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Cephalometric Examination of Soft Palate, Hyoid and Upper Airway Anatomy in Obstructive Sleep Apnea Syndrome Patients

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ABSTRACT

Objectives: In this study, the dimensions of the soft palate, the position of the hyoid bone in relation to the mandibular plane and C3 vertebrae, and the width of the upper airway were measured on lateral cephalograms of patients with obstructive sleep apnea syndrome of different severities diagnosed by polysomnography. This study aimed to investigate the association between increased apnea severity and anatomical formations relevant to dental practice.
Materials and Methods: Our study was designed as a retrospective data analysis of 182 patients, 78 females and 104 males. In our study, patients were divided into four groups: patients with simple snoring with an Apnea-Hipopnea index (AHI) value below 5, patients with mild OSAS with an AHI value of 5-15, patients with moderate OSAS with an AHI value of 15-30 and patients with severe OSAS with an AHI value above 30. Measurements obtained from lateral cephalograms were compared between these groups.
Results: Statistically significant narrowing was observed in all other groups compared to the control group in oropharyngeal width values in upper airway measurements ($P<0.05$). The distance between the hyoid and mandibular plane was significantly lower in the control group than in the severe OSAS group ($P=0.001$). A statistically significant elongation of the soft palate was also observed in patients with OSAS compared to the control group ($P<0.05$).
Conclusions: Our findings support that the position of the hyoid bone is important in the diagnosis of OSAS. Furthermore, a significant correlation was found between soft palate length and OSAS. These results suggest that surgical techniques such as maxillary advancement or mandibular advancement, or both, to increase airway width may be effective in the treatment of OSAS.

Keywords: Cephalometry; Hyoid bone; Obstructive Sleep Apnea Syndrome; Soft Palate; Upper Airway Anatomy.

Makalenin Türkçe Başlığı

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ÖZ

Amaç: Bu çalışmada, polisomnografi ile tanı konulan farklı şiddetlerdeki obstrüktif uyku apne sendromlu hastaların lateral sefalogramlarında yumuşak damak boyutları, hyoid kemiğin mandibular düzlem ve C3 vertebrasına göre konumu ve üst hava yolunun genişliği ölçülmüştür. Bu çalışma, artan apne şiddeti ile diş hekimliği pratiğiyle ilgili anatomik oluşumlar arasındaki ilişkiyi araştırmayı amaçlamıştır.
Gereç ve Yöntemler: Çalışmamız 78 kadın ve 104 erkek olmak üzere 182 hastanın retrospektif veri analizi olarak tasarlanmıştır. Çalışmamızda hastalar dört gruba ayrıldı: Apne-Hipopne indeksi (AHİ) değeri 5'in altında olan basit horlamalı hastalar, AHİ değeri 5-15 olan hafif OSAS'lı hastalar, AHİ değeri 15-30 olan orta OSAS'lı hastalar ve AHİ değeri 30'un üzerinde olan ağır OSAS'lı hastalar. Lateral sefalogramlardan elde edilen ölçümler bu gruplar arasında karşılaştırılmıştır.
Bulgular: Üst hava yolu ölçümlerinde orofarengeal genişlik değerlerinde kontrol grubuna kıyasla diğer tüm gruplarda istatistiksel olarak anlamlı daralma gözlendi ($P<0.05$). Hyoid ve mandibular düzlem arasındaki mesafe kontrol grubunda ağır OSAS grubuna göre anlamlı derecede düşüktü ($P=0.001$). OSAS'lı hastalarda kontrol grubuna kıyasla yumuşak damakta da istatistiksel olarak anlamlı bir uzama gözlendi ($P<0.05$).
Sonuçlar: Bulgularımız hyoid kemiğin pozisyonunun OSAS tanısında önemli olduğunu desteklemektedir. Ayrıca, yumuşak damak uzunluğu ile OUAS arasında anlamlı bir ilişki bulunmuştur. Bu sonuçlar, maksiller ilerletme veya mandibular ilerletme veya her ikisinin birlikte yapıldığı hava yolu genişliğini artırma operasyonları gibi cerrahi tekniklerin OSAS tedavisinde etkili olabileceğini düşündürmektedir.

