for the maxillofacial region has greatly improved the ability to analyse upper airway space in a broader range of patients, including those who have had maxillofacial surgery, implantation, or orthodontic treatments. There are no standard procedures for assessing the location of the hyoid bone in 3D imaging therefore we used cephalometric points to analyse the hyoid position as proposed by Costa et al.[15]

There is a retrospective study[16] describing mandibular advancement using removable and fixed appliances causing increase in upper and lower pharyngeal airway dimensions in growing children. A retrospective analysis by T. Rückschlo et al[17] shows that there are significant gains in almost all airway measurements six months postoperatively after mandibular advancement surgery in adult patients. But, there are no studies describing changes in pharyngeal airway space and hyoid bone position in adult patients with mandibular retrusion using functional appliances for dentoalveolar changes in prospective manner.
Hence the aim of the present study is to evaluate changes in pharyngeal airway space and hyoid bone position in adults with Skeletal Class II malocclusion treated with mandibular advancement.

MATERIAL AND METHODS

After Ethical approval from Sumandeep Vidyapeeth Institutional Ethical Committee (SVIEC), the study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, K. M. Shah Dental College & Hospital. This prospective study was conducted on 20 patients, with skeletal class II adults requiring mandibular advancement. The hyoid bone moves downward and forward with growth; therefore, the ages were selected to exclude the influence of development. The inclusion criteria for selection of patients was as follows- patients with age 16-30 years, mandibular clockwise rotation: Sum < 398, S-Ar-Go <145, Skeletal Class II patients with mandibular retrognathism (SNB< 78 degree, ANB angle >4degree, overjet >5mm, low or normal vertical growth pattern determined by SN-MP angle). Patients with sleep-disordered breathing (SDB), obstructive sleep apnea hypopnea syndrome (OSASH), degenerative disease of the temporomandibular joint and oral parafunctional activity, craniofacial anomalies, syndromes, severe asymmetries, or clefts and other developmental disorders, pregnant females, participants with Mallampati score 3 and 4, participants with bone loss or weak periodontium, history of drug intake that interferes in tooth movement, systemic disease, previous orthodontic treatment, poor oral hygiene were excluded.

Detailed case history and clinical examination were performed for all the included participants. Patients of both groups were subjected to pre- treatment full head CBCT scans in standard head position and cephalometric analysis was performed. Participants were subjected to mandibular advancement with either fixed or removable appliance. After complete mandibular advancement into class 1 molar relation, post-treatment CBCT scans were taken in the standard head postion. Post- treatment cephalometric analysis was performed and the following parameters were analysed given in **Table 1**.

TABLE 1	
Tooth Descriptions	
Ü1-PP; U1-NA, (mm)	U1-PP- the angle between the palatal plane and the long axis of U1 , U1-NA: linear distance from incisal edge of U1 to NA line
L1-MP; L1-NB, mm	L1-MP: the angle between mandibular plane and long axis of L1, L1-NB: linear distance from incisal edge to L1-NB line
Mandibular Measurements	
Articulare angle	Angle between Sella point, articulare point and gonion point.
Sum	Sum = Angle N-S-Ar (saddle angle) + Angle S-Ar-Go(articular angle) + angle Ar-Go-Me(gonial angle) (N: nasal point, Me: menton)
MP-SN	Angle formed by lines MP (Mandibular plane) and SN (Sella- Nasion line)
NBa-PtmGn	Angle formed by lines NBa (Nasion- basion) and line PtGn (line from pterygomaxillary fissure to Gn: gnathion)
Pog-NTVL, mm	Linear measurement from Pog to N true vertical line (Pog: pogonion)
SNB	Angular measurement between SN plane and NB line
ANB	Angular measurement between lines AN and NB
Hyoid Bone Position, mm	
H-HRP	Linear measurement from hyoid point to horizontal reference plane (7 degree clockwise rotation of SN plane at S point)
H-VRP	Linear measurement from hyoid point to vertical reference plane (HPR vertical line passing through S point)
H-Cv3ia	Linear measurement from hyoid point to most inferior-anterior point on the corpus of the third cervical vertebra

H-RGn	Linear distance from hyoid point to rgn(retrognathion) point.
Airway Parameters	
Nasopharynx mm^3	From PNS plane -So line (So: the midpoint of the line connecting sellar point and basion point) to PNS plane (line parallel to the lower border of the CBCT images passing through the posterior nasal spine
Palatopharynx mm^3	From PNS plane to UT(uvula top) plane (line parallel to the lower border of the CBCT images passing through the uvula top)
Glossopharynx mm^3	From UT plane to ET plane (line passing through the epiglottis pavimentum parallel to the lower border of the CBCT images)
Hypopharynx mm^3	From ET plane to Cv3ia plane (line parallel to the most inferior anterior point of cervical vertebrae 3.

