

EFFECT OF MANDIBULAR SET-BACK SURGERY VERSUS BIMAXILLARY ORTHOGNATHIC SURGERY ON PHARYNGEAL AIRWAY SPACE AND CONSEQUENT DAYTIME SLEEPINESS IN DENTO-SKELETAL CLASS III MALOCCLUSION PATIENTS

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ABSTRACT

Purpose: Pharyngeal airway space (PAS) assessment after orthognathic surgery is crucial due to the possible resultant breathing hazards. This study compared PAS after mandibular set-back surgery and bimaxillary surgery and its consequent effect on the patients' daytime sleepiness in class III dento-skeletal patients.

Patients and methods Twenty-four patients with dento-skeletal class III deformity were divided equally into two groups; group A underwent mandibular set-back surgery while group B had bimaxillary orthognathic surgery through mandibular set-back and maxillary advancement surgeries. PAS area was measured on lateral cephalometric radiographs. Daytime sleepiness was assessed by Epworth sleepiness scale (ESS). All results were recorded pre-surgically, immediate post-surgically and at 6-months post-surgically.

Results In group A patients, the PAS value at T0 (mean of 546.72 ± 66.61 mm²) revealed a non-significant decrease after mandibular set-back surgery at T1 to reach a mean of 542.89 ± 68.65 mm², which appeared to minimally relapse at T2 to a value still less than T0 (544.00 ± 68.62 mm²) with a final decreased PAS value. In group B patients, the PAS value (mean of 555.05 ± 75.04 mm²) revealed a non-significant increase after bimaxillary surgery at T1 reaching a mean of 555.73 ± 79.34 mm² which re-increased at T2 to a mean value of 557.79 ± 78.23 mm². Following the pattern of PAS, the ESS recorded non-significant changes in both groups from the preoperative values to values at T1 and T2.

Conclusion Despite of the resulted post-surgical different changes, orthognathic surgery appeared to have no significant effect on PAS area nor on daytime sleepiness in a six-month duration.

KEYWORDS: Orthognathic surgery, Pharyngeal airway space, skeletal class III patients, Epworth sleepiness scale, daytime sleep level.

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INTRODUCTION

Changes of the jaws' positions after different orthognathic surgery logically affect the pharyngeal airway space (PAS), since the jaws act as insertion points for the pharyngeal muscles and the surrounding tissues⁽¹⁾. Additionally, PAS has a strong muscular envelope and a close relationship with the surrounding structures namely, the soft palate, epiglottis, tongue, and hyoid bone which tend to change after orthognathic surgery⁽²⁻⁴⁾.

Depending on the extent of skeletal defect, dento-skeletal class III patients needed 1-jaw surgery in the form of mandibular set-back (MS), or 2-jaw in the form of MS and maxillary advancement (MA) orthognathic surgeries as a treatment⁽⁵⁻⁶⁾.

Some studies declared that single-jaw surgery, which moves the mandible slightly backward, along with the muscles and other soft tissue attachments, affected the PAS and positioning of the tongue due to the slight backward rotation of the angle of mandible and cervical spine with reference to the skull base and hyoid bone⁽⁷⁻⁸⁾.

Accordingly, authors speculated the advantageous 2-jaw surgeries over single-jaw surgeries on PAS affection, due to the reduced amount of mandibular set-back which is usually compensated by the concomitant maxillary advancement resulting in less posterior tongue movement and less sealing of the oropharynx. Additionally, they expected a resultant superseding stability after the associated smaller jaw movements in sagittal dimensions⁽⁹⁻¹⁰⁾.

In the literature, no agreement appeared to be on the effect of different orthognathic surgeries on PAS changes. *Mehra et al*⁽¹¹⁾ and *Liukkonen et al*⁽¹²⁾ stated that corrections of the maxillo-mandibular deformities may lead a decreased PAS in cases of mandibular setback. However, *Kawakami et al*⁽¹³⁾ asserted that mandibular setback has no significant effect on PAS. Then again, the null hypothesis in the

literature stated that orthognathic surgery would not change the PAS dimensions⁽¹⁴⁾.