Anahtar Kelimeler: Hiyoid kemik, Sefalometri, Solunum yolu, Tıkayıcı uyku apnesi, Yumuşak damak,

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Introduction

Obstructive sleep apnea syndrome (OSAS) is a disorder characterized by recurrent collapse of the upper airway and apnea, hypopnea and episodes of respiratory arousal during sleep.[1,2] It is the most common sleep disorder among respiratory diseases.[3] OSAS can lead to serious clinical conditions such as mortality and morbidity. Recent studies have shown a close association between OSAS and cardiovascular disease and stroke.[4,5] In children, OSAS may have a direct impact on behavioral and learning disorders, pulmonary hypertension and impaired somatic cell growth. These consequences can include serious safety and economic harms.[6,7] Thus, all these conditions provide a strong rationale for effective treatment.[6]

Many studies have shown that OSAS is a heterogeneous disease.[8,9] The known risk factors for OSAS are obesity, genetic factors, alcohol, cigarette and drug use, tonsil and adenoid enlargement, hypothyroidism, respiratory system diseases and anatomical factors related to upper airway (UA).[10] This explains why the treatment applied in one patient may not work in another patient.[8] According to some studies, craniofacial structures and UA anatomy are crucial factors in the development of OSAS.[11,12] Based on this idea, in order to determine the most appropriate treatment method in patients with OSAS, studies on the contribution of anatomical variables in the UA to the pathogenesis of the disease and cause-oriented treatment planning are emphasized. In some studies, changes in the upper airway due to OSAS are discussed.[13]

In conclusion, whether changes in craniofacial and airway anatomy play a role as factors leading to OSAS or are a consequence of the disease, understanding normal anatomy and being able to define the pathology of these structures is very important in the diagnosis and treatment of the disease.

Materials and Methods

G*Power (Düsseldorf/Germany) program was used to determine the sample size required for our study. Since One Way ANOVA and Kruskal Wallis tests were applied in comparisons between groups, One Way ANOVA test was selected from F tests in G*Power program. 180 sample size requirement was obtained as a result of Cohen's effect size of 0.25 (medium size), 95% confidence interval and 0.80% power and 4 group selections.

Acquisition of Data

Our study was designed as a retrospective study. In our study, AHI data and cephalograms of 182 patients who underwent PSG in the sleep room due to night snoring and respiratory distress in 2020-2021 in Mengücek Gazi Training and Research Hospital Chest Diseases Clinic were used. The study group consisted of 78 female and 104 male patients. All patients were adults over 18 years of age.

Ethics committee approval was obtained with the decision numbered 15/04 taken at the meeting of Erzincan Binali Yıldırım University Clinical Research Ethics Committee dated 21.02.2022 and numbered 15.

Patients who had undergone upper airway or craniofacial surgery, lateral head radiographs with artefacts, and radiographs not taken in the standard position due to patient movement during acquisition were not included in our study.

All patients were subjected to overnight PSG (55 channel polysomnography-Alice Sleepware; Philips Respironics, Pennsylvania, USA). Patients who were subjected to polysomnography at the hospital's sleep laboratory were divided into 4 groups according to the AHI values obtained. Group 1 consisted of 42 patients with AHI<5 (simple snoring), group 2 consisted of 56 patients with 5<AHI<15 (mild OSAS), group 3 consisted of 39 patients with 15<AHI<30 (moderate OSAS), group 4 consisted of 45 patients with AHI>30 (severe OSAS).

Cephalograms were taken with a cephalometric radiography device (DRGEM Diamond-6A, Korea) in the natural head position, with teeth in centric bite, lips in slight contact or at rest with no contraction. During the acquisition of lateral head radiographs, the patient's distance to the beam source was set to 152 cm and the mid-axial plane-to-film cassette distance to 13 cm as standard (80 kV, 320 mA, 51.2 mAs). All X-rays were taken by the same radiology technicians. Lateral head radiographs were transferred to Corel-Draw software (Austin, USA) and analyzed. The distance between certain points on the lateral head radiograph of each patient was measured and recorded in millimeters for comparison between groups. For the reliability of the measurements, the measurements were repeated 20 days later by the same researcher.

The measurements made on the lateral head radiographs were compared between four groups formed according to the degree of AHI. The points determined on the lateral head radiographs and the measurements made are given below.

Upper Airway Width Variables

The spina nasalis posterior point was identified on radiographs and marked as the SNP point. The most posterior point of the section of the pharynx in the same sagittal plane as this point marked and named P1. Then the distance between SNP-P1 was measured in mm and recorded as UPA. The lowest point of the soft palate was marked and named U. The most posterior point of the section of the pharynx in the same sagittal plane as U was marked as point P2. The distance between points U and P2 was measured in mm and recorded as MPA. Pharyngeal airway's anterior border at the hyoid bone level was marked and named HyP. The most posterior point of the section of the pharynx in the same sagittal plane as HyP was marked as point P3. The distance between HyP and P3 points was measured in mm and recorded as LPA.