Fig.1

Fig.2

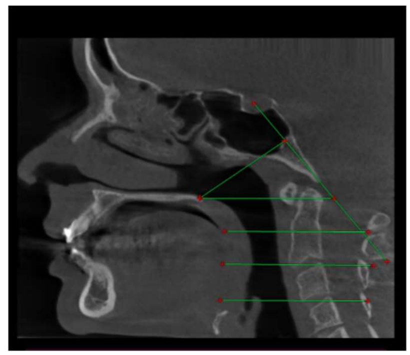

FIG.1. Hyoid Parameters.H-HRP (a) Distance between pt H and HRP. H-VRP (b) Distance between pt H and VRP. H-C3vai (c) Distance between pt H and antero-inferior point of 3rd cervical vertebrae. H-RGn (d)Distance between pt H and Retrognathion. FIG.2.Airway Parameters. Nasopharynx (a) Between line passing from PNS to So point (midpoint of the line sella pt to basion pt. Palatopharynx (b) Between PNS plane and UT plane. Glossopharynx (c) Between ut plane and ET plane. Hypopharynx (d) Between ET plane and line passing through antero-inferior point of C3 parallel to cbct image.

Statistical Analysis
GraphPad Prism 10 software was used for statistical analysis. Paired t test was used for evaluation between pre-treatment and post treatment dental changes, skeletal changes, change in position of hyoid bone and changes in pharyngeal airway.

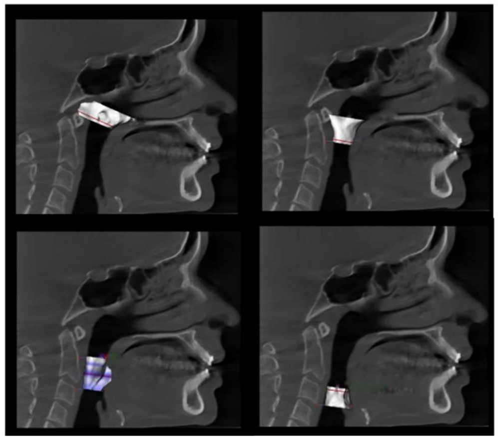

Fig.3 Volumetric measurements of the (a) nasopharynx, (b) palatopharynx, (c) glossopharynx, and (d) hypopharynx on the reconstructed 3D surface model.

RESULTS
Table 2 shows the mean difference in the pre-treatment and post treatment measurements of patients with Skeletal Class II with mandibular advancement.
U1-NA showed mild statistically significant decrease post treatment. There was a statistically significant increase in the proclination of lower incisors represented by increase in the L1-MP and L1-NB. Articular angle, NaBa- Ptm Gn, Pog-NTVL showed significant change post advancement. Bjorks sum and and MP-SN did not show statistical significant difference.
There was decrease in the post treatment value of H-HRP indicating an upward movent of the hyoid bone. Increase in H-VRP, H-C3vai and decrease in H-RGn indicated significant forward movement of the hyoid bone.
Nasopharynx showed only moderately significant increase in airway volume whereas palatopharynx, glossopharynx and hypopharynx showed highly significant difference in patients with Skeletal class II malocclusion after mandibular advancement.

<table>
<tr><td colspan="6">TABLE 2 - CLASS II MANDIBULAR ADVANCEMENT</td></tr>
<tr><th></th><th>PARAMETER</th><th colspan="2">MEAN/SD</th><th>MEAN DIFFERENCE</th><th>P VALUE</th></tr>
<tr><td rowspan="8">Dental Parameters</td><td rowspan="2">U1-NA</td><td>pre-</td><td>5.52±1.55</td><td rowspan="2">1.04 ± 1.65</td><td rowspan="2">0.019*</td></tr>
<tr><td>post-</td><td>3.6±1.72</td></tr>
<tr><td rowspan="2">U1-PP</td><td>pre-</td><td>116.7±1.2</td><td rowspan="2">0.59 ±0.42</td><td rowspan="2"><.001***</td></tr>
<tr><td>post-</td><td>115.91±1.15</td></tr>
<tr><td rowspan="2">L1-MP</td><td>pre-</td><td>92.3 ±2.7</td><td rowspan="2">14.80 ±1.5</td><td rowspan="2"><.001***</td></tr>
<tr><td>post-</td><td>97.12± 2.5</td></tr>
<tr><td rowspan="2">L1-NB</td><td>pre-</td><td>4.22± 1.4</td><td rowspan="2">2.86 ±0.9</td><td rowspan="2"><.001***</td></tr>
<tr><td>post-</td><td>7.2± 1.3</td></tr>
<tr><td rowspan="2">Mandibular Parametrs</td><td rowspan="2">ARTICULAR ANGLE</td><td>pre-</td><td>139.74 ±3.6</td><td rowspan="2">2.44 ± 0.87</td><td rowspan="2"><.001***</td></tr>
<tr><td>post-</td><td>143.1 ± 3.5</td></tr>
</table>

