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WORD COUNT	4503	TIME SUBMITTED	31-JAN-2024 12:37PM
		PAPER ID	106564543

Assessment of pharyngeal airway space in patients with different maxillofacial skeletal abnormalities using cone beam computed tomography

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ABSTRACT

Background. The patency of the pharyngeal airway has a far-reaching impact on craniofacial development. Conversely, the position of the maxillofacial skeletal components in certain disorders may lead to a compromised airway. Therefore, the evaluation of the airway is an essential step in treatment planning.

Objectives. The basic aim of this study was to measure the pharyngeal air space volume in the patients with maxillofacial skeletal abnormalities (like Class II, Class III malocclusion, TMJ Ankylosis, Condylar abnormalities and Syndromic cases) and those without any skeletal abnormalities. The objectives were to assess the Linear, Cross-sectional, and Volumetric dimensions of the pharyngeal airway in patients with and without maxillofacial skeletal abnormalities. (Study and Control group)

Materials and Methods. The Study group included 49 patients with maxillofacial Skeletal abnormalities like Class II and Class III malocclusion, Temporomandibular Joint Ankylosis, Condylar abnormalities, Syndromic cases. 49 Control group patients did not present with any skeletal abnormalities. The Linear, Cross-sectional, and Volumetric dimensions of the pharyngeal airway in the Study group and Control group were calculated and compared within the groups. Statistical Analysis: Unpaired t -test, ANOVA test and Tukey's Post Hoc analysis test were for the data analysis of the above study.

Outcomes. The Anteroposterior dimension of the airway at the Superiormost level was found to be significantly greater in Class II (p-value-0.039), Class III (p-value-0.002), and Control groups (p-value<0.001) when compared with the TMJ Ankylosis group. The Volume and Cross-sectional area of the airway at the most constricted level of the airway was found to be significantly greater in Class III (p-value<0.001) and Control group (p-value 0.013, 0.003) respectively when compared with the TMJ Ankylosis group.

Conclusions. The pharyngeal airway was narrowest anteroposteriorly at all three levels (Superior-most, Most constricted, and Inferior-most levels) in the TMJ Ankylosis group and widest in the Class III group. The least cross-sectional area was found in

the TMJ Ankylosis group whereas the greatest was found in the Class III group. The airway volume in the TMJ Ankylosis group and Class II group is significantly lesser than that of the Control group.

KEYWORDS: Pharyngeal airway, Cone Beam Computed Tomography, Skeletal Abnormality

Research Grant: The above research was not provided with any Research grant not it was sponsored by any company.

Introduction:

Pharynx is a wide muscular tube situated behind the nose, the mouth and the larynx [1]. There are various etiological factors like Nasal septal deviation, hypertrophy of nasal membranes, palatine, or pharyngeal tonsils, enlarged adenoids which cause nasal obstruction and alteration in the pharyngeal airway [2]. There is a significant relationship between the compromised pharyngeal airway and craniofacial development. A change in the nasorespiratory pattern or an obstructed airway results in the altered posture of the mandible and functional imbalance of muscles which in turn results in some undesirable changes in craniofacial growth [3].

Developmental anomalies such as Temporomandibular joint (TMJ) ankylosis; both Unilateral and Bilateral are very important causes for acquired mandibular hypoplasia and may lead to narrow oropharyngeal airway [4,5]. Micrognathia and retrognathia are common features seen in several congenital craniofacial anomalies including Treacher Collins syndrome, Hemifacial Microsomia along with associated Goldenhar Syndrome and Pierre Robin syndrome [4]. Condylar aplasia, condylar hypoplasia could be a cause of airway obstruction. An obstruction in the pharyngeal airway space has numerous consequences such as Obstructive sleep apnea syndrome (OSAS). It is a disease characterized by collapse of the pharyngeal airway resulting in repeated episodes of airflow cessation, oxygen desaturation, and sleep disruption [6]. Thus, there is a need for the assessment of airway because of its close correlation with the craniofacial development as well as other influences and their after-effects. The complex morphology of the airway has been studied by using imaging modalities such as Lateral Cephalograms, Computed Tomography(CT). Cone Beam Computed Tomography (CBCT) poses several advantages over CT such as lesser radiation exposure and cost effectiveness.

