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INVESTIGATING THE ASSOCIATION BETWEEN CERVICAL VERTEBRAL ANOMALIES AND OBSTRUCTIVE SLEEP APNEA THROUGH CONE-BEAM COMPUTED TOMOGRAPHY IMAGING

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Abstract
Background: A comprehensive review of cone beam computed tomography (CBCT) scans from a cohort of Obstructive Sleep Apnea (OSA) patients and a control group without sleep disorders was conducted. Radiological analysis focused on identifying cervical vertebra anomalies. Additionally, clinical data related to OSA severity and symptoms were collected and correlated with the CBCT findings.
Method: A total of 118 patients were included in this study. The C2, C3, and C4 cervical vertebrae were measured in terms of height, width, area, and sagittal canal diameter. The presence of osteoarthritis between cervical joints was examined. Fusion between both the right and the left facet joints was assessed. The study sample was the experimental group, consisting of patients with OSA and the control group without OSA. Each group consisted of 59 subjects.
Results: The analysis of C2, C3, and C4 cervical vertebrae revealed that the experimental group had significantly greater values of height, width, and area. The examination of osteoarthritis between cervical joints in the sagittal plane showed that the sagittal canal diameter was significantly greater in the control group than in the experimental group, except for C4. Fusion between the right and left facet joints in the coronal plane was approximately 80 % greater in the OSA group than in the control group.
Conclusion: The present results indicate that cervical vertebral fusions, height, width, and area measurements exhibit greater abnormalities, while the canal diameter is narrower in the OSA group, except at the C4 level.

Keywords: Obstructive Sleep Apnea, cervical vertebrae, sagittal canal diameter, CBCT.

Introduction :

Obstructive Sleep Apnea (OSA) is a common sleep disorder characterized by recurrent partial or complete obstruction of the upper airway during sleep. This results in episodic hypoxia, sleep fragmentation, and a variety of systemic health consequences [1, 2]. While the primary etiological factors for OSA are often related to anatomical and functional attributes of the upper

airway, accumulating evidence suggests that this disorder may also be influenced by extrapharyngeal factors [1, 3].

The cervical spine, which consists of vertebral bodies C1 to C7, plays a crucial role in supporting the head, facilitating neck movement, and protecting the spinal cord [1, 4, 5]. Previous research has demonstrated a strong correlation between OSA and osteoarthritis, which is characterized as a metabolic disorder involving inflammation [2, 6]. Anatomical anomalies or degenerative changes in the cervical vertebrae can potentially affect the structure and function of the upper airway, thereby contributing to the pathogenesis and severity of OSA [1, 7]. These cervical vertebral anomalies encompass a range of variations, including changes in vertebral morphology, fusion abnormalities, and alterations in spinal canal dimensions [8].

The term 'spondylolisthesis' serves as an ideal starting point for exploring a cohort of conditions characterized by a defect in the pars interarticularis of the posterior vertebral arch. Spondylolisthesis is characterized by the anterior translation of one vertebral body over another, potentially leading to spinal instability and subluxation of the adjacent facet joints, further complicating the clinical presentation. Any common force imposed by the body's weight can cause subluxation of the lumbosacral facets and subsequent vertebral body subluxation [4].

In recent years, advancements in medical imaging have revolutionized our ability to diagnose and comprehensively study spondylolisthesis, enhancing our understanding of the disease process [4]. The availability and accessibility of imaging modalities such as two-dimensional radiography, computed tomography, and magnetic resonance imaging have significantly improved the accuracy and precision of diagnosis and evaluation. These imaging techniques provide crucial insights into the extent of vertebral displacement, the involvement of adjacent neural structures, and the overall impact on patient quality of life [1, 5, 8].

Though less common than its lumbar counterpart, cervical spondylolisthesis can result in significant clinical implications, including neck pain, radiculopathy, and myelopathy [4]. Accurately diagnosing cervical spondylolisthesis is crucial for tailoring appropriate treatment strategies and optimizing patient outcomes. In this context, cervical X-ray imaging, particularly in the lateral view, has emerged as a valuable tool for detecting cervical spondylolisthesis [5, 8]. This modality allows direct visualization of vertebral alignment and potential anterior displacement, providing critical information for early diagnosis and clinical decision-making [5, 9].

Cone Beam Computed Tomography (CBCT) is an advanced imaging modality that provides detailed three-dimensional visualization of the cervical spine and surrounding structures, offering a unique opportunity to investigate the relationship between cervical vertebral anomalies and OSA [10]. CBCT allows for a comprehensive assessment of the entire cervical region, including bones, and joints, which is particularly valuable when studying complex anatomical structures and anomalies [5,12].

