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THREE-DIMENSIONAL EVALUATION OF THE AIRWAY SPACE AFTER DISTALIZATION USING CARRIERE MOTION APPLIANCE

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KEYWORDS

Airway dimensions, Carrière Motion Appliance, CBCT, Orthodontic treatment.

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ABSTRACT

Introduction: Class II malocclusion is a common issue that orthodontists must deal with, representing almost one third of all malocclusions. A link between Class II malocclusion and reduced pharyngeal airway dimensions has been reported. This malocclusion has been treated using a variety of methods. Distalization with Carrière Motion appliance is one of these methods. **Aim**: Evaluation of the effect of distalization with Carrière Motion appliance as a part of orthodontic treatment on airway dimensions. **Materials and methods**: Eighteen adult Patients aged from 18-30 years with a full set of permanent dentitions were subjected to wear Carrière Motion appliance for about 4 to 6 months. CBCT images were taken before and after distalization for comparison. **Results:** The results of this study showed a positive effect of Carrière Motion II on increasing the total airway volume. For the total airway volume, there was a significant increase from 39.9 ± 2.7 ml to 44.9 ± 2.6 ml. **Conclusion**: Total airway volume (upper airway) was increased significantly.

INTRODUCTION

There are two distinct upper airways in human beings: those in the nose and the mouth, and those that continue down into the larynx, which are known as cricoid cartilages. There are three pharyngeal regions: the nasopharynx, the oropharynx, and the hypopharynx, which are all located within the pharynx where the oral and nasal cavities meet and combine. The amount of air that can be moved via the upper airway depends on its size and shape. Upper airway, dental structures and craniofacial have a tight anatomical link, which means that they have an interdependent effect on one another. In order for the craniofacial structures to develop normally, a clear nasal breathing and airway are required [1, 2] .

An interest in airway analysis by orthodontists has been a longstanding one because of its possible role in proper craniofacial growth and its role in diagnosing mouth breathing and sleep issues. The upper airway has to be examined objectively by clinicians in order to detect normal and aberrant anatomical borders and dimensions. In spite of the fact that two-dimensional lateral cephalograms have been in widespread usage for years to analyze the airway's size, shape, location, and connection to other anatomical structures, they do not provide enough information to depict the anatomically complicated airway structure in 3 dimensions. Although lateral cephalograms can be employed as a first screening approach to airway evaluation, three-dimensional cone-beam computed tomography (CBCT) scans have a much more complete and reliable tools for volumetric measures and airways evaluation[1, 2] .

CBCT scans in three dimensions are a more accurate and complete tool for evaluating the airways and taking volumetric measurements. Its precision and accuracy for airway measuring were verified. A precise and dependable 3D study of the upper airway may be performed with CBCT. Luis Carrière created a new appliance bearing his name, the Carrière Motion appliance. The Carriere Motion appliance is a technique that initially describes the patient's sagittal dimension to build a Class I platform prior to completing orthodontic treatment. During the early phase of therapy, when patient compliance will be at its highest, the Motion Appliance is used to rectify cases to a Class I Platform for the macro repair of the occluded. There are many different types of fixed or aligner appliances that can be used to finish the case [3].

MATERIALS AND METHODS

1. Samples Size Calculation:

The present study was conducted on 18 adult patients after the approval of Research Ethics Committee,192/2019 Faculty of Dentistry, Suez Canal University.

To assess and evaluate changes in airway space after distalization using Carrière Motion Appliance in adult patients; a paired samples t-test (dependent samples t-test) was proposed for parametric data or other equivalent test for nonparametric data. A total sample size of 18 was appropriate to detect the effect size of 0.65, a power of 80% (1-β= 0.80) and at a two-tailed significant level of 5% (*p*-value<0.05). Based on previous calculations a total sample size of 18 was applied with a power of 0.80 (80%) . Sample size was determined by G*Power ver. 3.1.9.2 software.

2. Participants:

Patients were recruited from the outpatient clinic at the Department of Orthodontics, Faculty of Oral and Dental Medicine, Suez Canal University. The Research Ethical Committee of the Faculty of Oral and Dental Medicine, Suez Canal University approved this study.

3. Exclusion criteria:

a) Patients with no history of any serious trauma or surgery of orofacial region.

b) No gender predilection.

c) No history of orthodontic treatment of the subjects.

d) No history of obstructive breathing disorders.

4. CBCT

The selected patients were submitted to two CBCT scans; one pre-operative and another after completion of distalization using Carrière Motion appliance. The CBCT images were acquired using a SOREDEX SCANORA 3D present in radiology department in the Faculty of Dentistry, Suez Canal University. CBCT scanning is performed according to the manufacturer's protocol and by the same operator.