Nevertheless, some studies acknowledged that post-surgical reduction in PAS leads to a decrease in pharyngeal pressure and breathing difficulty specially during sleep. The main issue in the resulted sleep apnea is the periodic airway obstruction and sleep disturbance accompanied with multiple daytime sleep. Accordingly, pharyngeal airway reduction after mandibular setback surgery remains vital when planning jaws' surgeries mainly in dento-skeletal class III patients to prevent possible resultant airway hazards⁽¹⁵⁻¹⁶⁾.

Considering the above, this study aimed to assess the changes in the PAS after the one-jaw mandibular set-back surgery and the two-jaw bimaxillary orthognathic surgery and its consequent effect on daytime sleepiness.

PATIENTS AND METHODS

The trail was designed as prospective clinical trial. A power analysis was designed to have adequate power to apply a two-sided statistical test of the null hypothesis that there is no difference between pre and post treatment pharyngeal airway area. By adopting an alpha and beta levels of (0.05) (i.e. power=95%) and an effect size (d) of (1.32) calculated, based on the results of *Agarwal*⁽¹⁷⁾, the predicted sample size (n) was a total of (20) cases. Sample size was increased by (20%) to account for possible dropouts to be (24) cases. Sample size calculation was performed using G-Power version 3.1.9.7.

The present study was performed in the department of oral and maxillofacial surgery, faculty of Dentistry, Cairo University. The ethical approval was obtained from Cairo University institution and written consents were acquired from all patients after explanation of the procedure steps and complications. The trial was recorded on ClinicalTrial.gov (ClinicalTrials.gov identifier: NCT04629859)

Preoperative preparation and Patient grouping

This study included twenty-four medically stable patients suffering from dento-skeletal class III malocclusion. Study model analysis, cephalometric assessment, and orthodontic treatment were performed for all the patients preoperatively. Patients with uncontrolled systemic diseases, craniofacial syndromes, bone anomalies, and sleep-breathing disorders were excluded. All surgeries were performed by the same surgical team.

The selected patients were divided equally into two groups, 12 patients each; *Group A* patients underwent mandibular set-back surgery in the form of bilateral sagittal split osteotomy (BSSO) surgery, while *group B* patients had Bimaxillary orthognathic surgery in the form of le fort I maxillary advancement with mandibular set-back BSSO surgery utilizing typical documented methodology^(18,19). (Fig. 1-2).



Fig. (1): A photograph showing mandibular set-back cuts.

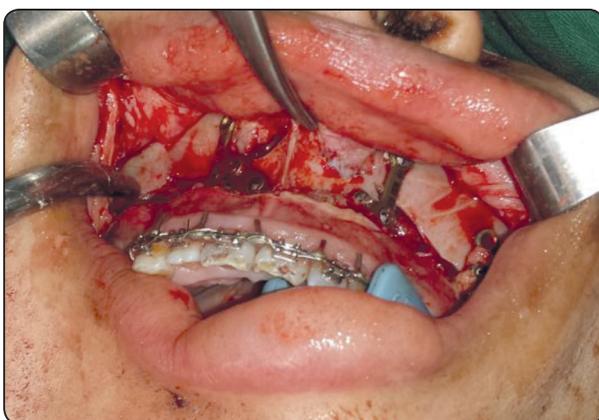


Fig. (2): A photograph showing maxillary advancement cuts and fixation.

All patients were followed-up for a period of six months to record any postoperative complications, and their clinical and esthetic content.

Pharyngeal airway surface area and Cephalometric analysis

To measure surgical changes and the PAS, the cephalometric radiograph of each patient in the maximum inter-cuspal position was taken at a magnification ratio of 1:1 before surgery (T0), immediately after surgery (T1) and at 6-months post-surgery as a follow-up. Cephalometric analysis was conducted using the superimposition technique.

Cephalometric analyses were performed through the superimposition technique of the pre-surgical, post-surgical and follow up images. The integrated reference points were the nasion (N), sella (S), and basion (B). A horizontal line corresponding to the Frankfurt horizontal plane (passing through the inferior borders of the bony orbits and the upper margin of the auditory meatus) and a vertical line perpendicular to the Frankfurt horizontal plane through the sella point was used. As delineated by the authors in several procedures^(2,20), the pharyngeal airway is demarcated inferiorly by a line passing through the tip of epiglottis and the superior tip of the hyoid bone, namely Line A, while the retro-glossal and the retro-palatal airway is separated by a line extending from the basion parallel to line A.