The purpose of this study is to identify and characterize cervical vertebral anomalies in patients diagnosed with OSA and compare these findings with those from a control group without sleep apnea. Through the use of CBCT imaging, this research aims to elucidate any significant differences in cervical spine morphology between the two groups, thereby investigating the potential role of cervical vertebral anomalies in the pathogenesis and severity of OSA.

Methods

Patient Selection:

CBCT scans from 200 patients, comprising 100 patients diagnosed with OSA and 100 control subjects, were acquired between the duration January 2011 to December 2016 and retrospectively analyzed. This analysis included reviewing the polysomnography records and body mass index data of the OSA patients from the Near East Hospital's Sleep Center at the Department of Allergy, Sleep and Respiratory Diseases. The CBCT data were collected from the Near East University Faculty of Dentistry, Department of Dentomaxillofacial Radiology, using the Newtom 3G imaging system (Quantitative Radiology SRL, Verona, Italy). All images were acquired using a 12-inch (304.8 mm) field of view, with an axial slice thickness of 0.3 mm and isotropic voxels, at settings of 120 kVP and 3-5 mA. The imaging system automatically adjusted the milliamperes to optimize image quality while minimizing radiation exposure. Patients were instructed to lie in supine position and remain motionless during the 36-second scan time. Both the CBCT imaging and the overnight polysomnography assessments were acquired on the same day for all OSA patients.

Inclusion Criteria:

The inclusion criteria for the study were as follows: any adult patient (over 20 years old), CBCT images without any artifacts that clearly show the C2, C3, and C4 cervical vertebrae for all groups. For inclusion in the OSA patient group, subjects must have had an Apnea-Hypopnea Index (AHI) greater than 5. Patients with other significant sleep disorders, such as central sleep apnea, narcolepsy, or restless legs syndrome, were excluded from the study. The control group had no polysomnography test. They were composed of individuals without any clinical symptoms of OSA such as snoring, excessive daytime sleepiness or daytime fatigue.

Out of the 200 CBCT images, only 59 OSA patients and 59 control group subjects met the inclusion criteria. The reasons for exclusion primarily included poor image quality, artifacts, and insufficient cervical vertebra imaging.

The overall mean age was 61 years (range: 34-92; standard deviation [SD]: 13.13 years) for the OSA patient. The diagnosis of OSA was established through overnight polysomnography. The mean body mass index (BMI) was 32.616 kg/m (range: 25-49; standard deviation [SD]: 7.0689), and the mean apnea hypopnea index (AHI) was 28.038 (range: 5.2-95.5; standard deviation [SD]: 24.559).

Patients in the control group were also selected to be as close as possible in age to the OSA group. 59 (31 males/28 females) CBCT scans were selected from the archive whose scans met the inclusion criteria. The control group was selected to ensure that it represented a diverse range of individuals in terms of age, sex, and relevant clinical characteristics. The overall mean age was 44 years (range: 24-92; standard deviation [SD]: 15.46).

Image Evaluation:

The acquired images were generated in Digital Imaging and Communications in Medicine (DICOM) file format. These DICOM files, with a matrix size of 512 × 512, served as the primary data source for subsequent analysis.

Following image acquisition, the DICOM files were imported into InVivo 5.1.2 software (Anatomage) for the measurements, ensuring the accuracy and reliability of the data for subsequent analysis.

To investigate the potential differences between individuals with sleep apnea and control patients, a set of key parameters was selected. The height, width, and area of the cervical

vertebrae were measured via CBCT. These measurements were used to calculate changes in the body diameter of the vertebrae to help discern potential differences between the two groups. Outlining the boundaries of each cervical vertebra in the mid-sagittal plane to create distinct regions of interest (ROIs) is a critical step in accurately measuring the total area of the cervical vertebrae. After outlining the boundaries of all the cervical vertebrae in the mid-sagittal plane, the InVivo Anatomage area measurement tool was used to calculate the area of each segmented vertebra.

