ERD European Journal of Research in Dentistry

ORIGINAL ARTICLE / ARAŞTIRMA MAKALESİ

Effects of Orthognathic Surgery on Posterior Airway Volume and Development of Obstructive Sleep Apnea

Ortognatik Cerrahinin Posterior Hava Yolu Hacmi ve Obstrüktif Uyku Apnesi Gelişimi Üzerine Etkileri

Zeynep Beyza Kırıştıoğlu[1], Sema Saraç[2], Fatma Özbaki[2], Gülcan Berkel[1], Gökhan Göçmen[1]

[1] Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Marmara University, Istanbul, Türkiye.
[2] Department of Chest Diseases, Sureyyapasa Teach and Research Hospital, University of Medical Science, Istanbul, Türkiye.

Corresponding Author
Zeynep Beyza Kırıştıoğlu (✉)
beyzakiristioglu@gmail.com

Article History

Submitted	06.02.2025
Revised	13.05.2025
Accepted	13.05.2025
Published	29.08.2025

ABSTRACT

Objectives: This study aimed to compare preoperative and postoperative polysomnography (PSG) measurements and evaluated the changes in posterior airway space (PAS) volume according to the movements performed in orthognathic surgery.
Materials and Methods: The mean age of the 14 patients included in this prospective observational study was 29.57 ± 8.05 years, 9 were female and 5 were male. Patients scheduled to undergo bimaxillary surgery, underwent overnight PSG in the sleep laboratory 1 week before and 3 months after the operation. PSG included the following: Apnea – Hypopnea Index (AHI) (/h), sleep onset (min), sleep efficiency (%), sleep stages (SS) 1 (%) – 2 (%) – 3 (%), rapid eye movement sleep (REM) (%) and oxygen saturation. For all patients, 3D cone beam computed tomography (CBCT) images were acquired 1 week before and 3 months after surgery. The pharyngeal airway was divided into two regions, the nasopharynx (NPV) and oropharynx (OPV). These regions were defined using the posterior nasal spine, posterior part of the ala of vomer and cervical vertebra. Preoperative and postoperative data obtained from CBCT and PSG were compared.
Results: In the comparison between AHI changes; the rate of decrease in NPV score was higher in patients with high AHI scores compared to others (p: 0,006). In patients with decreased AHI, the change in REM % was higher than the other groups (p: 0,019).
Conclusions: Orthognathic surgery causes changes in posterior airway volume and these changes cause changes in polysomonography data. In this study, it was concluded that NPV decreased more in patients with increased AHI values.
Keywords: Obstructive sleep apnea, polysomnography, orthognathic surgery

ÖZ

Amaç: Bu çalışmada, ortognatik cerrahide uygulanan hareketlere göre posterior hava yolu hacmindeki (PAS) değişikliklerin değerlendirilmesi ve preoperatif ve postoperatif polisomnografi (PSG) ölçümlerinin karşılaştırılması amaçlanmıştır.
Gereç ve Yöntemler: Bu prospektif gözlemsel çalışmaya dahil edilen 14 hastanın yaş ortalaması 29.57 ± 8.05 yıl olup, 9'u kadın ve 5'i erkekti. Bimaksiller cerrahi planlanan hastalara operasyondan 1 hafta önce ve 3 ay sonra uyku laboratuvarında gece boyu PSG uygulanmıştır. PSG'de, Apne-Hipopne İndeksi (AHİ) (/saat), uyku başlangıcı (dk), uyku etkinliği (%), uyku evreleri (SS) 1 (%) – 2 (%) – 3 (%), hızlı göz hareketi uykusu (REM) (%) ve oksijen satürasyonu parametreleri ölçülmüştür. Tüm hastalardan ameliyattan 1 hafta önce ve 3 ay sonra 3D konik ışınlı bilgisayarlı tomografi (CIBT) görüntüleri elde edilmiştir. Faringeal hava yolu nazofarenks (NPV) ve orofarenks (OPV) olmak üzere iki bölgeye ayrılmıştır. Bu bölgeler posterior nazal spine, ala vomerin posterior kısmı ve servikal vertebra kullanılarak tanımlanmıştır. CBCT ve PSG'den elde edilen preoperatif ve postoperatif veriler karşılaştırılmıştır.
Bulgular: AHİ değişiklikleri arasındaki karşılaştırmada; AHİ skoru yüksek olan hastalarda NPV skorundaki azalma oranı diğerlerine göre daha yüksekti (p: 0,006). AHİ'si düşük olan hastalarda REM % değişim oranı diğer gruplara göre daha yüksekti (p: 0,019).
Sonuç: Ortognatik cerrahi posterior hava yolu hacminde ve polisomonografi verilerinde değişikliklere neden olmaktadır. Bu çalışmada AHİ değerleri yüksek olan hastalarda NPV'nin daha fazla azaldığı sonucuna varılmıştır.
Anahtar Kelimeler: Obstrüktif uyku apnesi, polisomnografi, ortognatik cerrahi