Hyoid Bone Related Variables

The top point of the hyoid bone's anterior boundary was marked and labeled as Hy. The antero-inferior point of the C3 vertebral corpus was marked and named as C3 and the distance between these two points was measured in mm and recorded as HyC3. The lowest point of the angulus mandible (Go) and the anterior lowest point of the mandible (Me) were marked and combined to form the mandibular plane. A perpendicular line was drawn from the Hy point to the mandibular plane, measured in mm and recorded as HyMP. A line was drawn from the Hy point to the Me point and the distance between these two points was measured in mm and recorded as HyMe.

Soft Palate Variables

The soft palate length was determined by measuring the distance between SNP and U in mm and recorded as SPL. The thickest part of the soft palate, measured perpendicularly to the SNP-U line, was measured in mm and recorded as the SPTh. Marking of the mentioned anatomical formations on lateral cephalograms (Figure 1), followed by the measurements described above (Figure 2) data obtained were recorded in millimeters.

Statistical Analysis

IBM SPSS Statistics for Windows Version 22.0. (IBM Corp., Armonk, NY) was used. The conformity of the values to normal distribution was analyzed by analyzing normality with the Kolmogorov-Smirnov test, in addition, skewness, kurtosis values and coefficients of variation were calculated. Comparisons between more than two groups that were compatible with normal distribution were made with One-Way ANOVA Post Hoc test (Bonferroni Post Hoc with equal distribution of variances for HyME, HyC3 and Tamhane's T2 Post Hoc Test without equal distributions of variances for UPA, LPA, HyMD, SPL, SPTh) and comparisons between two groups were made with Independent Groups T test. Levene's Test was used to check the homogeneity of variances. Kruskal-Wallis test was used for variables that were not normally distributed (MPA for our study).

Pearson's Chi-Square test was used for intergroup comparison for gender variable. P values greater than 0.05 were considered insignificant, values less than 0.05 were considered significant, and values less than 0.001 were considered highly significant. Spearman Brown Rank Difference Correlation Test was used to determine the relationship between AHI groups and all anatomical measurements.

Results

In our study, the data of the patients divided into four groups were compared. The distribution of gender and age variables according to the groups is given in Table 1. Gender and age were not significantly different between groups (P>0.05). The mean values of the parameters measured on radiographs in the four groups in our study are given in Table 2.

Measurements of the UA space at different levels were compared between the groups and the data obtained are presented in Table 3. According to these results, UPA parameters were not significantly different between groups (P>0.05). The following results were obtained in the comparison of MPA parameter between the groups. Compared to the control group, the MPA level in the other groups was observed to gradually decrease. Significance levels were P<0.05 with Group 2, P<0.01 with Group 3 and P=0.001 with Group 4, respectively. Significance was also determined between Group 2 and Group 4 (P<0.01). There was no statistical significance between the groups for the LPA parameter (P>0.05).

The measurements made to determine the level of the hyoid bone were compared between the groups and the data obtained are given in Table 4. HyMe parameter showed no difference in the groups (P>0.05). HyC3 values, although not significant, were higher in the severe OSAS group compared to the other groups. In the comparison of HyMP values between the groups, an increase was noted in Group 4 compared to Group 1 (P<0.05) and Group 2 (P<0.05).

Soft palate dimensions were also compared and the data obtained are presented in Table 5. When the three groups of patients with OSAS were compared among themselves, no significant difference was found in terms of SPTh. (P>0.05). In SPL data, an increase was found in Group 2, Group 3, and Group 4 (P<0.05) compared to the values in mild snoring patients.

In the correlation tests; MPA, HyMP and SPL values showed significant correlation with the groups. The results are given in Table 6. A moderate negative correlation (r=-0,446) between MPA value and AHI groups as shown in Figure 3. A positive (r=0,310) correlation between SPL value and AHI groups as shown in Figure 4. A positive (r=0,393) correlation was observed between HyMP value and AHI groups as shown in Figure 5. No correlation was found between the UPA, LPA, SPTh, HyC3, HyMe values and the groups.

