ORIGINAL ARTICLE

Effect of Obstructive Sleep Apnea on Condylar Malformation, Vertebral Column, and Head Posture: A Cephalometric Evaluation

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Abstract

Aims and objectives: Obstructive sleep apnea (OSA) is by far the most common sleep-related breathing disorder, affecting 2–4% of the adult population. The present study aims to compare the descriptive morphology of the cervical column in subjects with normal craniofacial morphology with those having condylar hypoplasia with OSA and to evaluate a positive correlation between the cervical columns, the cranial base angle, and the posture of the head and neck in subjects of condylar hypoplasia.

Materials and methods: The present study comprised of lateral cephalogram of 40 subjects divided into two equal groups—control groups ($n = 20$) and OSA with condylar hypoplasia ($n = 20$).

Results and observation: The condylar hypoplasia group has fusion anomalies of 65% and 35% has a posterior arch deficiency. The cervical lordosis, inclination of the cervical column is found to have a positive statistically significant correlation in condylar hypoplasia subjects.

Conclusion: Morphological deviations and deviation pattern of the cervical column occurred significantly more often in subjects with condylar hypoplasia as compared with normal craniofacial morphology which can be verified by the increased cranial base angle, cervical lordosis, the inclination of the upper cervical spine, and cranial base angle were positively correlated with a fusion of cervical column.

Clinical significance: Specific types of craniofacial morphology and head postures such as a reduced posterior airway space, an abnormally long soft palate, a low position of the hyoid bone, and an extended head posture are considered predisposing factors of OSA. As posture of the head and neck is considered to be associated with OSA, OSA may be associated with fusion of the cervical column. Hence, to know the result of malformation in the cervical column prove to be important with regard to phenotypical subdivision, diagnosis, and treatment of OSA.

Keywords: Diagnosis, Head and neck, Management.

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Introduction

Obstructive sleep apnea (OSA), by far the most common sleep-related breathing disorder, is characterized by loud snoring, frequent arousals, sleep fragmentation, intermittent hypoxemia, and daytime sleepiness affecting around 2–4% of the adult population.[1] Obstructive sleep apnea is multifactorial with age, gender, and body mass index (BMI) as predisposing factors. Many authors have already agreed to the fact that there are certain craniofacial morphological and postural characteristics, i.e., reduced posterior airway space, an abnormally long soft palate, low position of the hyoid bone, and an extended head posture[1] associated with OSA.

Recently, an association between the morphology of the cervical column, craniofacial pattern, and head posture has been demonstrated. Furthermore, head posture is also associated with the development and function of dentofacial structures. Previous research has also focused on the association between the dimensions of the atlas (C1) and craniocervical posture.[2]

Till now, morphological deviations of the upper cervical vertebrae have been investigated in relation to craniofacial syndromes, i.e., cleft lip and palate, and a strong association between cervical vertebrae and maxilla is observed which may be caused by the developmental fault of the mesenchyme (which are obtained by same or similar paraxial mesoderm). While the associations are well described for the maxilla, no studies have investigated deviations of the cervical vertebrae in patients with mandibular condylar hypoplasia.[2]

So, the aim of the present study is:

- To compare the descriptive morphology of the cervical column in subjects with normal craniofacial morphology with that having condylar hypoplasia with OSA.
- To evaluate a positive correlation between the cervical columns, the cranial base angle, and the posture of the head and neck.

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Materials and Methods

The present study was done on the subjects residing in various areas of Lucknow and attending the OPD, Department of ENT in Hind and Mayo Medical College, Lucknow, who had come for the investigation of OSA. Out of them, 60 subjects were scrutinized having moderate to severe OSA with a mean age of 23 years and a mean BMI of 28.2 kg/m.[2]

Obstructive sleep apnea was diagnosed using overnight polysomnography. The subjects with moderate to severe OSA were diagnosed based on respiratory distress index (RDI), which records the number of episodes of apnea and hypopnea during polysomnographic records. A consultant respiratory physician specialized in OSA was appointed for the clinical scrutinization of the subject. No subjects with craniofacial anomalies or any previous intranasal or pharyngeal surgical procedures were included in the study.