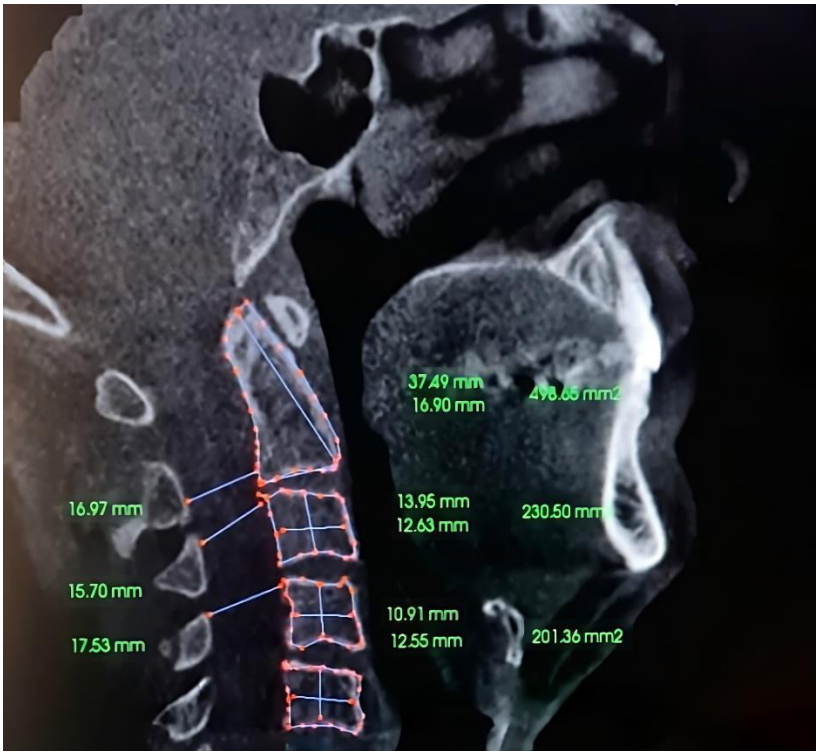

Figure 1. Measurements of cervical vertebrae in the midsagittal plane included height, width, and area calculations. The region of interest for the area calculation of each vertebra is indicated by the red dotted area. Additionally, the sagittal dimension of the spinal canal within the cervical vertebrae was measured.

The sagittal dimensions of the spinal canal within the cervical vertebrae were assessed to identify any alterations or anomalies. A standardized method for measuring the height of the cervical vertebrae was employed, following Remes's [10] method, as depicted in Figure 1. For C2, height was measured from the tip of the dens, a prominent anatomical structure, to the anterior-inferior corner of the vertebral body. This method captured the specific height dimension of C2, a crucial vertebra within the cervical spine. To assess the height of the cervical vertebrae, the midpoint between the upper and lower surfaces of C3 and C4 was identified and measured.
The width was measured at the midpoint between the anterior and posterior surfaces of the vertebral body.

To measure the sagittal canal diameter, the distance between the closest two points of the vertebral body and the spinous process was determined.

The presence and severity of cervical osteoarthritis were evaluated using the Kallgren and Lawrence classification system (Figure 2). This system, renowned for its clinical utility and reliability, provides a standardized approach for grading the extent of cervical osteoarthritic changes [2, 11].

The Kallgren and Lawrence classification categorizes cervical osteoarthritis into the following grades:

- Grade 0: This grade corresponds to the absence of osteoarthritis within the cervical joints.
- Grade 1: Joints classified as Grade 1 exhibit suspicious characteristics, such as mild space narrowing and the presence of osteophytes.
- Grade 2: Joints display clear evidence of osteophytes and probable space narrowing, indicating the progression of osteoarthritic changes.
- Grade 3: Multiple moderate osteophytes are observed, along with evident space narrowing. Additionally, there may be signs of sclerosis and probable bone deformity.
- Grade 4: The most severe classification, grade 4, was assigned to joints with large osteophytes, marked narrowing of the joint space, significant sclerosis, and substantial bone deformation.