How to cite this article: Kırıştıoğlu, Z., B., Saraç, S., Özbaki, F., Berkel, G., Göçmen, G. Effects of Orthognathic Surgery on Posterior Airway Volume and Development of Obstructive Sleep Apnea. European Journal of Research in Dentistry, 2025; 9(2): 85-91. DOI: http://dx.doi.org/10.29228/erd.98

INTRODUCTION

Orthognathic surgery has effects such as causing changes in the surrounding soft tissues, tongue, hyoid bone, soft palate, adjacent muscles and volume of the posterior airway (Qahtani, 2016 ; Lee et al., 2019 ; Achilleos et al., 2000). Orthognathic surgery may lead to direct or indirect changes in the volume of the posterior airway and affect the patients breathing positively or negatively (Shin et al.,2015; Yamashita et al., 2017). Adequate airway volume is important in maintaining healthy vital functions. Decreased airway volume caused by various etiologic factors is among the causes that may lead to systemic diseases with high morbidity and mortality risk and predispose to obstructive sleep apnea syndrome (OSAS)(Achilleos et al., 2000). Polysomnographic (PSG) measurement remains the gold standard in the diagnosis of OSAS (Madani et al., 2007).

Many methods have been used to evaluate changes in airway volume. Some studies have performed two dimensional (2D) measurements with lateral cephalometric films, but volumetric changes in the airway, which is a three dimensional (3D) structure, cannot be adequately detected with lateral cephalometric radiographs (Pereira-Filho et al., 2011; Gokce et al., 2012; Burkhard et al., 2014). Airway volume can be measured more clearly with 3D cone-beam computed tomography (CBCT); however, few studies have investigated the relationship between volume measurements using CBCT and PSG respiratory parameters(Canellas et al., 2016a; Canellas et al., 2016b; Yajima et al., 2017).

In this study, we compared preoperative and postoperative polysomnography measurements and evaluated the changes in posterior airway space (PAS) volume according to the movements performed in orthognathic surgery.

MATERIALS AND METHODS

Patients

Approval for the study was obtained from the Marmara University Faculty of Medicine Clinical Research Ethics Committee (decision number 09.2022.1034 dated 29.11.2022). In the power analysis of this study, the required sample size was determined as 14 patient. This prospective observational study included patients with dentofacial deformities who were admitted to the Marmara University Faculty of Dentistry, Oral and Maxillofacial Surgery Clinic for bimaxillary orthognathic surgery between February 2023 and March 2024. A consent to participate form was obtained from all patients. The study included 14 patients aged between 21 and 44 years. Nine of the patients were female and five were male.

Patients scheduled to undergo bimaxillary surgery underwent overnight PSG in the sleep laboratory 1 week before and 3 months after the operation. For all patients, 3D CBCT images were acquired 1 week before (T0) and 3 months after surgery (T1).

The inclusion criteria for the study were that the patients were admitted to our clinic with the indication of orthognathic surgery, had a follow-up of at least 3 months postoperatively, and had pre – and postoperative polysomnographic measurements. Patients with congenital or syndromic deformities, a history of trauma, respiratory problems or without preoperative and postoperative evaluation with CBCT and PSG were excluded from the study.

Surgery

All the operations were performed under general anesthesia with nasotracheal intubation in the operating room of Marmara University Faculty of Dentistry, Department of Oral and Maxillofacial Surgery. All the surgeries were performed by the same surgical team.

The surgical technique and osteotomy lines were standardized across all patients. Osteotomies were performed with piezo surgery (Piezosurgery®, Mectron, Italy). In Le Fort osteotomy, the osteotomy lines are determined between a standard apertura piriformis and zygomatic buttresses. The osteotomy lines were made at the same nasal level in the patients. Posteriorly, the osteotomy line is extended bilaterally to the lower part of the pterygomaxillary junction and the pterygoid processes are separated from the tuber region. The nasal mucosa was preserved intact and a down fracture was performed.