All the reference points and lines were conveyed to the images taken at T1 and T2. The PAS was measured twice by the same assessor at different times for each follow-up visit. The average values were recorded and compared.

Daytime sleepiness level and Epworth sleepiness score (ESS)

Daytime sleepiness level was assessed for all patients in each group by self-administrated questionnaire based on *ESS*^(16, 21). It consisted of a 4-point scale (0-3) with a total score of 0 to 24. The collected data at T0, T1, and T2 were documented and statistically compared.

Statistical analysis

Numerical data were represented as mean and standard deviation (SD) values. The normality was tested by Shapiro-Wilk's test while homogeneity of variances was tested using Levene's test. Mauchly's test was used to check the Sphericity assumption. For PAS area, inter and intragroup comparisons were analyzed using independent t-test and repeated measures ANOVA, respectively. While for Epworth score, inter and intragroup comparisons were analyzed using Mann Whitney U and Friedman's tests. A value of $p \leq 0.05$ was considered the significance level within all tests. Statistical analysis was performed with R-statistical analysis software version 4.0.3 for Windows.

RESULTS

Twenty-four patients suffering from Dento-skeletal class III malocclusion were included in this study, distributed equally into *Group A* patients who underwent mandibular set-back surgery in the form of BSSO surgery, and *group B* patients who had Bimaxillary orthognathic surgery in the form of maxillary advancement with mandibular set-back surgery. They were 16 females and 8 males with a mean age of 21.3 years at the surgery time.

No unexpected events were reported after surgeries of both groups. All patients were clinically content. The mean mandibular set-back distance in group A was 5.4 mm, while in group B had

a maxillary advancement mean of 3.4 mm and mandibular set-back mean of 4.2 mm.

Group A Mandibular set-back follow-up

The preoperative total PAS value at T0 recorded a mean of 546.72 mm² which revealed a non-significant decrease at T1 to a mean value of 542.89 mm². This appeared to re-increase after 6 months at T2 to a mean value of 544.00 mm² which was still less than T0. (Fig. 3)

Similarly, the *ESS* records non-significantly changed from the preoperative value of 6.25 to a post-surgical T1 value of 6.67 and a decreased T2 value of 6.17. (Table 1)

Group B Bimaxillary surgery follow-up:

The total preoperative mean PAS value at T0 was 555.05 mm² revealed a non-significant increase post-surgically at T1 to a value of 555.73 mm² which appeared to re-increase after 6 months post-surgically at T2 to a mean value of 557.79 mm². (Fig. 4)

Regarding the *ESS* values, a non-significant change from 6.42 preoperatively to 6.92 at T1 and 6.93 at T2. (Table 1)

By statistical comparison over the 6-months study period, LCR analysis of the total non-segmented PAS and the *ESS* values in both techniques showed non-significant intra-group changes in different follow-up intervals. ($p > 0.05$) (Table 2-3) (Fig. 5-6)

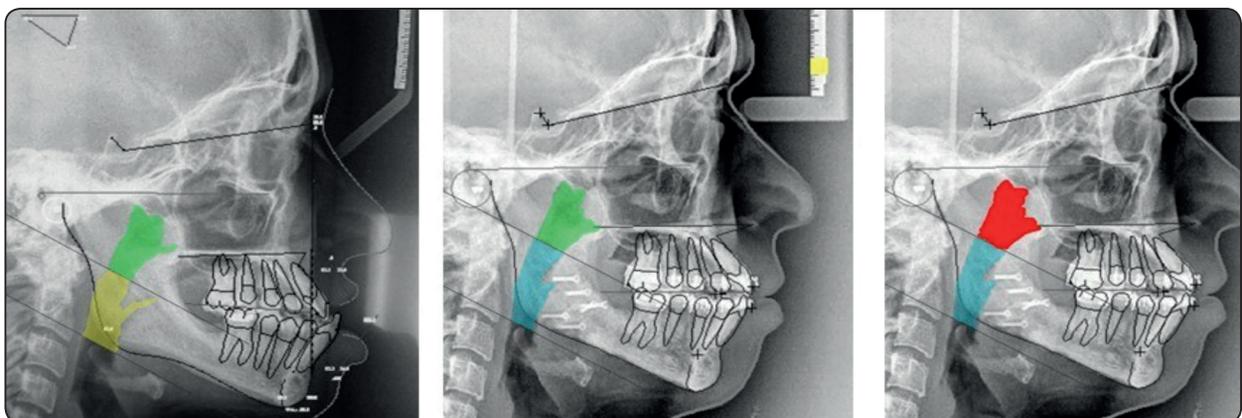


Fig. (3): Lateral cephalometric images showing pre-surgical PAS measurement at T0, T1 and T2 respectively in group A.