5. CBCT imaging technique

5.1 Patients orientation:

All patients were situated in a natural head posture on the chair of the CBCT equipment, with their teeth at maximal intercuspation and their lips and tongue in a resting position. The patients were instructed to refrain from swallowing and head or tongue movement. CBCT scans were obtained before to treatment initiation (T_1) and after treatment completion (T_2). The DICOM files obtained from the CBCT scans were opened using On Demand application software upon which the landmarks and reference planes were identified. The threshold, in which 3D On Demand Application software tool control the filling degree of the air was adjusted to -1000 below this threshold no air was detected by the software. The pharynx was separated and subdivided into naso-pharyngeal airway, oro-pharyngeal airway, and hypo-pharyngeal airway in accordance with the airway parameters specification.

5.2 Landmarks and reference planes identification

First, the landmarks were recorded in the landmarks module then, the reference lines and planes were recorded in the reference module after that, the measurements were recorded in the measurement module. All the landmarks, references measurements were recorded as a customized analysis on the software to be used to all the CBCT images of all participants.

After reorientation of the image, the landmarks (**Table 1**), were located on the 3D volume and refining was done on the generated multi-planar slice locator in the three cuts (axial, sagittal and coronal). By using the recorded special analysis, the readings were generated. All estimates were done by a similar observerand repeated again after 2 weeks. Mean values were taken thus decreasing the intra-observer reliability.

Table (1) *landmarks and reference planes*

Landmarks and reference planes	Definition
Landmarks	
Posterior nasal spine (PNS)	PNS; most posterior point on the bony hard palate
Pterygomaxillary points (PTM)	Intersection of the inferior border of the foramen rotundum with the posterior wall of the pterygomaxillary fissure
C1	Inferior anterior point of Atlus
C3	Inferior anterior point of the third cervical vertebra
C4	Inferior anterior point of the third cervical vertebra
Reference planes	
PNS plane	Plane passing through PNS perpendicular to the sagittal plane
PTM-PNS	Plane connecting right and left PTM passing PNS
C3 plane	Plane passing through inferior anterior point of third cervical vertebra perpendicular to the sagittal plane
Frankfort horizontal (FH)	Plane connecting most inferior border of orbital to most superior border of porion.
C1 plane	Plane passing through inferior anterior point of atlas perpendicular to sagittal plane
C3 plane	Plane passing through inferior anterior point of third cervical vertebra perpendicular to sagittal plane
C4 plane	Plane passing through inferior anterior point of fourth cervical vertebra perpendicular to sagittal plane

Airway volume analysis using OnDemand 3D Program

- Airway volume analysis will be performed according to the following steps:

1. The bounds of the specified area will be drawn using the indicated landmarks as guides. The landmarks and reference planes included in the investigation are detailed in (Table 1).
2. The coronal, axial and sagittal view were adjusted as follows:

- Axial view was adjusted till the cut where PNS appears
- Coronal view and sagittal view were adjusted for standardization. Overlay (**VOI**) icon was used to choose the desired area.

Statistical Analysis

Data were collected, handled, and organized in tables and figures. Data were explored for normality by checking the distribution of data normality tests (Kolmogorov-Smirnov and Shapiro-Wilk tests). Data showed normal (parametric) distribution (i.e. non-significant according to Shapiro-Wilkd). Data were presented as mean, standard deviation (SD), min, maximum.

Intra-observer reliability was assessed using Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (ICC) at 0.05 level.

RESULTS

Total airway space

Intra-observer reliability

Total Airway space volume (ml) was assessed by two different readings (R1, R2) of one observer, mean and standard deviation were presented in Table (2) showing the intra-observer difference in total airway space volume (Nasopharyngeal+Oro pharyngeal+hypopharyngeal). Intra-observer reliability and internal consistency were assessed by Cronbach's alpha and interclass correlation (ICC) at 0.05 level. Therefore, a high excellent intra-observer reliability was observed between R1 and R2 in pre-distalization (Cronbach's alpha= 0.990; ICC= 0.981; sign. <0.001***), and also between readings in post-disalization (Cronbach's alpha= 0.993; ICC= 0.986; sign.<0.001***).

The total airway space in pre distalization ranged between 24.58 to 64.35 ml with an average of 44.43±11.95 ml in readings 1, and between 23.15 to 61.56 ml in reading 2 with an average of 44.54±11.39 ml. However, in post-distalization total airway space volume ranged between 31.08 to 68.45 ml and from 32.44 to 69.79 ml in reading 1 and 2 with an average(±SD) of 52.73±10.97 ml and 53.27±11.09 ml; respectively (Table 2).