The selected subjects consented to the lateral cephalogram for the research purpose. Ethical approval for this study was obtained from the ethical committee of Chandra Dental College and Hospital, Barabanki.

Lateral profile radiographs of both the control group and OSA with Class II skeletal pattern were recorded with teeth in occlusion and standardized head posture with proper mirror image and a plumb line representing true vertical in the department of orthodontics, Chandra Dental College, Barabanki.

The OSA group with condylar malformation includes 20 subjects (10 females and 10 males) with an age group of 17–30 years (mean age—23 years) were scrutinized from various areas of Lucknow. Inclusion criteria for these subjects were mandibular retrognathism, steep occlusal plane, increased mandibular plane angle, shorter mandibular length, increased upper and lower facial height, caudally placed hyoid bone, decreased pharyngeal dimensions, and changes in pharyngeal spatial position.

The control group consists of 20 subjects (10 females and 10 males), with the age group of 17–30 years (mean age—23 years). The subjects selected were found to be in neutral occlusion with Class I skeletal base, and no previous history of orthodontic treatment was observed. None of the subjects had an obstruction in the upper airway, craniofacial anomalies, or any systemic muscle or joint disorders.

Cephalometric landmarks of both control and OSA group were identified and marked on cellulose acetate tracing sheets and the tracings were done. The relevant reference points and lines describing the posture of the head and neck in normal as well as in condylar retrognathic subjects were considered under the following parameters. With these parameters, we evaluate the head posture and cranial base angle and relate it to the cervical column (Fig. 1).

- Cranial base angle parameters: (a) n-s-ba.
- Craniovertical parameters: (a) NSL/VER, (b) NL/VER, (c) NSL/CVT, and (d) NL/CVT.
- Craniocervical parameters: (a) NSL/OPT and (b) NL/OPT.
- Craniohorizontal parameters: (a) OPT/HOR and (b) CVT/HOR.
- Cervical curvature parameters: (a) OPT/CVT.

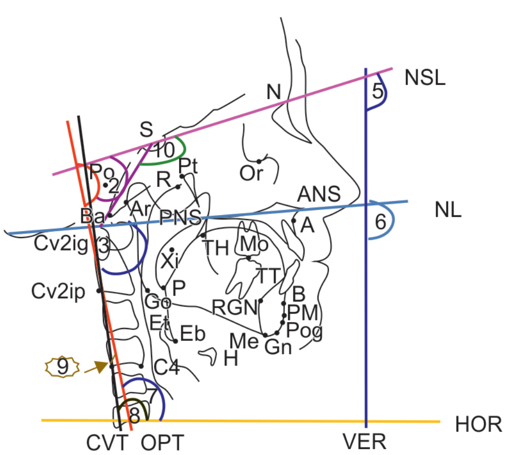

Fig. 1: Lateral cephalogram tracing showing head posture and cranial base angles

Statistical Analysis

Following results obtained are subjected to relevant statistical analysis.

Results

The results obtained are categorized in two aspects:

Morphology of the Cervical Column (Table 1)

Characteristics of the cervical column were classified according to Sandham[3] and divided into two categories: "*POSTERIOR ARCH DEFICIENCY*" and "*FUSION ANAMOLIES*".

POSTERIOR ARCH DEFICIENCY[3] consisted of partial cleft[3] and dehiscence[3] according to Sandham.3 Partial cleft[3] is defined as a failure from the fusion of the posterior part of the neural arch. Dehiscence[3] is defined as the failure to develop a part of a vertebral unit (Fig. 2).