Materials and Methods:

The study was conducted with the approval of the Institutional Ethical Committee (Ref.No.GDC/108/18). The guidelines of Declaration of Helsinki were thoroughly followed while performing the above study. The above study was a Cohort Study of a Mixed type as it involved both Prospective and retrospective analysis. Purposive Sampling technique was adopted for the selection of participants for the above study. Patients included for the above study were divided in two groups: Study group included 49 patients with maxillofacial skeletal abnormalities. It had 11 patients showing Angle's Class II malocclusion, 11 patients with Angle's Class III malocclusion, 15 patients with Temporomandibular Joint Ankylosis either Unilateral or Bilateral, 6 patients with either Condylar Hypoplasia, Hyperplasia or Condylar Aplasia, 6 patients diagnosed with skeletal abnormalities in relation with specific syndromic conditions such as Treacher Collin's Syndrome, Crouzon's Syndrome, Hemifacial Hypoplasia. For categorizing the patients, a detailed intraoral and extraoral clinical examination was performed. Out of 49 patients, 25 were females and 24 were males. The age range of the patients was in between 6 to 36 years. Control group included 49 patients with no maxillofacial skeletal abnormalities.

Written and informed consent was obtained was obtained from the participants. Informed consent of the patients less than 21 years of age was obtained from their parents or guardians. Patient/Parents who did not give informed consent to undergo this study or patients with extensive dental restorations, implants, which were likely to cause severe streaking and degrade the image quality were excluded from the above study.

Patients selected according to the inclusion criteria were subjected to CBCT imaging using Planmeca ProMax 3D Mid machine with following exposure parameters; FOV-16cm x 16cm, kVp-90, mA-10 and Exposure time- 27seconds. The CBCT scans were thoroughly assessed using Romexis 3.2 software by two observers independently to avoid personal bias and to make the study more reliable. ANB angle, that denotes the relative position of the maxilla and mandible to each other was calculated on CBCT for the patients who were categorized in the Angle's Class II (ANB > 3^0), Angle's Class III (ANB < 0^0) malocclusion group and Control group (1^0 < ANB < 3^0) for the confirmation of the diagnosis made clinically. An increase in this angle is indicative of Class II skeletal tendency while an angle less than normal or negative angle is suggestive of skeletal Class III relationship.

For the purpose of the study, the upper limit of the airway was considered at the level corresponding to hard palate (PNS) and the lower limit was considered at the level corresponding to the most antero-inferior point of third cervical vertebra (C3), as they are the stable bony landmarks **(Figure 1).** During the assessment of pharyngeal airway, emphasis was given on the Linear, Cross-sectional and Volumetric dimensions. The linear dimensions such as Supero-inferior dimension representing the 'Height' of the airway and Antero-posterior dimensions were calculated from the anterior pharyngeal wall to the posterior pharyngeal wall at three different levels **(Figure 2).**

1) Antero-posterior (AP-SM) Superior most (At the level of hard palate)

2) Antero-posterior (AP-MC) Most constricted (At the level of greatest constriction), represents minimal antero-posterior dimension.

3) Antero-posterior (AP-IM) Inferior most (Level of most antero-inferior point of third cervical vertebra).

The linear measurements were made on the midsagittal section with the help of 'Measure Length' tool provided by the CBCT Romexis 3.2 software. Volumetric measurements (V) of pharyngeal airway space that was predefined was calculated and computed using a specialised tool provided by CBCT Romexis 3.2 software. The cube was selected from the available tool bar and it was dragged to the region of the pharyngeal airway under study. The dimensions of this cube were adjusted such that the complete pharyngeal airway was included in all the three dimensions between the selected upper and the lower limits. Further, the 3D measurement tool was used by selecting the 'Air cavity' option to determine the volumetric dimensions of the airway for the region under study The cross-sectional area (C.S.A) at the most constricted level was determined on the axial section. **(Figure 3).** Similarly, Linear, Cross sectional and Volumetric assessment was done in the Control group of patients without any maxillofacial skeletal abnormalities.