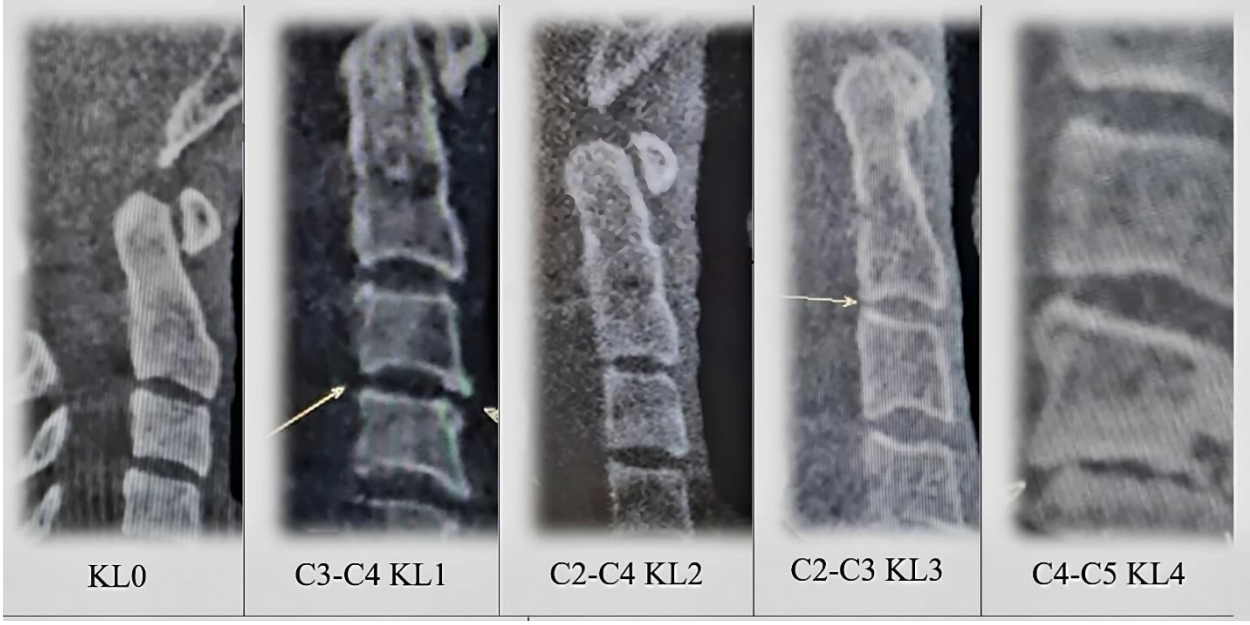

Figure 2. Sagittal projection of cervical vertebrae representing grading values of the severity of osteoarthritis. The grading, from 1 to 4 (Kellgren and Lawrence), reflects the loss of joint space compartments, the presence of osteophytes, and obvious deformities.

The grading process for cervical osteoarthritis followed a standardized approach, with experienced assessors applying the Kallgren and Lawrence classification system uniformly to all CBCT scans in both the OSA and control groups. This rigorous adherence to the classification criteria ensured the consistency and reliability of the osteoarthritis assessments.

To evaluate the presence and characteristics of block fusion within the cervical spine, we followed the classification proposed by Sonnesen and Kjaer (Figure 3) [12]. Block fusion refers to the fusion of more than two vertebral units at various anatomical sites, including the vertebral bodies, articulation facets, neural arch, or transverse processes.

The Sonnesen and Kjaer [12] classification system identifies block fusion through specific criteria:

Vertebral Units: Block fusion involves the fusion of more than two vertebral units, resulting in a contiguous structural block.