FUSION ANOMALIES are fusion,[3] occipitalization,[3] and block fusion.[3] Fusion[3] is defined as the fusion of one unit with another at the articulation facets, neural arch, or transverse process (Fig. 3). Occipitalization[3] is defined as assimilation, either partially or completely, of the atlas (C1) with the occipital bone (Fig. 4). The definition of block fusion[4] has been modified according to Sonnesen and Kjaer[4] and defined as a fusion of more than two units at the vertebral bodies, articulation facets, neural arch, or

Table 1: Morphology of the cervical column among OSA patients

Cervical column morphology	*Number*	*%*
Fusion	13	65
Posterior arch deficiency	7	35
Total	20	100

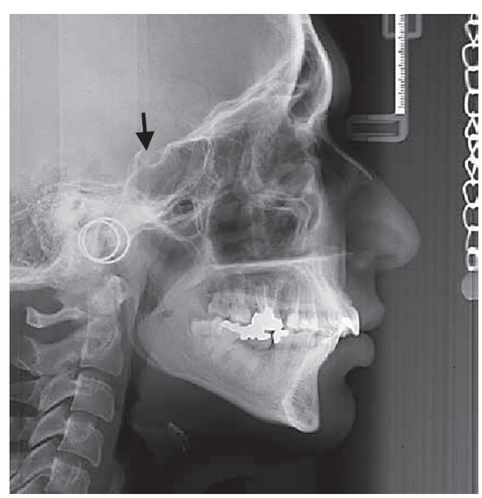

Fig. 2: Lateral cephalogram showing posterior arch deficiency of cervical vertebrae