OUTCOMES (RESULTS):

The data obtained after CBCT evaluation was recorded and tabulated under specific headings. The observations after the completion of the study were subjected to statistical analysis and objective conclusions from the acquired results were drawn for further discussion purpose. The statistical analysis was performed (IBM SPSS software version 20.0) and results were formulated. The Intraclass Correlation Coefficient (ICC) was found to be 0.891, which is excellent. Out of 49 patients from the Study Group, 24 (49%) were Males and 25 (51%) were Females whereas out of 49 patients from the Control Group, 30 (61.2%) were Males and 19 (38.8%) were Females.

Table 1 depicts comparison of Linear, Cross sectional and Volume dimensions among Study group and Control groups using Unpaired T-test. The mean Anteroposterior dimension at the Superior-most level and mean Superoinferior dimension is lesser in Study Group as compared to Control group with a p value of < 0.001, which shows that it is highly statistically significant. The mean Anteroposterior dimension at the inferior-most level and mean volume is significantly lesser in Study Group than in Control Group with a p-value of 0.019 and 0.011 respectively.

Table 1 Comparison of Linear, Cross sectional and Volume dimensions among Study group and Control groups using Unpaired T-test

	Group	N	Mean	Std. Deviation	t value	P value
AP Superior most	Study	49	12.327	5.3989	5.429	<0.001**
	Controls	49	17.429	3.6744		
AP Most constricted	Study	49	5.710	3.4124	1.662	0.100
	Controls	49	6.670	2.1159		
AP Inferior most	Study	49	10.457	4.1088	2.378	0.019*
	Controls	49	12.373	3.8214		
Supero-inferior	Study	49	51.938	6.6607	3.347	<0.001**
	Controls	49	56.039	5.3174		
CS area	Study	49	442.295	301.9363	1.801	0.075
	Controls	49	534.916	191.0531		
Volume	Study	49	12.224	6.8307	2.604	0.011*
	Controls	49	15.118	3.5882		

Table 2 represents Comparison of mean AP- Superiormost (AP-SM), AP- Most constricted (AP-MC), AP-inferior most (AP-IM), Superoinferior (SI) among all the groups respectively using one way ANOVA test.

Table 3 represents Comparison of Cross sectional area (C.S.A) and Volume (V) values among all the groups respectively using one way ANOVA test.

It shows that there was a highly statistically significant difference between the various groups for the parametres of AP-Superiormost, AP-Most constricted dimensions and Volume with a p-value of <0.001 whereas a statistically significant difference was observed between the different groups for the parametres AP-Inferiormost, Superoinferior dimensions and Cross-sectional area with p-values of 0.022, 0.004 and 0.002 respectively. **(Figure 4, 5)**

TABLE 2 :COMPARISON OF LINEAR DIMENSIONS; MEAN AP-SM, AP-MC, AP-IM, AND SI DIMENSION VALUES AMONG ALL THE GROUPS

		AP SUPERIORMOST		**AP MOST CONSTRICTED**		**AP INFERIORMOST**		**SUPEROINFERIOR**	
Groups	**N**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
TMJ Ankylosis	15	9.028	3.5867	3.053	2.4313	8.216	3.6141	54.333	8.5942
Class II	11	14.165	5.8320	5.910	2.0880	11.074	2.8197	49.381	4.0024
Class III	11	15.854	4.6605	8.891	3.1661	12.283	4.2756	53.418	5.0394
Condylar Abnormalities	6	11.768	2.7774	6.100	3.1819	11.201	5.2232	51.533	6.8768
Syndromic Cases	6	11.300	7.4519	5.766	3.5539	10.835	4.6560	48.333	6.0645
Controls	49	17.429	3.6744	6.670	2.1159	12.373	3.8214	56.039	5.3174
Total	98	14.852	5.2685	6.185	2.8718	11.405	4.0643	53.968	6.3461
		f value: 10.527		f value: 7.961		f value: 2.770		f value: 3.806	
		p value: **<0.001****		p value: **<0.001****		p value**: 0.022***		p value : **0.004***	