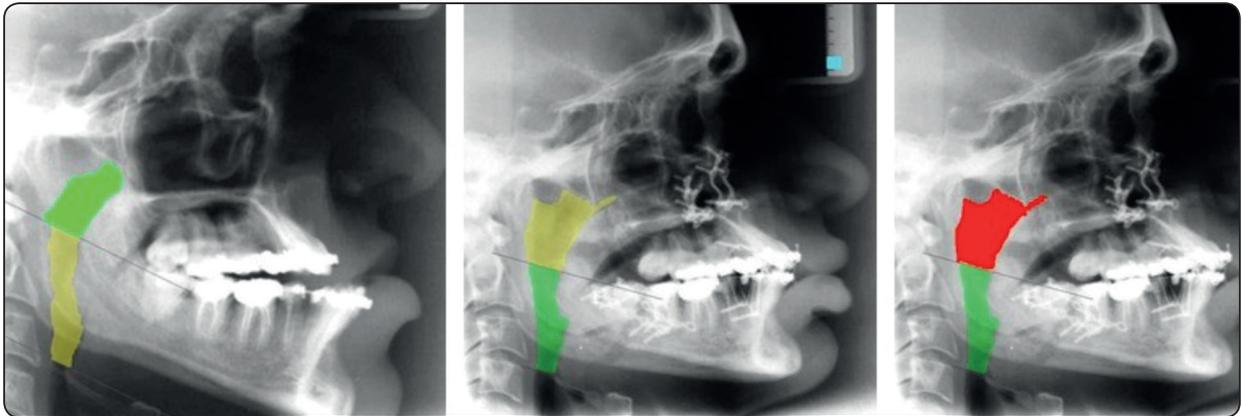


Fig. (4) Lateral cephalometric images showing pre-surgical PAS measurement at T0, T1 an T2 respectively in group B.

TABLE (1): Descriptive statistics of PAS and ESS records.

Measurement	Time	Material	Mean	95% CI		SD	Median	IQR
				Lower	Upper			
Pharyngeal airway surface area (mm ²)	Pre-operative	Mandibular setback	546.72	509.03	584.41	66.61	534.66	97.89
		Bimaxillary surgery	555.05	512.59	597.50	75.04	558.12	141.86
	T1	Mandibular setback	542.89	504.05	581.73	68.65	531.50	115.74
		Bimaxillary surgery	555.73	510.84	600.62	79.34	553.82	148.00
	T2	Mandibular setback	544.00	505.17	582.82	68.62	532.19	115.98
		Bimaxillary surgery	557.79	513.53	602.05	78.23	554.85	147.45
Epworth score	Pre-operative	Mandibular setback	6.25	5.70	6.80	0.97	6.00	1.25
		Bimaxillary surgery	6.42	5.85	6.98	1.00	6.00	1.00
	T1	Mandibular setback	6.67	6.39	6.95	0.49	7.00	1.00
		Bimaxillary surgery	6.92	6.54	7.29	0.67	7.00	0.25
	T2	Mandibular setback	6.17	5.49	6.84	1.19	6.50	2.00
		Bimaxillary surgery	6.93	6.25	7.42	1.03	7.00	2.00

95%CI= 95% confidence interval for the mean; SD=standard deviation; IQR=interquartile range

TABLE (2): Inter and intragroup comparisons for PAS area

Time	Pharyngeal airway surface area (Mean ±SD)		Statistic	p-value
	Mandibular setback	Bimaxillary surgery		
Pre-operative (mm ²)	546.72±66.61 ^A	555.05±75.04 ^A	0.287	0.777ns
T1 (mm ²)	542.89±68.65 ^A	555.73±79.34 ^A	0.424	0.676ns
T2 (mm ²)	544.00±68.62 ^A	557.79±78.23 ^A	0.459	0.651ns
Pre-operative-T1 (%)	0.95±1.13	1.53±2.53	0.726	0.479ns
T1-T2 (%)	0.21±0.08	0.41±0.70	1.011	0.333ns
Pre-operative-T2 (%)	0.79±1.13	1.44±2.69	0.777	0.449ns