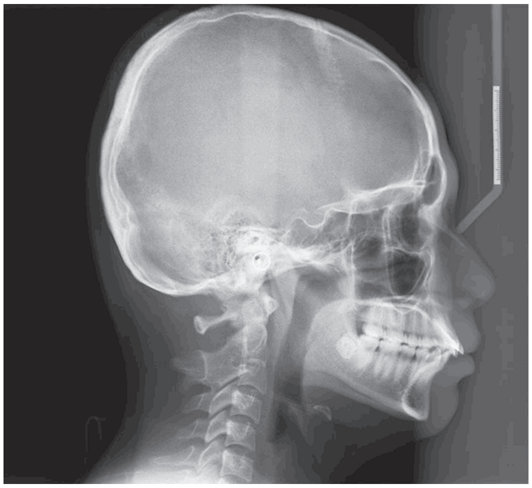

Fig. 3: Lateral cephalogram showing fusion anomalies of cervical vertebrae

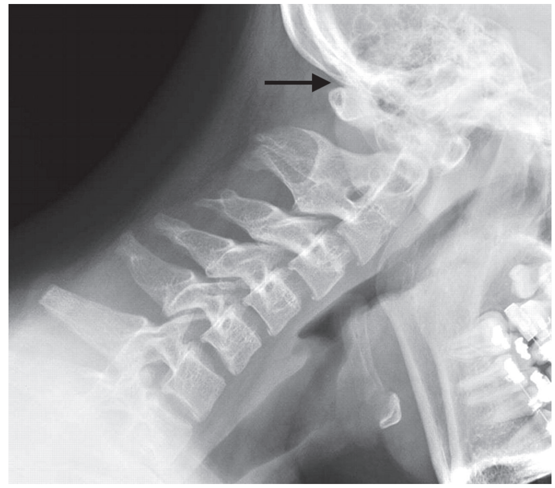

Fig. 4: Lateral cephalogram showing occipitalization

Fig. 5: Lateral cephalogram showing block fusion between two cervical vertebrae

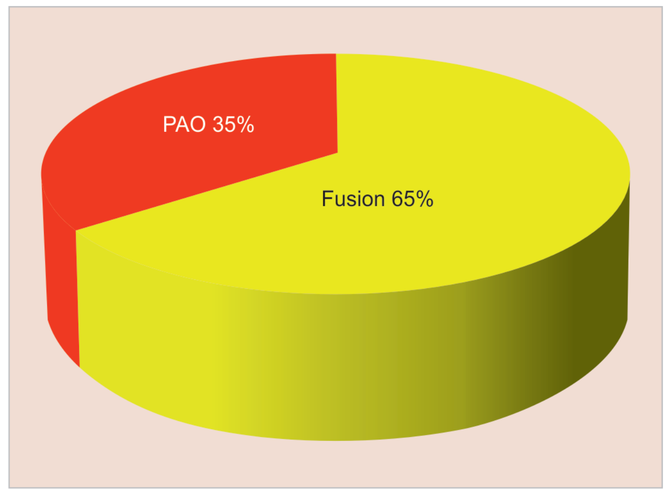

Fig. 6: Distribution of fusion anomalies and posterior arch deficiency in OSA patients with condylar hypoplasia

transverse process (Fig. 5). The fusion anomalies of the cervical column occurred significantly more often in the sleep apnea group and at a lower level in the spine as compared to subjects having neutral occlusion and normal craniofacial morphology.

Based on radiological findings of the cervical spine, the OSA group has been further subclassified according to the characteristics of the craniofacial profiles (as related to craniofacial malocclusion).

In the control group, 2% of fusion of the cervical column was observed. Fusion always occurred between C2 and C3. In OSA with condylar hypoplasia group, 65.0% had fusion anomalies and 35.0% had a posterior arch deficiency. Fusion occurred between C2 and C3 and between C3 and C4. Occipitalization always occurs in combination with either fusion or PAD. No statistically significant changes were found in both males and females. So, both genders were combined to form a large sample size for significant results (Fig. 6).

Head Posture and Cranial Base Angle Related to the Cervical Column (Table 2)

Cranial Base Parameters

The statistical comparison of cephalometric variables between normal and Class II malocclusion with OSA showed smaller values for cranial base angle (n-s-ba = mean diff-1.55) in Class II when compared to normal occlusion, but no significant changes are visible.

Craniocervical Parameters

For the cervical lordosis (OPT/CVT = mean diff-2.15, *p* value < 0.001), increased angulation was observed in Class II. The inclination of the upper cervical spine (OPT/HOR = mean diff-2.6) and angulation of cranial base as related to true vertical (NSL/VER = mean diff-3.1) show increased angulation in Class II. This implies that the cervical column was more curved and the inclination of the upper cervical spine was more backwardly angulated in subjects with fusion. The cranial base angle was also positively correlated with a fusion of the cervical column as the angle was more flexed in the subjects with fusion. Since the subjects taken are young adults, these associations are not due to the effect of age but due to obstruction in airway passage. So, all the postural angles for OSA samples were markedly increased.

In OSA patients, NL/OPT (mean diff-2.2) and NL/CVT (mean diff-0.5) showed decreased angulations than the control group.

Craniovertical Parameters

NSL/VER (mean diff-9.9) is significantly increased and NL/VE (mean diff-0) is decreased in OSA patients as compared to control.

Table 2: Head posture and cranial base angle related to the cervical column in OSA patients

		Group I (control n = 20)		*Group II (control n = 20)*			*Statistical significance*		
		Mean	*SD*	*Mean*	*SD*	*Mean diff.*	*t*	*p*	
Craniocervical	NSL/OPT	103.90	6.50	104.3	6.50	0.45	0.246	0.807	NS
	NSL/CVT	105.15	6.83	107.10	4.10	1.95	1.094	0.281	NS
	NL/OPT	96.00	4.50	98.20	7.22	2.2	1.157	0.254	NS
	NL/CVT	98.40	3.89	98.90	7.42	0.5	0.267	0.791	NS
Craniovertical	NSL/VER	96.40	6.44	100.30	3.97	3.9	2.304	0.027	S
	NL/VER	90.25	5.42	90.25	2.29	0	0	1.000	NS
Cervicohorizontal	OPT/HOR	82.05	4.88	84.65	5.77	2.6	1.538	0.132	NS
	CVT/HOR	80.95	4.87	83.40	6.86	2.45	1.302	0.201	NS
Cervical curvature	OPT/CVT	1.25	0.85	3.40	1.23	2.15	6.425	<0.001	S
Cranial base angle	n-s-ba	132.55	5.61	130.00	4.03	2.55	1.044	0.322	NS