TABLE 3: COMPARISON OF MEAN CROSS-SECTIONAL AREA AND VOLUME VALUES AMONG ALL THE GROUPS

		CROSS-SECTIONAL AREA		VOLUME	
Groups	**N**	**Mean**	**SD**	**Mean**	**SD**
TMJ Ankylosis	15	297.133	222.4960	9.477	5.4980
Class II	11	396.318	218.8936	10.314	4.9556
Class III	11	682.681	324.5886	18.808	5.7337
Condylar Abnormalities	6	435.333	229.0318	12.083	5.7362
Syndromic Cases	6	455.750	426.9735	10.662	9.3021
Controls	49	534.916	191.0531	15.118	3.5882
Total	98	488.128	256.1639	13.656	5.6346
		f value: 4.214		f value: 7.016	
		p value: **0.002***		p value: **<0.001****	

Table 4 represents statistically significant values for Intergroup comparison for Linear, Cross-sectional and Volumetric dimensions done using Tukey's Post Hoc Analysis test. At the Superiormost level, there is a statistically significant difference between

TMJ Ankylosis and Class II (p-value – 0.039), TMJ Ankylosis and Class III (p-value – 0.002) & TMJ Ankylosis and Controls (p-value – <0.001) for the AP-SM. In addition, a statistically significant difference was observed in the said parameter between Condylar Abnormalities and Controls (p-value – 0.036) as well as Syndromic cases and Controls (p-value – 0.018).

At the most constricted level, there is a statistically significant difference between TMJ Ankylosis and Class II (p-value – 0.048), TMJ Ankylosis and Class III (p-value – <0.001) for AP-MC. At the inferiormost level, there is a statistically significant difference between TMJ Ankylosis and Controls (p-value – 0.006) for AP-IM. A statistically significant difference was observed between Class II and Controls (p-value – 0.014) & Syndromic Cases and Controls (p-value – 0.039) for Supero-inferior values. A statistically significant difference is noted between TMJ Ankylosis and Controls (p value – 0.006), TMJ Ankylosis and Class III (<0.001) for Cross sectional area at most constricted level. For the parameter of Volume, a highly statistically significant difference is observed between Class III and TMJ ankylosis, Class II and Class III (p value < 0.001). A statistically significant difference is observed between TMJ ankylosis and Controls (p value – 0.003), Class II and Controls (p value – 0.049), Class III and Syndromic cases (p value – 0.019) for the said parameter.

TABLE 5: INTERGROUP COMPARISON FOR ALL LINEAR, CROSS-SECTIONAL AND VOLUMETRIC DIMENSIONS USING TUKEY'S POST HOC ANALYSIS

	TMJ ANKYLOSIS	**CLASS II**	**CLASS III**	**CONDYLAR ABNORMAL-ITIES**	**SYNDROMIC CASES**	**CONTROLS**
TMJ ANKYLOSIS		0.039 **(AP-SM)** 0.048 **(AP-MC)**	0.002 **(AP-SM)** **<0.001 (AP-MC)** **<0.001 (C.S.A)** **<0.001 (V)**			**<0.001 (AP-SM)** **<0.001 (AP-MC)** 0.006 **(AP-IM)**

						0.013 **(C.S.A)** 0.003 **(V)**
CLASS II	0.039 **(AP-SM)** 0.048 **(AP-MC)**					0.014 **(SI)** 0.049 **(V)**
CLASS III	0.002 **(AP-SM)** **<0.001 (AP-MC)** **<0.001 (C.S.A)** **<0.001 (V)**	< 0.001 **(V)**				
CONDYLAR ABNORMAL-ITIES						0.036 **(AP-SM)**
SYNDROMIC CASES						0.018 **(AP-SM)** 0.039 **(SI)** 0.019 **(V)**
CONTROLS	**<0.001 (AP-SM)** **<0.001 (AP-MC)** 0.006 **(AP-IM)** 0.013 **(C.S.A)** 0.003 **(V)**	0.014 **(SI)** 0.049 **(V)**		0.036 **(AP-SM)**	0.018 **(AP-SM)** 0.039 **(SI)** 0.019 **(V)**	

Note: Statistically significant p-values have been mentioned in the above table.