Means with different superscript letters in the same vertical column are statistically significant different; *significant (p<0.05)

TABLE (3): Inter and intragroup comparisons for ESS

Time	Epworth score (Mean ±SD)		Statistic	p-value
	Mandibular setback	Bimaxillary surgery		
Pre-operative	6.25±0.97 ^A	6.42±1.00 ^A	76.500	0.740ns
T1	6.67±0.49 ^A	6.92±0.67 ^A	82.000	0.362ns
T2	6.17±1.19 ^A	6.83±1.03 ^A	94.000	0.199ns
Pre-operative-T1 (%)	13.07±11.85	12.11±7.97	-0.233	0.818ns
T1-T2 (%)	10.32±12.11	14.10±7.90	0.906	0.376ns
Pre-operative-T2 (%)	8.78±14.95	12.38±14.47	0.600	0.555ns

Means with different superscript letters in the same vertical column are statistically significant different; ns; not significant (p<0.05)

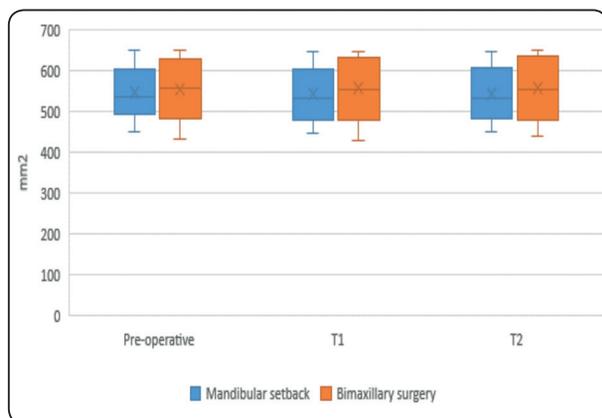


Fig. (5): Box plot showing PAS area (mm2)

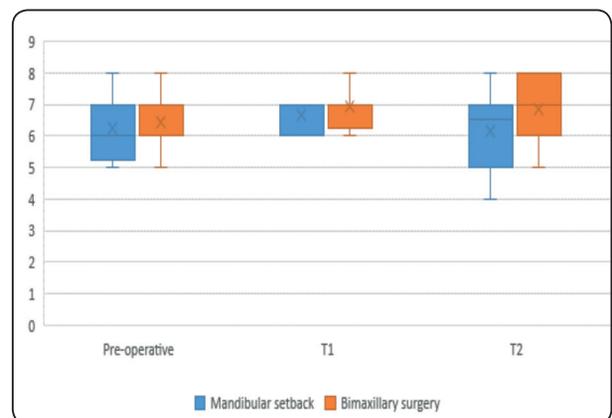


Fig. (6): Box plot showing ESS

DISCUSSION

Patients with class III dento-skeletal deformity are generally treated either by MS (1-jaw surgery) or bimaxillary surgery (2-jaws surgery). The post-surgical resultant change in the bony relations in turn affect the surrounding structures, including PAS, with different values depending on the primary surgical bony alterations. Thus, a detailed analysis of airway changes before orthognathic surgery is crucial due to the possible post-surgical clinical consequences of pharyngeal narrowing and collapse with the resultant airway hazards^(1,15).

Though PAS is a three dimensional volumetric structure which supposed to require an analysis in the three planes using an 3D-imaging technique, namely CBCT or CT, *Kim et al*⁽²²⁾ and *Sutthiprapaporn et al*⁽²³⁾ affirmed the various deceiving pitfalls of the complex analysis in the 3D-CBCT and CT along with their high radiation exposure drawback. Moreover, *Kochel and Meyer*⁽²⁴⁾ correlated strongly between the accuracy of the 2D-LCR and that of the 3D-CBCT in spaces interpretation.

Therefore, despite the debate in the literature, LCR remains the most suitable, with least radiation exposure, easy and inexpensive standard method for skeletal and soft tissue and PAS evaluation^(25,26). Accordingly, in this study, LCR has been implemented in delineating PAS as a 2D area calculated via superimposition of standardized bony and soft tissue landmarks.