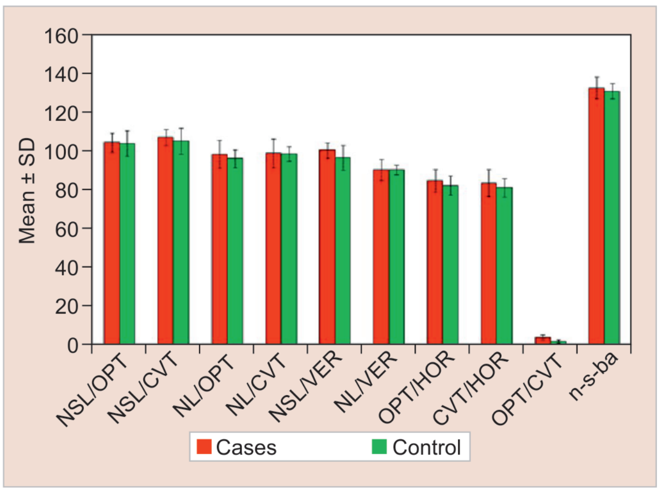

Fig. 7: Graph showing craniovertical and cervicohorizontal parameters in OSA group

Cervicohorizontal Parameters

OPT/HOR (mean diff-2.6) and CVT/HOR (mean diff-2.45) show increased value in Class II patients indicating an increased tendency for fusion and angulation of cervical vertebrae (Fig. 7).

Discussion

A sample size of 20 subjects with condylar hypoplasia having OSA was selected to compare with the control group (*n* = 20). Even though the groups were small, they provide useful and valid information. It is not possible to extend both samples as they are unique. The mandibular condylar hypoplasia with OSA is a sample collected over a long period and consisted of patients with severe condylar malformations.[2] Equally rare is the collection of the control group with neutral occlusion and normal craniofacial morphology.

In the present study, cervical column morphology was examined in OSA with condylar hypoplasia and then compared with the cervical column morphology in the normal craniofacial pattern. This study showed that cervical lordosis, the inclination of the upper cervical spine, and the cranial base angle in condylar hypoplasia were significantly positively correlated with the fusion of the cervical column.

In OSA as well as in the control group, no significant changes in the parameters were found regarding cervical column morphology in both males and females. So, both of them are clubbed together. The age group taken was 17–30 years (mean—23 years) for both OSA and control groups so that age variations and aging changes do not alter the results.

Previous studies have found an association between the morphology of C1, atlas, head posture, and the cranial base (Kylämarkula and Huggare,[5] Huggare,[6] Sandikcioglu et al.[7]). In the present study, cervical lordosis, the inclination of the upper cervical spine, and the cranial base angle were significantly positively correlated with the fusion of the cervical column.

This study confirms the morphological deviations of the cervical column which occurred significantly more often in patients with condylar hypoplasia as compared to those with neutral occlusion and normal craniofacial morphology. The pattern of morphological deviations significantly more severe in OSA with condylar hypoplasia. The explanation for the association between mandibular condyle and the cervical column may be signaling from the notochord to the neural crest cells (which determines the condylar development) before the notochord is surrounded by bone tissue and disappears during early embryogenesis occurring between the notochord and pharyngeal mesoderm. The neural tube and the neural crest cells are believed to be important for the connection between the malformation of the craniofacial structures and the cervical vertebrae.

The fusion of the cervical vertebral bodies seen in the control always occurred between C2 and C3, while those in the OSA group seemed to be located more caudally in the cervical column as the fusion occurs between C2 and C3, C3 and C4, or C4 and C5.