DISCUSSION:

As the airway and the dentofacial structures have a close relationship with each other, the analysis of the airway is an integral part of the diagnosis, treatment planning and outcome of the best results. The current study made use of CBCT as a modality for the assessment of the pharyngeal airway. An excellent intra-observer and inter-observer reliability of 0.891 was obtained, which showed that the dimensions were reproducible and the method was perfectly reliable.

Studies pertaining to Class I, Class II and Class II groups were performed earlier, but an extensive perusal of the literature has shown that there were no studies found where volume measurements of the airway have been performed in the patients specifically with TMJ Ankylosis, Condylar abnormalities and Syndromic manifestations. This study is a unique one where detailed measurements of the airway have been done in all the above-mentioned groups (6 groups).

In the present study, the hard palate was considered as the superior-most reference plane and the most antero-inferior point of the third cervical vertebra was considered as the inferior-most reference plane for the purpose of measuring airway dimensions which was in conjunction with studies performed by Dan Grauer et al [7], Mevlut

Celikoglu et al [8], El and Palomo et al [9], Claudino et al [10], Zheng et al [11] , Souza KR et al [12] and Takumi Ogawa et al [13].

The group having TMJ Ankylosis and Class II malocclusion shows significantly lower pharyngeal airway volume as compared to the Control group and Class III group. The above observation pertaining to Class II subjects was in concurrence with the findings of other studies performed by Grauer et al [7], El and Palomo et al [9], Claudino et al [10], Zheng et al [11], Dalmau et al [14], Alves et al [15], Kim et al [16]. The mean values for volume in our study resembled with the mean values in the studies performed by Grauer et al [7] , Zheng et al [11], Dalmau et al [14] . They reported that the volume of the pharyngeal airway did not differ significantly between Class III and Class I groups though the mean volume in Class III was greater than Class I group. These findings resembled with the study performed by Grauer et al [7] , Dalmau et al [14].

The cross-sectional area at the most constricted level shows a statistically significant difference among various groups. When we determine the individual group variations, it is noted that the cross-sectional area in TMJ Ankylosis group is significantly lesser than Class III and Control group. TMJ Ankylosis group had a significantly lower AP dimension at Superior-most level when compared with Control, Class II and Class III groups. This observation noted with respect to Class II, Class III and Control group was in accordance with the other studies conducted by Dalmau et al [14], Alves et al [15], Kim et al [16], Kikuchi et al [17], Alves et al [18]. In addition, AP dimension of the airway at the superior-most level was significantly lesser in Condylar abnormalities and Syndromic Cases group as compared to the Control group. From the earlier observations, it is evident that AP dimension at the most constricted site is significantly lesser in TMJ Ankylosis group than Class III and Control group. This has an indirect effect on the cross-sectional area in such a way that the area is also reduced in that region as compared to the area at other levels along the entire span of the airway. Similar findings are observed for this parameter as well. These findings were in accordance with the findings observed by Tso et al where they stated that shorter linear dimension was associated with smaller cross-sectional area [19]. It was noted that the length of the airway was found to be significantly lesser in Syndromic cases group and Class II group as compared to control group. Though the other parameters were affected in TMJ ankylosis, the Superoinferior height was not altered. This can be contributed by the fact that the airway is a continuous anatomic space from Nasopharynx down to trachea, the vertical height of the airspace is unlikely to be affected as the Superior-most and inferior-most reference planes are at the hard palate & third cervical vertebra and are not related to the height of the ramus, which is usually affected in TMJ ankylosis.