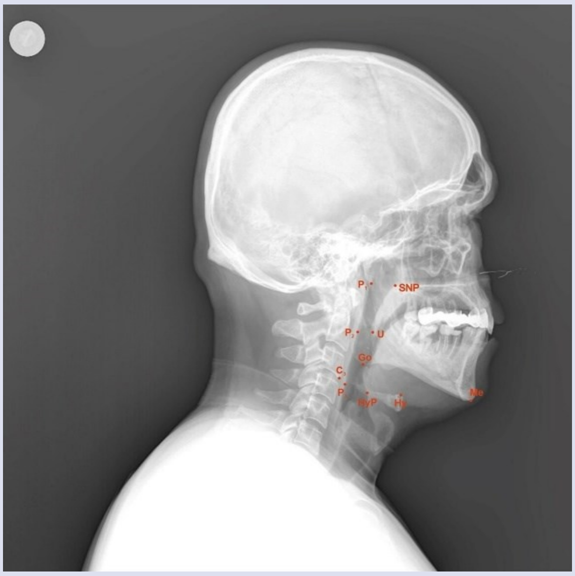

Figure 1. Figure 1. Anatomic Landmarks on Cephalogram.
SNP: Posterior nasal spine, U: Lowest point of the soft palate, Go: Gonion, Me: Mentum, Hy: Superoanterior point of the hyoid bone, C3: Inferoanterior point of the C3 vertebra, HyP: Pharyngeal airway anterior wall at the level of the hyoid bone, P1, P2, P3: Posterior wall boundaries of the pharynx at Nasopharynx, Oropharynx, and Laryngopharynx levels.

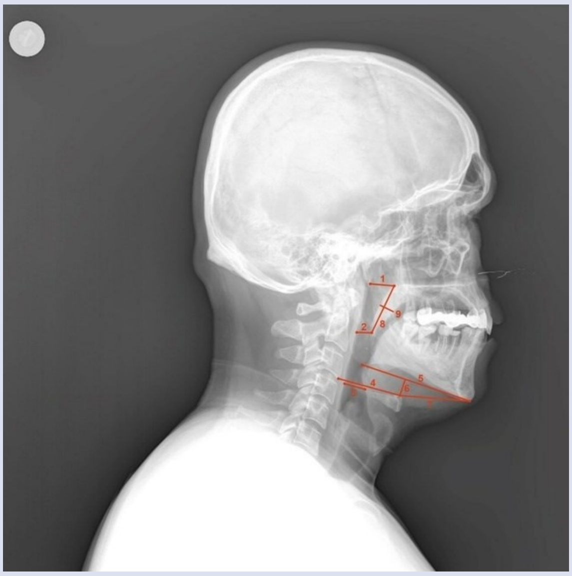

Figure 2. Measurements made on cephalograms.
1: UPA (Upper pharyngeal airway width), 2: MPA (Middle pharyngeal airway width), 3: LPA (Lower pharyngeal airway width), 4: HyC3 (Distance between the hyoid bone and C3 vertebra), 5: MP (Mandibular plane passing through Go and Me), 6: HyMP (Distance between the hyoid bone and the mandibular plane), 7: HyMe (Distance between the hyoid bone and Mentum), 8: SPL (Soft palate length), 9: SPTh (Soft palate thickness)

Table 1. Distribution of Age and Gender Variables According to Groups

	Group 1 (AHI<5) (n: 42)	Group 2 5<AHI<15 (n: 56)	Group 3 15<AHI<30 (n:39)	Group 4 30<AHI (n:45)	P
Age					0.10[a]
Mean ± SD	43.39±14.27	49.21±10.63	51.64±12.39	44.64±11.45	
Median	44.50	50.58	51.46	42.14	
Minimum-Maximum	(18-67)	(18-72)	(22-71)	(30-71)	
Gender					0.13[b]
Female	22/42 (%52)	24/56 (%43)	17/39 (%44)	15/45 (%33)	
Male	20/42 (%48)	32/56 (%37)	22/39 (%56)	30/45 (%67)	

a: Independent Samples T-test was used. b: Pearson's Chi-Square test was used.
AHI: Apnea-Hypopnea Index. n: number of patients in the group. P: Significance. SD: Standard Deviation. Group 1: simple snoring patients, Group 2: mild OSAS, Group 3: moderate OSAS, Group 4: severe OSAS.

Table 2. Mean and Standard Deviation of All Measured Values in the Groups

	Group 1 (AHI<5)	**Group 2 (AHI 5-15)**	**Group 3 (AHI 15-30)**	**Group 4 AHI>30**
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
UPA	19.39 ± 3.34	21.21 ± 6.75	18.87 ± 4.33	20.06 ± 5.35
MPA	8.41 ± 1.66	7.41 ± 1.38	7.24 ± 1.33	6.60 ± 0.78
LPA	12.65 ± 1.73	13.13 ± 2.75	13.75 ± 3.70	13.72 ± 2.18
SPL	42.16 ± 3.66	44.55 ± 3.61	45.54 ± 5.91	45.56 ± 7.25
SPTh	8.91 ± 1.70	9.75 ± 2.22	9.79 ± 2.79	8.76 ± 2.29
HyMe	41.64 ± 7.28	44.02 ± 6.99	42.00 ± 8.33	44.05 ± 7.30
HyC_3	41.90 ± 6.14	42.79 ± 6.41	40.76 ± 7.31	44.27 ± 6.26
HyMP	20.84 ± 3.35	22.18 ± 3.56	23.05 ± 5.23	25.06 ± 3.57