The sagittal split osteotomy line starting from the anterior edge of the ramus and extending anterolaterally to the middle of the second molar is determined. After the vertical bone incision extending to the lower edge of the mandible is prepared, the bone segments are separated with the help of hammers and osteotomes. The segments are freed with osteotomes. In genioplasty the osteotomy lines begin in the median region and extended laterally about 5 mm below the mental foramen, ensuring the roots of the teeth are preserved.

Polysomnography Evaluation

The patients were hospitalized in the Sleep Laboratory of Süreyyapaşa Chest Diseases Training and Research Hospital. All participants underwent a standard overnight polysomnography (PSG) test (Comet Grass; Astro-Med, Inc., West Warwick, RI, USA). The PSG procedure included monitoring sleep using three-channel electroencephalography, two-channel electrooculography, one-channel submental electromyography, oxygen saturation measured with an oximeter, respiratory movements tracked via chest and abdominal belts, nasal airflow monitored through a pressure sensor, thermistor, electrocardiography, and leg movements recorded with tibial surface electrodes. Sleep stages and respiratory parameters were scored based on the 2012 criteria set by the American Academy of Sleep Medicine (AASM). Apnea was defined as a reduction in airflow of 90% or more for at least 10 seconds, while hypopnea was defined as a reduction in airflow by at least 30% with a desaturation of 3% or more over the preceding 30 seconds, along with reduced chest wall movement and/or arousal. The apnea-hypopnea index (AHI) represents the average number of apneas and hypopneas per hour of sleep. Obstructive sleep apnea syndrome (OSAS) was diagnosed with an AHI of at least 5 events per hour, and the severity of OSAS was classified as mild (AHI 5.0-14.9 events/hour), moderate (AHI 15-29.9 events/hour), or severe (AHI >30.0 events/hour). (Berry et al., 2012).

The standard recording parameters during PSG included the following: AHI (/h), sleep onset (min), sleep efficiency (%), sleep stages (SS) 1 (%), 2 (%), and 3 (%) and rapid eye movement sleep (REM) (%). Arterial oxygen saturation (SaO_2) was measured continuously using pulse oximetry. The PSG results were evaluated by two experienced pulmonologists (SS, FO).

Evaluation of the Pharyngeal Airway

Digital Imaging and Communications in Medicine (DICOM) data from 3D CBCT were transferred to NemoStudio software (Nemotec, Madrid, Spain). Two reference lines (x-axis, i.e. the line tangent to the inferior part of the sella turcica and parallel to the Frankfort horizontal (FH) plane; y-axis, i.e. the line perpendicular to the x-axis and passing through N) were defined. The threshold for the assessing airway volume was set to a range of 1024 to 600 Hounsfield units, where the pharyngeal airway could be effectively distinguished from the adjacent soft tissue. The total pharyngeal airway volume is divided into two regions: nasopharyngeal volume (NPV) and oropharyngeal volume (OPV) (Fig. 1) These regions were defined using the PNS and cervical vertebra (CV) references according to a previous report (Yang et al., 2020).

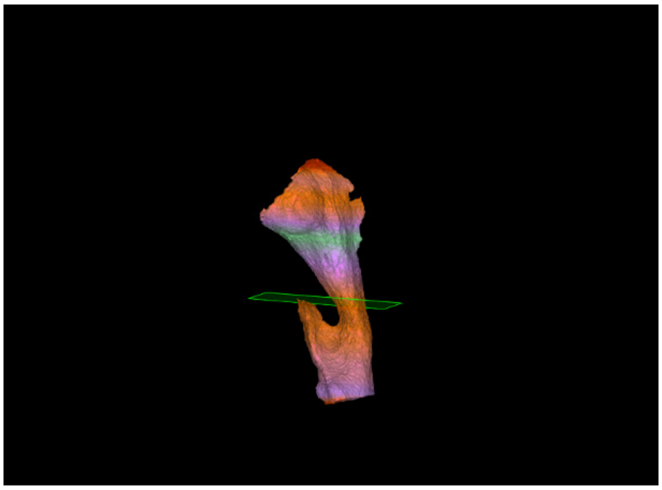

Figure 1: STL version of the total airway volume measured by CBCT.

The CV1 and CV2 planes are parallel to the FH plane through the most inferior point of each CV. For nasopharynx, the superior border was determined as the line between posterior nasal spine (PNS) - posterior part of the ala of vomer (Vp) and the inferior border was determined as the CV1 plane (Fig. 2A) For the oropharynx, the superior border was determined as the CV1 plane and the inferior border as the CV2 plane. (Fig. 2B) The minimum axial space (MAS) was recorded as the narrowest axial airway area detected by the program in the sagittal section and calculated by the own algorithm.