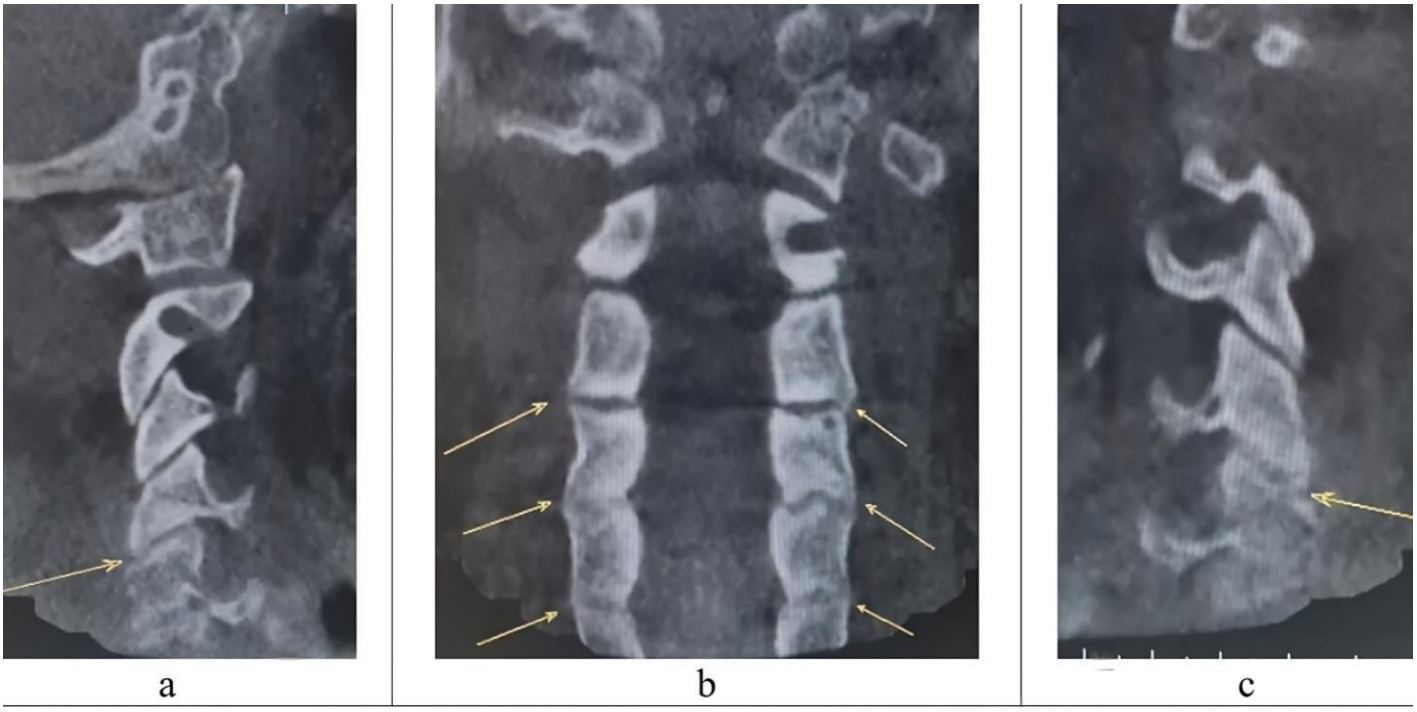

Figure 3. Block fusion was described as the joining of more than two units at the vertebral bodies, articulation facets, neural arch, or transverse processes. In the right and left sagittal (a and b); and coronal view (c), the facet joints will show signs of fusion.

Facet Joint Fusion: In both the sagittal and coronal views, facet joints exhibit signs of fusion, indicating the union of adjacent vertebral segments.

Identification of Block Fusion: Utilizing advanced imaging techniques, including sagittal and coronal views, we assessed the facet joints for signs of fusion.

Statistical analysis:

All the variables in the given data were random samples. These samples were analyzed according to the Shapiro–Wilk test to determine if they fit a normal distribution. Since the data fit a normal distribution, the “t test for independent samples” was applied for the parametric tests.

Based on the given values, the overall mean ($\bar{x}$), standard deviation, standard error, minimum and maximum values were calculated. The relationship between the results and the data showed that the confidence interval was 95% (α= 0.05 margin of error), and the lower and upper limits of

the confidence interval are given in the tables. The percentage and numerical quantity are written in the tables.
The t test for independent sample was applied for comparison of results between the groups related to the variables indicated by the measurement. The "Pearson chi-square test" was applied for the comparison of the numerical data between the groups.

Results
The study included a final sample of 118 patients divided into two distinct groups: the experimental group, which consisted of individuals diagnosed with OSA; and the control group, composed of individuals without OSA. This comprehensive sample allowed for a robust comparative analysis of cervical vertebra parameters between the two groups.
Table 1 provides a comprehensive summary of the mean measurements for height, width, area, and sagittal plane of the cervical vertebrae, along with the results of Student's t test. This comparative analysis aimed to discern whether significant differences existed between the two groups in each variable.
Height and width measurements C2, C3, and C4: The investigation of the height and width of cervical vertebrae C2, C3, and C4 yielded notable findings. In the OSA group, the mean height of these specific vertebrae was greater than that in the control group ($P \leq 0.05$) (Table 1).

Table 1. Represents the mean height, width, area, and sagittal plane of the cervical vertebrae, along with the results of the Student's t-test to determine if there is a significant difference between the two groups in each variable.