The morphology and patency of the airway is complex due to the interplay of Bone, dentition and soft tissue. In TMJ ankylosis, the growth of the entire mandible is affected as condyle is an important growth centre. Due to extreme Retrognathia and micrognathia, posterior displacement of tongue, soft palate, there is a narrowing of the airway resulting in reduced volumetric dimension and other anteroposterior dimensions. R.Gunaseelan performed a simultaneous genial distraction and interposition arthroplasty in a patient with TMJ Ankylosis. After the distraction of the mandible, it was noted that there was an increase in the patency of the airway [20]. On the other hand, in Class III malocclusion group, there is adequate space for the tongue as the mandible is prognathic or forwardly placed. This justifies the fact that the volume of the airway in Class III subjects is significantly higher than in subjects with TMJ Ankylosis. The group with Syndromic manifestations included three types of syndromes; Treacher Collin Syndrome, Hemifacial hypoplasia, Crouzon's Syndrome. Davinder Singh et al suggests that there are 3 main causes of Mandibular hypoplasia; Congenital, Developmental and Acquired [21]. This congenital mandibular hypoplasia seen in conditions like Treacher Collin Syndrome, Hemifacial hypoplasia could be one of the causes for airway compromise. Crouzon's Syndrome patients on the other hand, also face complications of airway obstruction along with premature fusion of the skull base, midface hypoplasia & Maxillary hypoplasia [22]. Sean Boutros et al in his study stated that the growth of the mandible in Crouzon's Syndrome patients is hampered at the condylar level leading to inward torque of the ramus and its deformation. This deformity is secondary to the cranial base abnormalities [23]. Airway compromise in these patients could be attributed to this factor along with primary skeletal abnormalities.

CONCLUSION:

The literature reveals that multiple recent studies have been performed for airway volume emphasizing on different forms of skeletal malocclusions [24-26]. The above study is very distinctive as it collectively incorporates all the skeletal abnormalities such as TMJ ankylosis, Class I, Class II, Class III, Condylar abnormalities, various Syndromic cases collectively in the same study in a very elaborative manner as all the above conditions can contribute to changes in airway volume. Patients with maxillo-facial skeletal abnormalities can be assessed for airway using CBCT though they do not present with any active symptoms related to airway obstruction. The detection of compromised airway in such patients will act as a preventive measure, as the airway compromise along with the etiology will be identified in its earlier stages and steps can be taken to avoid further worsening of the same. Airway analysis shall aid in modifying proposed treatment plan and minimize the risk of OSAS. OSAS has many potential complications including hypertension, congestive cardiac failure, arrhythmias, stroke, transient ischemic attacks, depression, growth interruption in children emphasizing the importance of airway analysis [27]. CBCT can be used as a modality to determine the pharyngeal airway volume in patients suffering from episodes of airway obstruction as a preliminary diagnostic method prior to polysomnography for the establishment of the diagnosis of OSAS.

1) CONFLICTS OF INTEREST:

There are no conflicts of interest to declare.

2) ETHICAL GUIDELINES:

The study was conducted with the approval of the Institutional Ethical Committee (Ref.No.GDC/108/18).

3) SOURCE OF FUNDING:

The above original research was Non-funded.

4) AUTHORS CONTRIBUTIONS:

First and Corresponding Author- Dr. Shraddha Jugade: Concepts, Design, Definition of Intellectual content, Literature Search, Data Acquisition, Data Analysis, Statistical analysis, Manuscript Preparation, Manuscript editing, Manuscript Review, Guarantor.

Second Author- Dr. Easwaran Ramaswami: Concepts, Design, Definition of Intellectual content, Data Analysis, Statistical analysis, Manuscript editing, Manuscript Review.

Third Author- Dr. Sonali Kadam: Design, Definition of Intellectual content, Literature Search, Data Analysis, Manuscript editing, Manuscript Review.

Fourth Author- Dr. Amit Ramchandani: Literature Search, Data Acquisition, Data Analysis, Statistical analysis, Manuscript Review.

Fifth Author- Dr. Hemant Umarji: Concepts, Design, Manuscript Preparation, Manuscript editing, Manuscript Review.

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