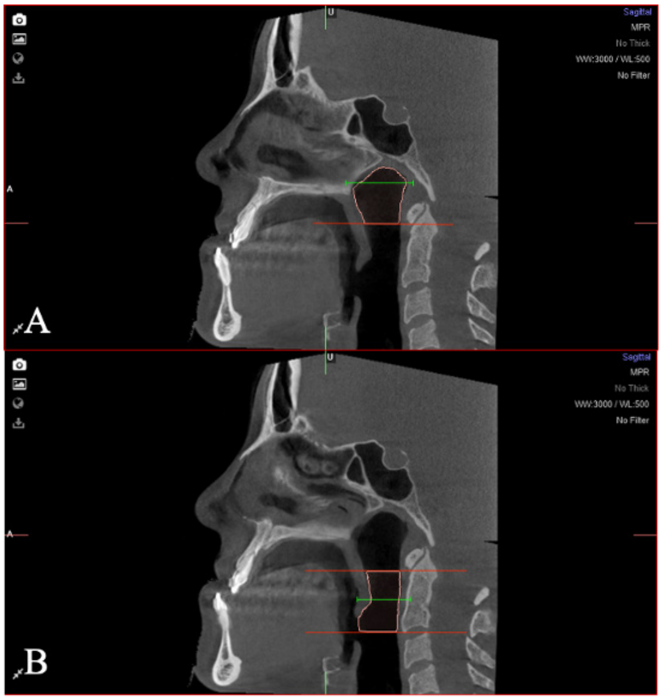

Figure 2: (A): For nasopharynx: Vp - PNS - CV, (B): For oropharynx: CV1 - CV2

Statistical Evaluation

The SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) program was used for data analysis. The conformity of the variables to normal distribution was examined by histogram plots and the Kolmogorov - Smirnov and Shapiro-Wilk tests. Mean, standard deviation, median and minimum - maximum values were used to present descriptive analyses. Pearson's chi-squared test was used to compare the results in eyes with more than 2x2. An independent t-test was used to evaluate normally distributed (parametric) variables between the groups. The change between preoperative and postoperative data was analyzed by a paired-samples t-test and the change between groups was analyzed by repeated measures analysis. P-values below 0.05 were considered as statistically significant results.

RESULTS

Fourteen patients, 5 males and 9 females, were included in the study. The mean age of the patients was 29.57 ± 8.05 years. The total volume, NPV, OPV, and AHI changes of the patients are shown in Table 1. The preoperative and postoperative values of NPV, OPV, AHI, total volume and PSG data were calculated. The significance of the change between the preoperative and postoperative values was analyzed, and no significant p-value was found.

Table 1. Demographic and Clinical Characteristics of Patients

		N /Mean ± SD	%/Median (Min-Max)
Sex	Male	5	(35,71)
	Female	9	(64,29)
Age		29,57 ± 8,05	28 (21-44)
Orthognathic	Bimaxillary	10	(71,43)
	Mandible	1	(7,14)
	Bimaxillary +Genioplasty	3	(21,43)
Total volume change	Increased	9	(64,29)
	Decreased	5	(35,71)
NPV change	Increased	9	(64,29)
	Decreased	5	(35,71)
OPV change	Increased	9	(64,29)
	Decreased	5	(35,71)
AHI change	Increased	6	(42,86)
	Decreased	7	(50)
	Unchanged	1	(7,14)

N: number, SD: Standart Deviation, NPV: Nasopharyngeal Volume, OPV: Oropharyngeal Volume, AHI: Apnea-Hypopnea Index

PSG data were compared between the groups with increased and decreased total volume, and no significant p-value was obtained. PSG data were compared between the AHI groups, and it was found that the mean postoperative SS 3 % of those with increased AHI was higher that of than the other groups. Preoperative - postoperative changes in PSG data between the groups were analyzed. The change in the REM percentage in those with decreasing AHI was higher than the other groups. Standard deviations could not be calculated because there was only one patient whose AHI preoperative - postoperative score did not change. (Table 2) (Fig. 3)