AHI: Apnea-Hypopnea Index. SD: Standard Deviation. UPA: Upper Pharyngeal Airway. MPA: Middle Pharyngeal Airway. LPA: Lower Pharyngeal Airway. SPL: Soft Palate Length. SPTh: Soft Palate Thickness. HyMe: Distance Between Hyoid Bone and Mentum. HyC_3: Distance Between Hyoid and C3 Vertebra. HyMP: Distance Between Hyoid Bone and Mandibular Plane. Group 1: simple snoring patients, Group 2: mild OSAS, Group 3: moderate OSAS, Group 4: severe OSAS. The values in the table are written in millimeters.

Table 3. Multiple Comparisons of Upper Airway Variables Between Groups

			P
UPA	Group 1 (AHI<5)	Group 2 (AHI 5-15)	0.409
		Group 3 (AHI 15-30)	0.992
		Group 4 (AHI>30)	0.981
	Group 2 (AHI 5-15)	Group 3 (AHI 15-30)	0.230
		Group 4 (AHI>30)	0.919
	Group 3 (AHI 15-30)	Group 4 (AHI>30)	0.842
MPA	Group 1 (AHI<5)	Group 2 (AHI 5-15)	**0.013***
		Group 3 (AHI 15-30)	**0.002***
		Group 4 (AHI>30)	**0.001****
	Group 2 (AHI 5-15)	Group 3 (AHI 15-30)	0.436
		Group 4 (AHI>30)	**0.001****
	Group 3 (AHI 15-30)	Group 4 (AHI>30)	**0.039***
LPA	Group 1 (AHI<5)	Group 2 (AHI 5-15)	0.877
		Group 3 (AHI 15-30)	0.463
		Group 4 (AHI>30)	0.072
	Group 2 (AHI 5-15)	Group 3 (AHI 15-30)	0.944
		Group 4 (AHI>30)	0.788
	Group 3 (AHI 15-30)	Group 4 (AHI>30)	1.000

AHI: Apnea-Hypopnea Index. P: Significance. *: statistically significant **: highly significant UPA: Upper Pharyngeal Airway. MPA: Middle Pharyngeal Airway. LPA: Lower Pharyngeal Airway. Group 1: simple snoring patients, Group 2: mild OSAS, Group 3: moderate OSAS, Group 4: severe OSAS.

Table 4. Multiple Comparisons of Variables Related to Hyoid Bone

			P
HyMe	Group 1 (AHI<5)	Group 2 (AHI 5-15)	0.707
		Group 3 (AHI 15-30)	1.000
		Group 4 (AHI>30)	0.791
	Group 2 (AHI 5-15)	Group 3 (AHI 15-30)	1.000
		Group 4 (AHI>30)	1.000
	Group 3 (AHI 15-30)	Group 4 (AHI>30)	1.000
HyC_3	Group 1 (AHI<5)	Group 2 (AHI 5-15)	1.000
		Group 3 (AHI 15-30)	1.000
		Group 4 (AHI>30)	0.548
	Group 2 (AHI 5-15)	Group 3 (AHI 15-30)	0.825
		Group 4 (AHI>30)	0.088
	Group 3 (AHI 15-30)	Group 4 (AHI>30)	1.000
HyMP	Group 1 (AHI<5)	Group 2 (AHI 5-15)	0.311
		Group 3 (AHI 15-30)	0.156
		Group 4 (AHI>30)	**0.001***
	Group 2 (AHI 5-15)	Group 3 (AHI 15-30)	0.935
		Group 4 (AHI>30)	**0.001***
	Group 3 (AHI 15-30)	Group 4 (AHI>30)	0.248

AHI: Apnea-Hypopnea Index. P: Significance. HyMe: Distance Between Hyoid Bone and Mentum. HyC_3: Distance Between Hyoid and C3 Vertebra. HyMP: Distance Between Hyoid Bone and Mandibular Plane. Group 1: simple snoring patients, Group 2: mild OSAS, Group 3: moderate OSAS, Group 4: severe OSAS.