In the literature, PAS area definition by borders is inconsistent making it difficult to compare the outcome of different studies^(27,28), hence the standardized protocol utilized by a single radiologist in PAS analysis in this study, employing *Gurani et al*⁽²⁾ proposed landmarks in other measurements, producing the length and width of the PAS which consisted mainly of the retro-glossal and the retro-palatal regions.

In contrast to the hypothesis in the literature which states that a skeletal change of 2 mm or more should supposedly arise a significant soft

tissue dimensional change^(29,30), in *group A* patients, PAS area reported a final insignificant decrease in the area measured on LCR at T2 after 6 months follow-up. This decrease was logically attributed to the posteriorly moved mandibular landmarks with the concomitant backward displacement of the soft tissue attachments and retro-glossal space reduction.

While in *group B* patients, an insignificant increase in PAS area was radiographically recorded post-surgically at T1 and after 6 months' follow-up at T2. This was due to the less decrease in retro-glossal space than that of *group A* due to the less surgical mandibular set back distance compensated by the accompanied maxillary advancement which produced an additional increase in the retro-palatal space, absent in *group A* patients.

In this study, the changes in PAS area values in each group were insignificant in both post-surgical readings; T1 and T2. According to *Lee and Hwang*⁽²⁰⁾, and *Jacobson et al*⁽³¹⁾, this was attributed to the limited expansile ability of the surrounding pharyngeal complex soft tissue layers and thick muscles.

In contrast to *Gurani et al*⁽²⁾ who had stable results for 2 years, in this study, the results of T2 revealed a slight increase in both groups. This change over time was attributed in other studies to the inter-individual adaptive ability of the complex soft tissue, fascia, and the two layer muscles of the pharynx^(1,3,29,32).

Worth mentioning, the needed mandibular setback distance in *group A* (mean of 4.4 mm) was more than that of *group B* (mean of 3.2 mm) due to the nature of the employed surgery in the second group with the compensatory maxillary advancement. This explained the reported controversial changes in PAS between studies in the literature which had segmented the total airway space into several compartments^(33,34).

While the patient's head posture, respiration and epiglottis might relatively affect the PAS analysis

on LCR, post-surgical minor rotation of the jaw along with the easily influenced position of the hyoid bone and its attachments after surgery had a direct relation on PAS records⁽³⁵⁻³⁸⁾. Moreover, **Kim et al**⁽³⁹⁾ declared the gender significance in airway volume appearing as a decrease in females more than males which was not applicable in this study due to the dominant female inclusion in the included sample. Additionally, according to **El and Palamo**⁽⁴⁰⁾, weight gain through pharyngeal fatty tissue proliferation change PAS values over time. Thus, these several reported factors appeared to be non-solvable as study variables due to their non-reproducible feature which may affect directly the measurement accuracy and the instability of the PAS results after surgery.

Therefore, this different methodological study designs and lack of standardization together with the various surgical and radiographic procedures and personal variations implemented in the soft tissue adaptation phenomenon, tended to convey no predictable outcome after orthognathic surgery regarding PAS area.

In another perspective, daytime sleepiness during different activities is primarily affected by night sleep disturbance problems and the concomitant sleep apnea. The main issue associated with sleep apnea is snoring due to the partial airway obstruction and the consequent oxygen deprivation and its effects⁽⁴¹⁾.

Various methods can be used to assess the sleep disturbances including the polysomnography and the *Epworth sleepiness score (ESS)*. In this study, similar to **Rosenthal and Dolan**⁽¹⁶⁾, the simpler self-administrated ESS was preferred and used, while, the polysomnography was prohibited for its expensive, complex, and non- easily available features.

For additional evidence of our results, *ESS* for both groups followed the PAS deviations' pattern and recorded similar non-significant alterations after surgery at T1 and T2 records. This was attributed to the recorded insignificant PAS changes previously

discussed, which had minimal effect on airway obstruction and the consequent sleep apnea and daytime sleepiness.

Therefore, despite of the resulted post-surgical decrease and increase in PAS after one-jaw mandibular setback and two-jaw bimaxillary surgery respectively, orthognathic surgery in management of dento-skeletal class III patients appeared to have no major or significant effect on pharyngeal airway space nor on daytime sleepiness in a six-month duration.

Recommendations

To address the shortcomings of this study and similar studies, we recommend a longer term follow-up studies with special attention to standardize head positioning and PAS segmentation in measurement.

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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