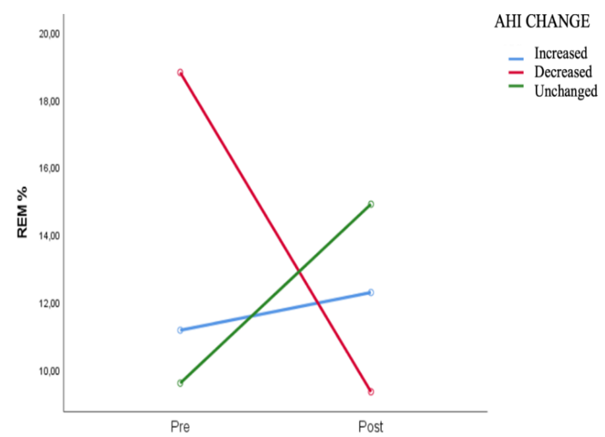

Figure 3: The Change in REM Percentage in Relation to AHI

Table 2. Preoperative and Postoperative Changes in PSG Data by AHI Groups

		AHI CHANGE						p¹
		Increased		Decreased		Unchanged		
		Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)	
Sleep Onset (min)	Preop	424,85 ± 66,18	450,8 (298-474)	422,07 ± 66,75	433,5 (281,5-479)	465 ±.	465 (465-465)	0,834
	Postop	401,13 ± 64,52	400,25 (306-506,3)	446,11 ± 71,63	463,5 (304,3-527)	474,3 ±.	474,3 (474,3-474,3)	0,422
	p^2	0,473						
Sleep Efficiency (%)	Preop	81,17 ± 9,54	77,65 (71,7-98,4)	82,99 ± 7,63	84,4 (66,6-89,5)	66,6 ±.	66,6 (66,6-66,6)	0,244
	Postop	84,25 ± 11,31	82,55 (69,5-98,6)	83,63 ± 13,87	90 (54,7-94,4)	99,2 ±.	99,2 (99,2-99,2)	0,532
	p^2	0,082						
SS 1 (%)	Preop	6,23 ± 4,5	4,45 (1,9-12,6)	5,61 ± 4,78	3,7 (1,3-12,5)	7,4 ±.	7,4 (7,4-7,4)	0,927
	Postop	4,3 ± 6,13	1,45 (0,5-16,2)	6,43 ± 7,01	3,7 (0,9-20,5)	6,8 ±.	6,8 (6,8-6,8)	0,833
	p^2	0,851						
SS 2 (%)	Preop	53,18 ± 19,68	57,25 (16,6-70,3)	49,9 ± 12,39	52,4 (28,8-62,8)	44,8 ±.	44,8 (44,8-44,8)	0,866
	Postop	52,97 ± 7,16	54,5 (42,8-60)	68,64 ± 14,79	67,3 (43,8-93,1)	72,2 ±.	72,2 (72,2-72,2)	0,082
	p^2	0,193						
SS 3 (%)	Preop	29,42 ± 16,36	26,65 (11,3-58,8)	27,23 ± 8,67	24,1 (20,8-46,3)	38,2 ±.	38,2 (38,2-38,2)	0,725
	Postop	32,25 ± 9,15	36,75 (19-39,8)	15,57 ± 6,03	15,6 (5,9-23,9)	6,1 ±.	6,1 (6,1-6,1)	**0,003**
	p^2	0,15						
REM (%)	Preop	11,17 ± 6,12	11,5 (3,7-19,6)	18,8 ± 8,93	15,7 (10,6-33,2)	9,6 ±.	9,6 (9,6-9,6)	0,211
	Postop	12,28 ± 7,62	13,85 (0-22)	9,34 ± 6,84	8,7 (0-20)	14,9 ±.	14,9 (14,9-14,9)	0,663
	p^2	**0,019**						
Saturation (%)	Preop	96,17 ± 0,75	96 (95-97)	93,14 ± 3,63	93 (87-97)	98±.	98 (98-98)	0,108
	Postop	95,67 ± 1,51	96 (93-97)	96,29 ± 0,95	96 (95-98)	97±.	97 (97-97)	0,512
	p^2	0,071						
SD: Standart Deviation, AHI: Apnea-Hypopnea Index, SS: Sleep Stage								

* p: Independent T Test / p2: Repeated Measures Analysis

The total volume, NPV, OPV, and AHI were compared between orthognathic conditions, and no significance was found. A significant p-value was obtained as a result of the comparison between the AHI change conditions, indicating that the rate of decrease in NPV score was higher in those with an increased AHI score than in the other groups (Table 3).