Table 5. Multiple Comparisons of Soft Palate Variables between Groups

			P
SPL	Group 1 (AHI<5)	Group 2 (AHI 5-15)	**0.011***
		Group 3 (AHI 15-30)	**0.020***
		Group 4 (AHI>30)	**0.041***
	Group 2 (AHI 5-15)	Group 3 (AHI 15-30)	0.931
		Group 4 (AHI>30)	0.952
	Group 3 (AHI 15-30)	Group 4 (AHI>30)	1.000
SPTh	Group 1 (AHI<5)	Group 2 (AHI 5-15)	0.193
		Group 3 (AHI 15-30)	0.438
		Group 4 (AHI>30)	1.000
	Group 2 (AHI 5-15)	Group 3 (AHI 15-30)	1.000
		Group 4 (AHI>30)	0.171
	Group 3 (AHI 15-30)	Group 4 (AHI>30)	0.353

AHI: Apnea-Hypopnea Index. P: Significance. *: statistically significant. SPL: Soft Palate Length. SPTh: Soft Palate Thickness. Group 1: simple snoring patients, Group 2: mild OSAS, Group 3: moderate OSAS, Group 4: severe OSAS.

Table 6. Correlation of AHI Groups and MPA, SPL, HyMP Values

		MPA Value[a]	SPL Value[b]	HyMP Value[b]
AHI GROUPS	Correlation coefficient (r)	-0.415*	0.222**	0.358*
	P	0.000	0.003	0.000
	n	182	182	182

AHI: Apnea-Hypopnea Index. *: Moderate Correlate. **: Strong Correlate. P: Significance (the correlation is significant at the 0.01 level). n: number of patients. [a]: Spearman's correlation Test. [b]: Pearson Correlation Test. MPA: Middle Pharyngeal Airway. SPL: Soft Palate Length. HyMP: Distance Between Hyoid Bone and Mandibular Plane. Group 1: simple snoring patients, Group 2: mild OSAS, Group 3: moderate OSAS, Group 4: severe OSAS.

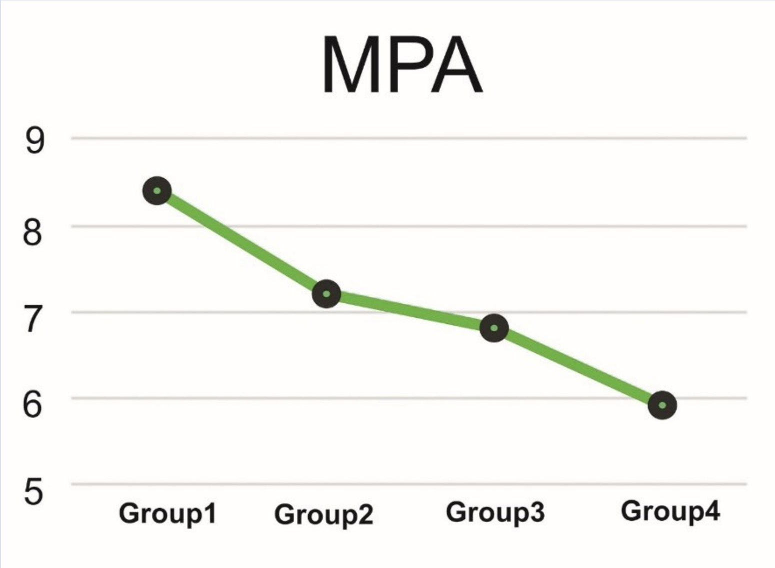

Figure 3. Relationship Between Groups and MPA Value.
MPA: Middle Pharyngeal Airway width, Group 1: simple snoring patients, Group 2: mild OSAS, Group 3: moderate OSAS, Group 4: severe OSAS.

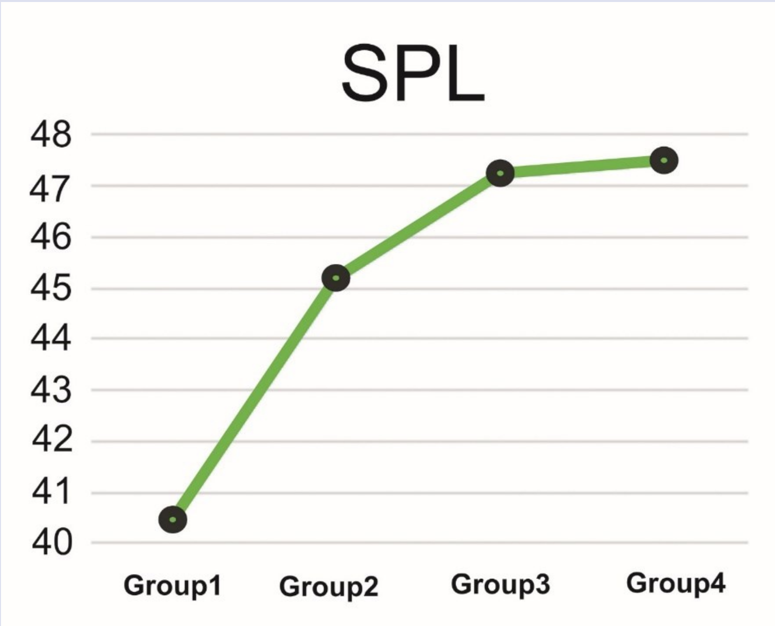

Figure 4. Relationship Between Groups and SPL Value.
SPL: Soft Palate Length, Group 1: simple snoring patients, Group 2: mild OSAS, Group 3: moderate OSAS, Group 4: severe OSAS.