Table (2) *Total airway space in readings 1 and 2 and both pre and post distalization. Intra-observer reliability and internal consistency were assessed by Cronbach's alpha and interclass correlation (ICC) at 0.05 level.*

Pre/ post	Total airway volume (ml)			Inter observer reliability		
	R_1	R_2	Total	Cronbach's	ICC	Sign.
	Mean ± SD	Mean ± SD				
Pre-distalization	**44.43 ± 11.95**	**44.54 ± 11.39**	**44.48 ± 11.67**	0.990	0.981	**<0.001*** **
Post-distalization	**52.73 ± 10.97**	**53.27 ± 11.09**	**53.00 ± 11.03**	0.993	0.986	**<0.001*** **

**** significant at p<0.001; NS, non-significant at p>0.05*

Table (3) *Total airway space in pre- and post- distalization. Difference between pre- and post-was assessed by Paired samples t-test at 0.05 level.*

Descriptive measure	Total airway volume (ml)		Change	
	Pre-distalization	Post-distalization	ml	%
Mean	**44.48**	**53.00**	8.51	19.14
SD	11.51	10.88		
SE	2.712	2.564		
Min	23.15	31.08		
Max	64.35	69.79		
Paired t-test (pre/post)		**<0.001*** **		
Correlation: (r)		**0.989**		
sign.		**<0.001*** **		

**** Significant at p<0.001; NS, non-significant at p>0.05*

DISCUSSION

"The Carrière Motion Appliance" is a brand-new invention. First, the first maxillary molar is rotated and raised to a class I position before any further braces or appliances are placed, and the entire posterior segment is then distalized, starting from the canine and ending at that tooth. According to the inventor, the mandibular incisor protrusion during appliance activation might be prevented using various anchoring methods such as lingual arch or lower Essix appliance [14].

Mergen & Jacobs then Timms & Trenouth were the first to attempt to link the pharyngeal airway with distinct anteroposterior malocclusions [15]. Because of this, it has been established the nasopharyngeal depth and area of patients with class II malocclusion are lower. The retruded mandibular posture in these individuals, which makes them more susceptible to obstructive sleep apnea, was mostly responsible for this. Also, Kirjavainen and Kirjavainen discovered that Class II malocclusion patients had a smaller Oro- and hypopharyngeal space compared to Class I and normal occlusion patients.

Orthodontists have led to an increased interest in airway analysis due to the obvious airway's possible role in normal growth and development of the craniofacial area including its participation in the treatment and diagnosis of sleep problems and mouth breathing. The upper airway must be examined objectively by clinicians in order to distinguish between normal and pathological anatomical borders and dimensions. Because of their lack of information, the two-dimensional lateral cephalograms that were used for years to evaluate the airway's size and location relative to other anatomical structures are no longer effective. Airway examination can begin with lateral cephalograms, however, CBCT pictures give a more accurate and complete means of assessing and measuring the airway's volume than this screening approach. Instead of a fan-shaped x-ray beam, CBCT imaging employs a cone-shaped collimated x-ray beam [17] . Evidence of its precision and accuracy in airway measuring exists. A precise and dependable 3D study of the upper airway may be performed with CBCT [18]. Orthodontic software programmes have created features for airway studies, notably for volume size assessment.

Hsieh et al.[19] found a 3-cm3 reduction in airway volume following maxillary and mandibular setback surgery in their airway investigation. Wang et al.[20] found that extraction therapy reduced the anteroposterior breadth of the oropharyngeal airway by 1 to 1.5 mm. However, in the research of Germec-Caken et al.[21], the anteroposterior breadth of the oropharyngeal airway decreased by 2.1 mm and 3.8 mm in patients who received extraction and maximal anchoring. According to Chen et al.[22], the cross-sectional areas of the glossopharynx and palatopharynx decreased by 21.0 percent and 25.2 percent, respectively, following four extractions of the first premolars.

Researchers have recently become more interested in airway analysis and the effects of various treatment techniques on the airway space, which has resulted in inconsistent findings in the literature. A reduction in the size of the pharyngeal airway has been documented in several investigations[19-22] Guilleminault et al.[23] proposed that extraction therapy may predispose individuals to obstructive sleep apnea (OSA). Larsen et al.[24] on the other hand, presented significant evidence that there has been no link between premolar extraction therapy and OSA that used a large population matching for gender, age range, and body weight. Non-extraction Class II patients' airways have not been studied as a result of distalization of the maxillary teeth.

The Carrière Motion appliance, which was initially launched in 2004, was used in this study to distalize the whole posterior segment from the maxillary canine to the first molar using Class II intermaxillary elastics. The protocol demonstrated by Luis Carrière had been followed in terms of the diameter of the elastics and the time frame. Moreover, Lingual arch had been chosen as an anchorage device in order to decrease anchorage loss in the lower arch [25].