Table 3. Relationship Between AHI Changes and Pharyngeal Airway Volume Alterations

		AHI Change						p
		Increased		Decreased		Unchanged		
		n	%	n	%	n	%	
Total Volume Change	Increased	2	-33,33	6	-85,71	1	-100	0,108
	Decreased	4	-66,67	1	-14,29	0	0	
NPV Change	Increased	1	-16,67	7	-100	1	-100	**0,006**
	Decreased	5	-83,33	0	0	0	0	
OPV Change	Increased	3	-50	5	-71,43	1	-100	0,537
	Decreased	3	-50	2	-28,57	0	0	

N: number, NPV: Nasopharyngeal Volume, OPV: Oropharyngeal Volume, AHI: Apnea-Hypopnea Index

DISCUSSION

The aim of the study was to examine the changes in posterior airway volume caused by orthognathic surgery and to investigate the effect of these changes on PSG data. According to the findings, there were significant changes in the airway volume of the patients after surgery.

In several studies, orthognathic surgery has been performed on patients with dentofacial deformities, and its effect on the patients' airways has been investigated with 2D and 3D measurements (Gokce et al., 2012; Al-Moraissi et al., 2015; Canellas et al., 2016a). However, very few studies performed in the sleep laboratory have used PSG and 3D measurements. In this study, the effect of changes in the posterior airway after orthognathic surgery on the risk of OSAS development was reported by jointly evaluating 3D volume and PSG measurements in the sleep laboratory.

Few studies have used 3D imaging methods in airway evaluations after orthognathic surgery. Although previous studies have considered 2D cephalometric films to be the gold standard for measuring the airway, recent studies indicate that the pharynx is a 3D structure and that accurate volume measurements cannot be made only with linear and angular measurements (Larson, 2012; Kim et al., 2016). Although previous studies used CT for airway measurements, recent studies have recommended CBCT to eliminate the disadvantages of CT, such as high radiation, the use of a metal artifact, and its high cost (Degerliyurt et al., 2008; Larson, 2012; Tepecik et al., 2018). In this study, airway volume measurement with CBCT was preferred because of these advantages.

There is no definite consensus in the literature on the segmentation of the airway. Various studies have examined the posterior airway in one, two (oropharynx, nasopharynx), and three (oropharynx, nasopharynx, hypopharynx) sections (Park et al., 2010; Hernandez-Alfaro et al., 2011; Abramson et al., 2011; Li et al., 2014; Gokce et al., 2014). Usegi et al. reported that the obstruction causing apnea was mostly located in the oropharynx and nasopharynx (Uesugi et al., 2014). White et al. reported that the level of collapse in OSAS patients was usually not in the hypopharynx (White & Younes, 2012). Similarly, this study examined the airway in two sections, namely, the oropharynx and nasopharynx.

Many different time intervals have been used as follow-up periods in studies evaluating the airway. Hochban et al. reported that there was no significant difference in airway measurements at one-week, three-month, and one-year postoperative follow-up (Hochban et al., 1996). Kawakami et al. reported that one month postoperatively was sufficient for the physiologic adaptation of soft tissues that narrow the airway (Kawakami et al., 2005). Since it was thought that patients would have difficulty cooperating when the follow-up period was prolonged, three months was considered a sufficient postoperative follow-up period for the CBCT and PSG measurements in this study.

In their study, Gokce et al. reported a significant postoperative decrease in AHI values despite a decrease in oropharynx and hypopharynx volumes and reported that this result may be associated with an increase in NPV (Gokce et al., 2014). Similarly, this study found a greater reduction in NPV among patients with elevated AHI values.

The typical sleep cycle is made up of four stages: SS 1, SS 2, SS 3, and REM (rapid eye movement), which are categorized based on electroencephalography and the tone of the suprahyoid muscles. These stages account for approximately 5%, 50%, 25%, and 20% of total sleep time, respectively. The SS 1 stage is considered light sleep, during which a person can be easily awakened. SS 2 represents the transition to deeper sleep. SS 3, or slow-wave sleep, is when the body and mind undergo restorative processes, while the REM stage is associated with dreaming, memory consolidation, and high brain activity. Both the quality and quantity of sleep are indicators of overall health and well-being. A lack of sufficient sleep can result in reduced SS 3 and REM stages. In conditions like OSAS, the SS 3 phase is often diminished in the sleep pattern. During the REM stage, muscles around the oropharynx relax, leading to a narrowing of the upper airway and a higher risk of obstruction. As a result, episodes of apnea and hypopnea are more likely to occur in this stage, contributing to hypoxemia. Engboonmeskul et al. stated that since OSAS is usually more prominent during REM sleep, decreased REM sleep duration may contribute to lower AHI (Engboonmeskul et al., 2020). In this study, the rate of decrease in REM sleep was found to be higher in patients with decreased AHI than in the other groups.