	BJORKS SUM	pre-	377.98 ±9.5	6.86 ±67.17	0.65
		post-	360.52 ±64.05		
	MP-SN	pre-	25.8 ±2.22	1.109 ± 3.36	0.15
		post-	26.6 4.07		
	NaBa-PtmGn	pre-	95.18 ± 2.8	-2.7.3 ± 1.15	<.001***
		post-	92.48 ±2.7		
	Pog-NTVL	pre-	-3.49± 1.86	3.87± 0.956	<.001***
		post-	0.355 ± 1.7		
Hyoid parameters	H-HRP	pre-	93.52 ± 3.57	0.60 ±0.33	<.001***
		post-	92.86 ± 3.4		
	H-VRP	pre-	14.68 ±1.48	0.923 ± 0.57	<.001***
		post-	15.60 ± 1.52		
	H-C3vai	pre-	35.09± 3.5	0.718± 0.47	<.001***
		post-	35.8 ±3.6		
	H-RGn	pre-	37.59± 3.7	1.26 ± 0.61	<.001***
		post-	35.87 ± 4.06		
Airway Parametrs	Nasopharynx	pre-	10.77 ± 1.25	0.273 ±0.347	.002**
		post-	11.04 ±1.31		
	Palatopharynx	pre-	14.52± 1.42	0.441 ± 0.12	<.001***
		post-	14.97 ± 1.38		
	Glossopharynx	pre-	13.33 ±1.4	0.451 ± 0.07	<.001***
		post-	13.79± 1.49		
	Hypopharynx	pre-	12.78 ±1.43	0.37 ± 0.10	<.001***
		post-	13.16± 1.43		

P value (*) mild significance,
(**) moderate
(***)high significance

DISCUSSION

The upper airway has a length of 120–140 mm[18]. The nasopharynx, palatopharynx, glossopharynx, and hypopharynx are all parts of this uneven lumen. Breathing issues could arise if one or more upper airway segments are narrowed.

The hyoid bone is a special structure in the head and neck bones since it is not directly related to other bones. Its position is primarily controlled by the suprahyoid and hypohyoid muscles. It has a role in the creation of upper airways, swallowing, vocalisation, mandibular movement, and the preservation of clear airways both during normal head and neck posture and other activities[19]. The attachment of the genioglossus, geniohyoideus and other ligaments between the mandibular lingual body and hyoid bone making their positions independent and balanced[20].

The present study includes adult patients with Skeletal Class II malocclusion primarily due to retrusive mandible. Subjects with a retrognathic mandible typically have small posterior pharyngeal airway dimensions and anatomical adaptations of the soft palate[21,22,23]. When mandibular retrognathism is corrected using functional appliances, the upper airway's dimensions are improved[24]. Although, reproducibility of airway dimensions on lateral cephalograms was reported highly accurate[25]. 3D imaging would be an appropriate method for the evaluation of pharyngeal airway space analysis, hence, present study uses a CBCT for airway evaluation.

Post- treatment CBCT of patients showed a significant improvement in the entire pharyngeal airway space.

Mandibular retrusion in class II malocclusion individuals was corrected using fixed or removable myofunctional appliances, considerable improvement in the depth of nasopharynx, palatopharynx, glossopharynx, and hypopharynx was seen. In individuals with a retrognathic mandible, the soft palate is pushed posteriorly and the upper airway's dimensions are reduced due to the tongue's backward position. The removable or fixed functional appliance leads to anterior mandibular displacement and alteration in the hyoid bone's position, which in turn affects the tongue's position and enhances the upper airway morphology. In the present study the upward and forward movement of the hyoid can be attributed to mandibular advancement leading to increase of space in the oral cavity due to correction of the downward position of the tongue and hence upward and forward movement in the hyoid bone. The results of the present study are consistant with those of Jena et al[24] and Schutz et al[25] and inconsistent with the results of Hanggi et al[26]. But, the above mentioned studies are done in adolescents whereas the present study includes adults. Surgical correction of mandibular advancement leads to increased pharyngeal airway in the long term[27]. In the present study, the results were measured post mandibular advancement but, long term effects of functional appliances on pharyngeal airway in adults should be check in further studies.

CONCLUSION

There was significant improvement in the nasopharynx, palatopharynx, glossopharynx and hypopharynx immediately after mandibular advancement in adults with functional appliances. Hyoid movement occurred in upward and forward direction immediatedly after mandibular advancement. Long term studies are needed to check the retention of these results.

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