	Groups	Count	Mean	P-value
C2 height	OSAS	59	37.5436	**0.025***
	CONTROL	59	36.1541	
C3 height	OSAS	59	9.9781	**0.029***
	CONTROL	59	9.3671	
C4 height	OSAS	59	9.532	**0.001***
	CONTROL	59	8.8954	
C2 width	OSAS	59	14.1944	**0.004***
	CONTROL	59	13.3361	
C3 width	OSAS	59	13.7102	**0.001***
	CONTROL	59	12.6131	
C4 width	OSAS	59	13.4271	**0.002***
	CONTROL	59	12.2866	

C2 area	OSAS	59	397.7364	**0.004***
	CONTROL	59	364.0312	
C3 area	OSAS	59	188.4173	**0.001***
	CONTROL	59	164.088	
C4 area	OSAS	59	182.1983	**0.001***
	CONTROL	59	155.8985	
C2 sagittal plane	OSAS	59	15.4529	**0.013***
	CONTROL	59	16.0942	
C3 sagittal plane	OSAS	59	13.4619	**0.026***
	CONTROL	59	14.0642	
C4 sagittal plane	OSAS	59	12.4939	**0.051**
	CONTROL	59	13.1459	

***Significant difference**

There were significant differences in height between the OSA group and the control group for cervical vertebrae C2, C3, and C4 (P≤0.05).
The measurements of the vertebrae area in the sagittal view produced similar results to previous findings, indicating that the area was significantly larger in the OSA group than in the control group (P≤0.05). This difference was especially prominent for C2, C3, and C4.
The sagittal cervical canal linear measurements showed contrasting outcomes, with the OSA group showing smaller results than the control group, particularly for cervical vertebrae C2 and C3 but not for C4 (Table 1).

Table 2. Summarizes the results of the percentage of fusion in each of the groups, along with the outcomes of the chi-square test to assess significant differences between the two groups.

			Right fusion					**Left fusion**		
			OSAS	**CONTROL**	**p-value**			**OSAS**	**CONTROL**	**p-value**
C2C3	FUSION	n	25	7	**0.001***	**C2C3**	FUSION	28	8	**0.001***
		%	78.15	21.5				77.78	22.22	
	NO FUSION	n	34	52			NO FUSION	31	51	
		%	39.49	60.41				37.89	62.51	

C3C4	FUSION	n	19	5	**0.001***	**C3C4**	FUSION	28	6	**0.001***
		%	79.17	20.83				82.39	17.61	
	NO FUSION	n	40	54			NO FUSION	31	53	
		%	42.32	57.48				36.98	63.02	
C4C5	FUSION	n	11	2	**0.008***	**C4C5**	FUSION	12	3	**0.013**
		%	84.64	15.36				80	20	
	NO FUSION	n	48	57			NO FUSION	47	56	
		%	45.73	54.27				45.61	54.39	

***Significant difference**

Table 2 provides a comprehensive summary of the percentage of fusion observed in each group for both the right and left sides. The study divided the fusion into the right and left sides of the spinal cord from the coronal view. For both sides of the cervical vertebra, there was a greater percentage of fusion at the level of C2- C3, C3- C4 and C4- C5 in the OSA group ($p< 0.001$) than in the control group ($p=0.001$).

Table 3. Kallgren Lowrance result's between the two groups and chi-square test was applied to study the significant difference between OSAS and the control group.

Variables				**OSAS**	**CONTROL**	**P-value**
C2C3k	KL0 KL1	OR	n	38	45	**0.129***
			%	45.7831	54.2169	
	KL2		n	18	14	
			%	56.25	43.75	
	KL3		n	3	0	
			%	100	0	
C3C4k	KL0 KL1	OR	n	27	50	**0.001***
			%	35.0649	64.9351	
	KL2		n	18	7	

		%	72	28	
	KL3	n	13	2	
		%	86.6667	13.3333	
	KL4	n	1	0	
		%	100	0	
C4C5k	KL0 KL1	OR n	42	56	**0.005***
		%	42.8571	57.1429	
	KL2	n	7	0	
		%	100	0	
	KL3	n	6	2	
		%	75	25	
	KL4	n	4	1	
		%	80	20	

***Significant difference**

The results of the Kellgren and Lawrence classification system and the chi-square test indicate differences between the OSA and control groups at specific cervical levels.
C2 and C3 Levels: No significant differences were detected between the two groups at C2 or C3 levels ($P \leq 0.129$); C3 and C4 Levels: A significant difference was detected between the OSA and control groups at C3 and C4 levels ($P \leq 0.001$); C4 and C5 Levels: Similarly, a significant difference was detected between the OSA and control groups at C4 and C5 levels ($P \leq 0.005$) (Table 3).