Polysomnography is the gold standard in the diagnosis of OSAS. AHI has been reported as the most important indicator in PSG measurements (Tepecik et al., 2018). Although no statistically significant difference was observed in AHI in the PSG evaluations in our study;

when the patients were evaluated individually, the AHI was measured as 0 in three patients after orthognathic surgery. Total airway volume increased in three of the patients whose AHI value decreased to 0. One of these patients was a patient with preoperative OSAS (AHI:7.03).

The limitations of the study include the relatively small number of patients, the follow-up period of 3 months, and the fact that the preoperative and postoperative CBCT were taken while the patients were standing and the sleep tests were performed in the supine position.

Conclusions

This study showed that orthognathic surgery causes changes in posterior airway volume and these changes cause changes in PSG data. The effect of these dimensional changes on PSG data should be evaluated in future studies by increasing the number of patients.

Ethics Committee Approval

The ethics committee approval of the study was obtained from Marmara University Faculty of Medicine Clinical Research Ethics Committee (reference no: 09.2022.1034).

Conflicts of Interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Abramson Z, Susarla SM, Lawler M, Bouchard C, Troulis M, Kaban LB. Three-dimensional computed tomographic airway analysis of patients with obstructive sleep apnea treated by maxillomandibular advancement. J. Oral Maxillofac. Surg. 2011;69(3):677-86.
2. Achilleos S, Krogstad O, Lyberg T. Surgical mandibular setback and changes in uvuloglossopharyngeal morphology and head posture: a short – and long-term cephalometric study in males. Eur. J. Orthod. 2000;22(4):383-94.
3. Al-Moraissi EA, Al-Magaleh SM, Iskandar RA, Al-Hendi EA. Impact on the pharyngeal airway space of different orthognathic procedures for the prognathic mandible. Int. J. Oral Maxillofac. Surg. 2015;44(9):1110-8.
4. Berry RB, Budhiraja R, Gottlieb DJ, Gozal D, Iber C, Kapur VK, et al. Rules for scoring respiratory events in sleep: update of the 2007 AASM Manual for the Scoring of Sleep and Associated Events. Deliberations of the Sleep Apnea Definitions Task Force of the American Academy of Sleep Medicine. J. Clin. Sleep Med. 2012;8(5):597-619.
5. Burkhard JP, Dietrich AD, Jacobsen C, Roos M, Lubbers HT, Obwegeser JA. Cephalometric and three-dimensional assessment of the posterior airway space and imaging software reliability analysis before and after orthognathic surgery. J Craniomaxillofac Surg. 2014;42(7):1428-36.
6. Canellas JV, Barros HL, Medeiros PJ, Ritto FG. Effects of surgical correction of class III malocclusion on the pharyngeal airway and its influence on sleep apnoea. Int. J. Oral Maxillofac. Surg. 2016;45(12):1508-12.(a)
7. Canellas JV, Barros HL, Medeiros PJ, Ritto FG. Sleep-disordered breathing following mandibular setback: a systematic review of the literature. Sleep Breath. 2016;20(1):387-94.(b)
8. Degerliyurt K, Ueki K, Hashiba Y, Marukawa K, Nakagawa K, Yamamoto E. A comparative CT evaluation of pharyngeal airway changes in class III patients receiving bimaxillary surgery or mandibular setback surgery. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 2008;105(4):495-502.
9. Engboonmeskul T, Leepong N, Chalidapongse P. Effect of surgical mandibular setback on the occurrence of obstructive sleep apnea. J. Oral Biol. Craniofac. Res. 2020;10(4):597-602.
10. Gokce SM, Gorgulu S, Gokce HS, Bengi AO, Karacayli U, Ors F. Evaluation of pharyngeal airway space changes after bimaxillary orthognathic surgery with a 3-dimensional simulation and modeling program. Am. J. Orthod. Dentofacial. Orthop. 2014;146(4):477-92.
11. Gokce SM, Gorgulu S, Gokce HS, Bengi O, Sabuncuoglu F, Ozgen F, et al. Changes in posterior airway space, pulmonary function and sleep quality, following bimaxillary orthognathic surgery. Int. J. Oral Maxillofac. Surg. 2012;41(7):820-9.
12. Hernandez-Alfaro F, Guijarro-Martinez R, Mareque-Bueno J. Effect of mono – and bimaxillary advancement on pharyngeal airway volume: cone-beam computed tomography evaluation. J. Oral Maxillofac. Surg. 2011;69(11):e395-400.
13. Hochban W, Schurmann R, Brandenburg U, Conradt R. Mandibular setback for surgical correction of mandibular hyperplasia—does it provoke sleep-related breathing disorders? Int. J. Oral Maxillofac. Surg. 1996;25(5):333-8.
14. Kawakami M, Yamamoto K, Fujimoto M, Ohgi K, Inoue M, Kirita T. Changes in tongue and hyoid positions, and posterior airway space following mandibular setback surgery. J. Craniomaxillofac. Surg. 2005;33(2):107-10.
15. Kim HS, Kim GT, Kim S, Lee JW, Kim EC, Kwon YD. Three-dimensional evaluation of the pharyngeal airway using cone-beam computed tomography following bimaxillary orthognathic surgery in skeletal class III patients. Clin. Oral Investig. 2016;20(5):915-22.
16. Larson BE. Cone-beam computed tomography is the imaging technique of choice for comprehensive orthodontic assessment. Am. J. Orthod. Dentofacial. Orthop. 2012;141(4):402, 4, 6 passim.
17. Lee ST, Park JH, Kwon TG. Influence of mandibular setback surgery on three-dimensional pharyngeal airway changes. Int. J. Oral Maxillofac. Surg. 2019;48(8):1057-65.
18. Li YM, Liu JL, Zhao JL, Dai J, Wang L, Chen JW. Morphological changes in the pharyngeal airway of female skeletal class III patients following bimaxillary surgery: a cone beam computed tomography evaluation. Int. J. Oral Maxillofac. Surg. 2014;43(7):862-7.
19. Madani M, Frank M, Lloyd R, Dimitrova DI, Madani F. Polysomnography versus home sleep study: overview