The findings of this investigation revealed that Carrière Motion II had a good effect on both total airway capacity and lowest constricted area. The total airway capacity increased significantly from 39.9 ± 2.7 ml to 44.9 ± 2.6 ml. The smallest confined area went from 213.5 ± 11.2 mm^2 to 347.4 ± 14.9 mm^2 with a substantial increase. Difference in MCA and the total airway volume between pre-distalization and post-distalization was highly significant ($p<0.001$) for both of them with 12.43 % and 62.67 % increases respectively.

Recent research has addressed these alterations in the airway via recognizing that the majority of class II treatment mechanics entail the forward movement of the jaw as the primary contributor to rectifying the sagittal relationship. The hyoid bone moves to a new site due to the forward positioning of the mandibular arch and teeth, resulting in a change in the proportion of the posterior airway. In order to broaden the airway, Carrière motion II employs class II elastics to protract the mandible arch. This causes the tongue to shift anteriorly, which widens the airway.

Other studies are in line with those of the Attia KH et al. [26] study, which investigated the pharyngeal airway characteristics of class II patients using the Carrière motion II appliance using CBCT. A retrospective analysis of Twenty adult patients with malocclusions who had therapy with the Carrière motion II device was conducted. Anatomage software was used on the CBCT images to measure the total airway capacity and the minimum cross-sectional area after and before therapy. The acquired data were analyzed statistically. After correcting the class II malocclusion with the Carrier motion II appliance, the observed airway parameters rose dramatically.

However, no other researchers have examined the effects of distalizing the maxillary dentition with the Carrière Motion appliance on the airway space. On the other hand, many distalizing appliances had the same effect as Carrière Motion appliance. Mevlut Celikoglu et al. studied the effects of pharyngeal and skeletal airway of the skeletally anchored Forsus FRD EZ vs the Herbst appliance. Patients with Class II skeletal malocclusions related to mandibular retrusion have been included in the research. Lower pharyngeal airway size has been observed to be significantly larger in the skeletally anchored Forsus FRD EZ group, despite the fact that both groups demonstrated a rise in upper and lower pharyngeal airway dimensions [27].

In similar results, za-Bussolaro et al. [28] conducted a retrospective exploratory cohort study to determine the extent to which class II malocclusion treatment with either intermaxillary elastics (IME) or the Forsus fatigue resistance device (FFRD) results in a change in oropharyngeal airway dimensions. The results demonstrated that the oropharyngeal airway increased in size in a comparable way with both orthodontic treatment regimens.

Baka et al. [29] recently conducted a research to examine the cephalometric alterations in the hyoid bone, pharyngeal airway, and soft palate (SP) following Class II malocclusion treatments utilizing Forsus Fatigue Resistant Device (FFRD) and Twinblock (TWB). Results showed that, In the TWB group, McNamara lower and upper pharyngeal airway dimensions significantly increased, similarly, In the FFRD group, McNamara upper airway dimensions significantly increased.

Conversely, Park et al. [2] revealed that distalizaton of the maxillary dentition showed a significant decrease in the oropharyngeal airway and MCA. This could be explained that the types of appliances used were different. Moreover, no reciprocal force was applied between the maxillary and mandibular arches. A modified C-palatal plate (MCPP) was applied to 33 adult patients divided into extraction and nonextraction groups. Extractions exhibited a significant negative moderate connection with airway volume and MCA in the extraction group. This shows that as distalization increases, the airway volume decreases. Nevertheless, this was not discovered in the group that did not undergo extraction procedures. However, Chou et al. [30] conducted research in adolescents with Class II malocclusion to assess long-term skeletodental effects, maxillary tuberosity volume, and airway space alterations following maxillary molar distalization using a modified C-palatal plate (MCPP). The total airway volume and the airway MCA increased by just 1.40 mm3 and 7.54 mm2, respectively, following distalization, according to the results. Long-term monitoring also revealed no substantial changes in breathing room.

From the above-mentioned points, it would seem that a comparable increase in the total airway volume as well as in the MCA has been achieved using Carrière Motion appliance. Most of the increase is in the Oropharyngeal airway. This could be explained by the fact that this appliance is using a reciprocal force between the mandibular arch and maxillary arch - in terms of Class II elastics - trying to distalize the first and produce mesial movement of the latter. As a result, the hyoid bone will shift, changing the size of the posterior airway, causing the tongue gap to expand.

CONCLUSION

In terms of the approach for assessing the airway following various orthodontic treatments Within the constraints of this study, we conclude that various orthodontic treatment modalities on airway dimensions for the correction of Class II patients are linked to considerable improvements in upper airway dimensions. Distalization with Carrière was the focus of the current paper. The upper airway was improved by using the motion appliance. The total airway capacity (upper airway) was greatly expanded.

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