Discussion

OSA is a complex sleep disorder with multifactorial etiology. Its development and severity can be influenced by a variety of factors, including anatomical, physiological factors [13]. Understanding the distinct phenotypic characteristics of different sleep apnea types is a critical step toward unraveling complicated mechanisms underlying OSA [14, 15]. Therefore, the current study contributes to the broader body of research that aims to distinguish phenotypic characteristics within the sleep apnea. Specifically, focusing on cervical vertebrae deformities and their association with OSA.
In the present study, CBCT was selected as the imaging modality to enhance the precision of anatomical structures while minimizing radiation exposure. CBCT offers three-dimensional visualization of cervical spine structures, allowing for a more comprehensive and accurate assessment of anatomical variations, including fusion [5, 12, 16, 17]. CBCT can reduce the challenges associated with overlapping structures, as it provides detailed images from multiple

angles, reducing the potential for false fusion appearances [16, 17]. Besides, compared to traditional CT, CBCT typically involves lower radiation doses. This is a crucial consideration, especially when dealing with repeated imaging, as in the case of research studies or clinical evaluations [5, 12, 16, 17].

Earlier studies utilizing 2D lateral cephalograms have contributed valuable insights into cervical column morphology in adult OSA patients. These studies reported various anatomical variations, including fusion between cervical vertebrae, block fusions, occipitalization, partial cleft of C1, and dehiscence, with varying prevalence rates [2, 9, 18].

Notably, the current findings align with some of these earlier results, particularly about the greater prevalence of fusion between the cervical vertebrae in OSA patients than in normal participants. This consistency reinforces the knowledge that certain cervical spine anatomical variations may be associated with OSA.

The current results revealed significant differences between the OSA and control groups in terms of cervical vertebrae anatomy, specifically in height, width, and area. However, the sagittal canal diameter was found to be narrower in the OSA group, except at the C4 level. Although studies have reported a relationship between this ratio and neurological symptoms resulting from trauma or cervical spinal stenosis, it is challenging to relate cervical canal narrowing directly to OSA pathophysiology. Therefore, some previous papers concluded that measuring the canal/body ratio is a more reliable method than directly measuring canal diameter for detecting cervical spinal pathology [26].

The qualitative differences observed in cervical vertebral fusions between the OSA group and controls provide additional insights. The dispersion of cervical vertebral fusions between various levels (C2-C3, C3-C4, or C4-C5) in the OSA group suggested that the anatomical variations in OSA patients may not be limited to a specific region of the cervical spine. However, simply cervical spine pathophysiology may not be categorized into singular defect instead multifactorial lesions [1]. According to Khan et al. [1], Isolated projections from the cervical spine that can cause sleep apnea include osteochondromas, fusions, osteophytes, and other rare pathologies. Similarly, A narrow spinal canal in the neck has been identified as a significant factor that increases the risk of developing cervical spondylotic myelopathy [19,20]. It has been previously mentioned that a high prevalence of endogenous cervical fusions has been demonstrated in OSA patients. Finally, Shoda et al. [21] observed in their study that patients with OSA often experience shortening of the cervical region, which could lead to greater bending forces and horizontal pressure on surrounding tissues, possibly contributing to airway compression and subsequent collapse. The detection of such a prevalent abnormality may indicate that cervical fusion is a phenotypical variant of OSA; however, the mechanism of apnea in these cases remains unclear [1,12,15]. Although these results are very much in line with current findings, it is still not easy to establish a clear link between cervical pathology and OSA. This is especially true considering the interesting current finding that no significant differences were found in the sagittal canal diameter at the C4 vertebra between the OSA patients and the control group. This lack of variation at C4 might suggest that anatomical differences associated with OSA are limited to certain levels of the spine.

Nevertheless, the classification of abnormal cervical morphology, particularly based on noniatrogenic endogenous fusions or posterior arch deficits, provides a structured framework for understanding anatomical variations associated with OSA [14, 22]. The prevalence of these

abnormalities, as reported in the literature and in our research, highlights the potential significance of these anatomical factors. The prevalence of morphological aberrations in individuals with sleep apnea, as reported in earlier studies (46% and 43%), underscores the relevance of cervical column anomalies. These findings suggest that a substantial proportion of OSA patients may exhibit cervical spine variation, further emphasizing the complexity of OSA etiology [14, 23].

Sonnesen et al.'s [15] documentation of a significantly greater incidence of cervical fusion in OSA patients (46%) than in the control group (14%) highlights the potential association between cervical fusion and OSA.

The use of CBCT in the current study not only contributes to the precision of anatomical assessments but also has clinical relevance. CBCT's ability to provide accurate anatomical data, especially in cases involving fusion evaluation, can inform clinical decisions and potentially guide treatment strategies for patients with cervical spine pathologies [13, 24].