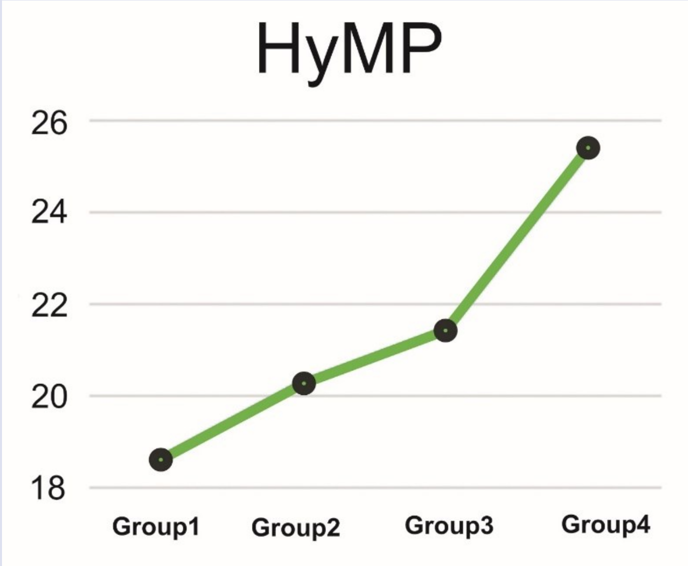

Figure 5. Relationship Between Groups and HyMP Value.
HyMP: Distance between hyoid bone and mandibular plane, Group 1: simple snoring patients, Group 2: mild OSAS, Group 3: moderate OSAS, Group 4: severe OSAS.

Discussion

OSAS is a syndrome that has not yet been fully elucidated in all its aspects and therefore continues to be investigated in many studies.[14] As is known, OSAS is a heterogeneous disease and many studies reveal the importance of anatomical factors in the pathogenesis of the disease.[8,15,16] In our study, we investigated the anatomical factors that predispose to OSAS and aimed to present the data we obtained as additional information to the literature. Since hypoxemia caused by OSAS in diseases such as cardiac arrhythmias, ischemic events and neurocognitive disorders, which are more common in elderly individuals, may worsen these diseases,[17] the relationship between age and OSAS severity was first examined. However, no significant relationship was found between age and AHI value in our study. In a retrospective study, Leppanen *et al*.[18] found no statistically significant difference between AHI and age. Ianella *et al*. [19] reported that age and AHI values did not reveal a statistical relationship (P=0.8) as a result of a meta-analysis based on studies comparing elderly (>65 years) and young (<65 years) OSAS patients in the literature. In contrast, Ernst *et al*.[17] showed that the rate of having OSAS was three times higher in people over 65 years of age than in the younger population (P<0.001). The finding of a significant relationship between age and AHI in the study by Ernst et al.[17] may be related to the sample size included in the study.

Based on the view that factors such as hormones, lifestyle, psychogenic status that differ between men and women may be effective in OSAS, the relationship between AHI severity and gender was also examined in order to contribute to the literature in determining whether a gender-oriented approach is necessary in the diagnosis and treatment of OSAS. In our study, no significant relationship was observed between gender and AHI groups. OSAS is more common in men than in women, according to some studies in the literature.[20–23] In addition, there are studies showing that OSAS affects women at higher rates.[24] There are studies in the literature indicating that this may be related to hormones, possibly progesterone may be effective in protecting women from the development of OSAS, while testosterone may constitute a risk factor.[25,26] When the literature is examined, it is seen that there is no consensus on the effect of gender on OSAS. In our study, no relationship was found between gender and OSAS and it is thought that both age and gender alone are not risk factors for OSAS.