As the head is resting on the spine, determined in prenatal life by the notochord, it may be advisable to examine more closely the early formation of the axial skeleton. The notochord developed in the human germ disc determines the development of the cervical vertebrae, especially the vertebral bodies and also the basilar part of the occipital bone in the cranial base. Therefore, a deviation in the development of the notochord may influence the surrounding bone tissue in the spine as well as in the posterior part of the cranial base. The common origin of the spine and posterior part of the cranial base is the background for the hypothesis of an association between the cervical spine, head posture, and cranial base.[2] The jaws including the condylar cartilage, also develop from the tissue which is derived from the neural crest. In the 1st branchial arch, the neural crest cell migrates from the neural toward the mandible, followed by the cells to the maxilla and lastly to the nasofrontal region.

The jaws, including the condylar cartilage, develop from tissue that derives from the neural crest. The neural crest cells express

HOX genes, i.e., homeobox-containing regulatory genes organized in four clusters located on different chromosomes, HOX A, B, C, and D.[8–11]

So, signs of deviation in the development of the notochord could be fusion anomalies or posterior arch deficiency of the cervical column as seen in the present study. Fusion of C2 and C3 was associated with the posture of the head and neck in terms of cervical lordosis and the inclination of the upper cervical spine. Furthermore, fusion was associated with the cranial base angle also.

The present study was performed on the north Indian population residing in Lucknow with young adults suffering from moderate to severe OSA. The result suggests that the craniofacial morphology differs markedly with the severity of OSA. The cranial base angle gets more flexed with the increase in the vertical growth pattern and more retrognathic lower jaw thereby contributing to the reduction of airway patency.

For the *postural variables* (NSL/VER, NSL/OPT, OPT/HOR, and NSL/HOR), the values recorded were markedly higher than the normal. Since the association of head posture, cervical column, and craniofacial morphology differ widely in interethnic groups, we have compared our results with other ethnic groups in which the Chinese and white control group also support our result.

Craniocervical angulations (NSL/OPT, NL/OPT) are representative of both head posture and forward inclination changes of the cervical column which explain a large difference in Class II subjects with that of normal. The difference in *craniovertical angulation* showed significant changes between the two groups which is further confirmed by the head postural changes. The craniocervical angles may become be useful as a diagnostic or monitoring measurement in OSA subjects as it represents both head posture and cervical vertebrae compensatory changes. The extreme extension of both head and cervical column may represent an overactive compensatory mechanism that ultimately leads the increased airway resistance but also had an adverse effect on airway patency that further compounds obstruction problems. The significant differences in OPT/CVT values between the two groups of our present study further support this hypothesis.[12] Further studies with a large sample size are needed for proper verification of the current pattern shown by two groups.

Conclusion

Morphological deviations and the patterns of such deviations of the cervical column occurred significantly more often in subjects with condylar hypoplasia as compared with subjects with neutral occlusion and normal craniofacial morphology. This can be verified by the increased cranial base angle, cervical lordosis, the inclination of the upper cervical spine, and cranial base angle which were positively correlated with the fusion of the cervical column.

The changes in the morphology and the angulation of the cervical column as related to head posture, cranial base angle, and condylar malformation had not been discussed to date.

It is suggested that the key to understanding the association between the cervical column, the cranial base, head posture, and the mandibular condyle seems to be the notochord and the common signaling from the notochord to the neural crest cells and surrounding structures forming these craniofacial structures during early embryogenesis.

Clinical Significance

Specific types of craniofacial morphology and head postures such as a reduced posterior airway space, an abnormally long soft palate, a low position of the hyoid bone, and an extended head posture are considered predisposing factors of OSA.

As posture of the head and neck is considered to be associated with OSA, OSA may be associated with fusion of the cervical column.

Hence, to know the result of malformation in the cervical column prove to be important with regard to phenotypical subdivision, diagnosis, and treatment of OSA.

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