and clinical application. Atlas Oral Maxillofac. Surg. Clin. North Am. 2007;15(2):101-9.

20. Park JW, Kim NK, Kim JW, Kim MJ, Chang YI. Volumetric, planar, and linear analyses of pharyngeal airway change on computed tomography and cephalometry after mandibular setback surgery. Am. J. Orthod. Dentofacial Orthop. 2010;138(3):292-9.
21. Pereira-Filho VA, Castro-Silva LM, de Moraes M, Gabrielli MF, Campos JA, Juergens P. Cephalometric evaluation of pharyngeal airway space changes in class III patients undergoing orthognathic surgery. J. Oral Maxillofac. Surg. 2011;69(11):e409-15.
22. Qahtani ND. Impact of different orthodontic treatment modalities on Airway: A literature review. Pak. J. Med. Sci. 2016;32(1):249-52.
23. Shin JH, Kim MA, Park IY, Park YH. A 2-year follow-up of changes after bimaxillary surgery in patients with mandibular prognathism: 3-dimensional analysis of pharyngeal airway volume and hyoid bone position. J. Oral Maxillofac. Surg. 2015;73(2):340 e1-9.
24. Tepecik T, Ertas U, Akgun M. Effects of bimaxillary orthognathic surgery on pharyngeal airway and respiratory function at sleep in patients with class III skeletal relationship. J. Craniomaxillofac. Surg. 2018;46(4):645-53.
25. Uesugi T, Kobayashi T, Hasebe D, Tanaka R, Ike M, Saito C. Effects of orthognathic surgery on pharyngeal airway and respiratory function during sleep in patients with mandibular prognathism. Int. J. Oral Maxillofac. Surg. 2014;43(9):1082-90.
26. White DP, Younes MK. Obstructive sleep apnea. Compr. Physiol. 2012;2(4):2541-94.
27. Yajima Y, Oshima M, Iwai T, Kitajima H, Omura S, Tohnai I. Computational fluid dynamics study of the pharyngeal airway space before and after mandibular setback surgery in patients with mandibular prognathism. Int. J. Oral Maxillofac. Surg. 2017;46(7):839-44.
28. Yamashita AL, Iwaki Filho L, Leite PCC, Navarro RL, Ramos AL, Previdelli ITS, et al. Three-dimensional analysis of the pharyngeal airway space and hyoid bone position after orthognathic surgery. J. Craniomaxillofac. Surg. 2017;45(9):1408-14.
29. Yang HJ, Jung YE, Kwon IJ, Lee JY, Hwang SJ. Airway changes and prevalence of obstructive sleep apnoea after bimaxillary orthognathic surgery with large mandibular setback. Int. J. Oral Maxillofac. Surg. 2020;49(3):342-9.