The narrowest area of the airway between the *choanas* and the *cart. epiglottica* is usually the retropalatal region. This region is thought to be the most likely region of airway obstruction during sleep.[27] The relationship between pharyngeal airway widths at different levels and AHI is a critical factor in the treatment of OSAS and is important in determining the treatment plan according to the anatomical characteristics of the patient. For example, surgical treatment may be more appropriate in a patient with pharyngeal airway stenosis, while CPAP (continuous positive air pressure) therapy may be more effective in another patient. In our measurements of upper airway widths, we found a considerable narrowing only in the middle pharyngeal airway as the severity of OSAS increased. Pollis *et al*.[28] reported a negative correlation between UPA value and AHI severity in their study (P=0.007). There was no significant difference between MPA and LPA values and AHI severity (p > 0.05). Ryu *et al*.[29] couldn't find a significant correlation between the anteroposterior dimension of the upper airway and OSAS disease severity. Neelapu *et al*.[30] stated that there was a significant decrease in pharyngeal space in OSAS patients in the results of a meta-analysis they conducted. Tanellari *et al*.[31] showed that patients with OSAS had narrower upper posterior airway space (p=0.03) and middle airway space (P<0.01) compared to the control group. In the literature, studies that found narrowing at different levels of the upper airway due to OSAS are at the forefront. We think that the narrowing of the middle pharyngeal airway in our study may be related to the presence of prolonged soft palate of patients with OSAS, which is another finding of our study.

In the literature review, it was found that the position of the hyoid bone varies significantly in patients with OSAS.[31–37] According to these results, the position of the hyoid bone may be an important factor in treatment planning. For example, surgical or orthodontic treatments that open the upper airway by pulling the hyoid bone forward and upward may reduce AHI in some patients. In the hyoid bone-related measurements of our study, no difference was observed between the groups in terms of HyMe and HyC3 values (P>0.05). When HyMP values were compared between the groups, it was observed that there was an increase between the control group and Group 4 (P<0.05) and Group 2 and Group 4 (P<0.05). The results we obtained about hyoid bone in our study overlap with many studies in the literature.[32–37] Tanellari *et al*.[31] found that both HyMP and HyC_3 values were found to be higher in individuals with OSAS in comparison to the control group (P<0.001). According to these results, we can say that inferiorly displaced hyoid bone is a characteristic feature in patients with OSAS and the distance of the hyoid bone to the mandibular plane may be a guide in the diagnosis and severity of OSAS.

We included soft palate dimensions in our study because we thought that the decreasing MPA value with disease severity might be related to increased soft palate length. In our study, it was observed that SPL value increased with increasing OSAS severity (P<0.05). This means that there is an increase in the length of the soft palate of patients with OSAS. SPTh scores did not differ significantly between groups. When we look at the existing studies in the literature on this subject; similar to our study, soft palate length was increased in OSAS patients.[27,37,38] In addition to the possibility that increased soft palate length may be a causative factor of OSAS, it should also be considered that it may be a consequence of OSAS. In either case, an elongated soft palate will tend to narrow the middle pharyngeal airway. The dimensions of the soft palate can have an impact on the choice and success of surgical or other treatment modalities. For example, soft palate reduction surgery may improve quality of life by reducing AHI in some patients.

Conclusions

In our study, the relationship between these parameters and OSAS was investigated by making measurements on both hard and soft tissues that shape the upper airway. In our study, we aimed to have a contribution to the literature by including all of the most commonly measured parameters in studies performed on lateral head radiographs. The data obtained in our study supported the importance of hyoid bone position in the diagnosis of OSAS. Accordingly, surgical techniques such as hyoid suspension following measurements of the hyoid bone on head radiographs in patients with OSAS may give a successful result in the treatment of the disease and reduction of symptoms. This surgical technique aims to facilitate breathing during sleep by widening the upper airway and preventing the tongue from sliding backwards. In addition, the results related to the SPL value in our study are also remarkable. Based on these results, it is thought that surgical applications to reduce the size of the soft palate may also be successful in reducing the severity of AHI by expanding the upper airway. The significant reduction in the middle airway space can be expanded by maxillary advancement, mandibular advancement or both operations in current applications. Our results support these treatment methods.

Lateral cephalograms are widely used in the evaluation of patients with OSAS. Although it has some disadvantages such as the formation of superpositions when a three-dimensional structure is examined in two dimensions and the necessity for the patient to be awake, it is preferred because it is inexpensive, widely available and technically easy to apply, and the patient is exposed to less radiation compared to other imaging methods. However, the pharynx also has a tendency to collapse laterally, which can only be detected by second-stage evaluations such as CT, MRI or endoscopy. Therefore, it would be appropriate to include MRI images in future studies to evaluate fat deposition in the pharyngeal tissues in the transverse plane. In addition, it is possible that the increase in the length of the soft palate may also be caused by an increase in the amount of fat in the soft tissues. In order to evaluate this, taking obesity status into consideration will help to reach clearer results.

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Conflict of Interest Statement

The authors had no conflict of interest to declare.

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