Variations in cervical column morphology, as revealed by CBCT, may play a role in the development or severity of OSA by influencing upper airway dynamics, spinal biomechanics, or other relevant factors.

These findings may assist clinicians in categorizing OSA patients into subgroups based on anatomical characteristics. Such categorization may help personalize treatment approaches, considering the unique anatomical factors contributing to an individual's OSA. The risk of OSA in elderly individuals with an elevated BMI is widely known and an elevated BMI highlights the importance of considering age-related factors and comorbidities in OSA assessment and management [13, 25].

The significantly greater frequency of cervical column fusion abnormalities in OSA patients is in line with the findings of Sonnesen et al. [15, 25] and Massengil et al. [22], who explored cervical column morphology in adult OSA patients compared to a control group. This consistency between studies emphasizes the robustness of the observed association between cervical column variations and OSA. These authors suggested that evaluating OSA patients should consider assessing cervical column morphology, particularly for fusion abnormalities.

Accurate assessment of cervical spine fusion can be challenging due to several factors. Overlapping structures, such as facet joints, may create a false appearance of fusion [16]. This phenomenon can be influenced by the oblique positioning of cervical facet joints relative to the X-ray beam, variations in spinal flexion or extension, and individual morphological differences among patients [5, 10, 17]. Additionally, all these pathophysiological factors mentioned above, such as fusion, height, width, and area measurements, should not be excluded as predisposing factors for OSA. On the contrary, all of them should be taken into account when considering indications and treatment alternatives for OSA patients.

Limitation of the study:

The difference in age between the OSA group and the control group might be considered a potential limitation of the present study. In this study, the overall mean age of the OSA group was greater than that of the control group, which may have affected the difference in canal diameter between the groups. One of the effects of aging is tissue degeneration, which leads to a decrease in the elasticity of the skin and musculoskeletal system. Additionally, it causes an increase in muscle stiffness. Researchers have used myotonometry, a reproducible invasive measurement method, and found that older individuals tend to have greater stiffness and lower elasticity in their superficial neck and facial muscles [19].

Another notable limitation of this study is the absence of polysomnography results for the control group. This lack of polysomnography data presents several challenges and potential biases in the study's findings, including issues with data comparability, validity of conclusions, and generalizability. To address these limitations in future research, it is recommended to include polysomnography assessments for both experimental and control groups. Alternatively, employing less invasive sleep assessment tools, such as portable polysomnography tests, could provide valuable comparative data.

Conclusion

In conclusion, the present results indicate that cervical vertebral fusions, height, width, and area measurements exhibit greater abnormalities, while the canal diameter is narrower in the OSA group, except at the C4 level.These findings have the potential to inform clinical practice and encourage further research into the mechanisms that connect abnormalities in the cervical column to OSA.

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Legends:

Figure 1. Measurements of cervical vertebrae in the midsagittal plane included height, width, and area calculations. The region of interest for the area calculation of each vertebra is indicated by the red dotted area. Additionally, the sagittal dimension of the spinal canal within the cervical vertebrae was measured.

Figure 2. Sagittal projection of cervical vertebrae representing grading values of the severity of osteoarthritis. The grading, from 1 to 4 (Kellgren and Lawrence), reflects the loss of joint space compartments, the presence of osteophytes, and obvious deformities.

Figure 3. Block fusion was described as the joining of more than two units at the vertebral bodies, articulation facets, neural arch, or transverse processes. In the right and left sagittal and coronal view, the facet joints will show signs of fusion.

Table 1. Represents the mean height, width, area, and sagittal plane of the cervical vertebrae, along with the results of the Student's t-test to determine if there is a significant difference between the two groups in each variable.

Table 2. Summarizes the results of the percentage of fusion in each of the groups, along with the outcomes of the chi-square test to assess significant differences between the two groups.

Table 3. Kallgren Lowrance result's between the two groups and chi-square test was applied to study the significant difference between OSAS and the control group.

Declarations

The manuscript submitted is an original work and the sole property of the Author(s). It has not been published nor have significant parts of the work been published and it is not subject to publication in another journal.

Ethic approval and consent to participants

This research has approved form scientific research ethics committee of the Near East University**.** All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). Informed consent was obtained from all patients for being included in the study.

Informed consent

I confirm that informed consent was obtained from all patients for which identifying information is included in this article.

Conflicts of interest

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Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due consideration of medical ethics but are available from the corresponding author on reasonable request.

Competing interest

There is no competing interest.