Original Article

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Impact of orthognathic surgical procedure and surgical movement distance on obstructive sleep apnea in skeletal class III malocclusion

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Objectives: To investigate the incidence of obstructive sleep apnea (OSA) in relation to the type of surgical procedure and the amount of mandibular setback.

Materials and Methods: The cohort study involved 20 participants (mean age: 25.1 ± 5.74) with skeletal Class III malocclusion. All participants had no prior history of sleep disorders and an apnea-hypopnea index (AHI) of fewer than 5 events/hour pre-surgery. They underwent either mandibular setback alone or two-jaw surgery (maxillary advancement and mandibular setback). OSA-related parameters were assessed at two time points: pre-surgery (T1) and six months post-surgery (T2), using a home sleep test device. The magnitude of surgical jaw movements was determined through data obtained from virtual surgical planning. The association between the type of surgical procedure, the categorized extent of mandibular setback, and the development of OSA was analyzed using Fisher's exact test.

Results: Twenty- five percent of participants developed an AHI of ≥ 5 events/hour at 6 months post-surgery, regardless of the type of surgical procedure. Notably, 11.11% of patients with a mandibular setback of < 7 mm demonstrated an AHI of ≥ 5 events/hour post-surgery, whereas 36.36% of those with a setback of ≥ 7 mm exhibited similar AHI levels post-surgery. Participants who maintained an AHI of < 5 events/hour post-surgery, had greater maxillary advancement and less mandibular setback compared to those with higher AHI levels.

Conclusions: No statistically significant differences in the incidence of OSA were observed between one-jaw and two-jaw surgeries or between surgical distances using a 7 mm cutoff. However, greater maxillary advancement, combined with limiting mandibular setback to less than 7 mm, may be associated with a lower risk of developing OSA.

Keywords: angle class III, obstructive sleep apnea, orthognathic surgery

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Introduction

Obstructive sleep apnea (OSA) is a sleep-related breathing disorder characterized by repeated episodes of upper airway collapse, resulting in intermittent hypoxia and sleep fragmentation. It is a multifactorial condition influenced by anatomical, neuromuscular, and lifestyle-related factors. OSA is associated with significant adverse health outcomes, affecting both physical and mental well-being, as well as overall quality of life [1, 2]. This condition is estimated to affect approximately 3-7% of adult men and 2-5% of adult women [3]. Given its high prevalence and association with severe health complications, OSA is recognized as a common and potentially life-threatening disorder [1, 2].

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Craniofacial disharmony is recognized as a risk factor for OSA [4], altering jaw position through orthognathic surgery holds the potential to impact the condition [5]. Among Asian patients with skeletal Class III malocclusion, the two predominant surgical-orthodontic procedures are isolated mandibular setback (one-jaw surgery) and combined maxillary advancement and mandibular setback surgery (two-jaw surgery). The effects of these two distinct orthognathic surgeries on OSA in skeletal Class III malocclusion remain a topic of ongoing deliberation. Pereira-Filho *et al.* [6] observed no significant differences in airway space following one-jaw surgery. A systematic review and meta-analysis [7] further revealed that neither surgical approach significantly altered all OSA-related parameters, and no substantial differences in post-surgical respiratory outcomes were found between the two techniques in healthy adult patients. Despite this, several studies [8-10] have advocated for two-jaw surgery over one-jaw surgery to minimize the extent of mandibular setback, thereby reducing the potential decrease in pharyngeal airway space (PAS), particularly in patients with OSA risk factors such as obesity and advanced age.

The recommendation of bimaxillary surgery to mitigate mandibular setback amount raises the possibility of surgical distance as another factor influencing sleep quality. Numerous studies have explored the impact of surgical distance, proposing various limits for mandibular setback that might affect OSA. Demetriades *et al.* [11] observed a significant number of subjects whose PAS decreased to the level possibly associated with OSA after mandibular repositioning distance equal to or exceeding 5 mm. Abbasi *et al.* [12] reported a notably lower post-operative apnea-hypopnea index (AHI) score in patients with less than 5 mm mandibular setback distance and also showed that bimaxillary surgery involving mandibular setback not exceeding 7 mm did not escalate OSA incidence in young, healthy, non-obese Class III patients. Engboonmeskul *et al*. [13] identified a significant increase in AHI after mandibular setback exceeding 6 mm. Furthermore, Kamano *et al*. [14] suggested that setback distances less than 9.05 ± 0.17 mm may be associated with a reduced risk of OSA. However, there is no established consensus regarding the maximum extent of mandibular setback that would induce post-operative OSA.

Our study aims to evaluate OSA incidence and its association with different types of orthognathic surgery in the correction of skeletal Class III malocclusion. The specific objectives of this study encompass: 1) To compare the occurrence of OSA following one-jaw versus two-jaw surgeries, 2) To investigate the average amount of mandibular setback in participants with a fewer than 5 events/hour post-surgery and 3) To compare OSA incidence in patients undergoing mandibular setbacks below and above the average setback value.

Materials and Methods

The study included twenty participants (eleven males and nine females) with a mean age of 25.10 ± 5.74 years. Among them, 8 patients underwent one-jaw surgery, while 12 patients underwent two-jaw surgery. The study was designed as a prospective cohort and conducted at the Dental Hospital of Mahidol University's Faculty of Dentistry. Ethical approval for the research was obtained (MU-DT/PY-IRB 2021/004.0801), and written informed consent was received from all participants before their participation. The study enrolled healthy adult patients with skeletal Class III malocclusion who were planned for orthognathic surgery,

defined by a Wits appraisal of less than -5 mm [15]. The exclusion criteria encompassed individuals with pre-surgical treatment whose home sleep test results indicated an AHI of ≥ 5 events/hour, as well as those with congenital deformities, cardiopulmonary disease, hypothyroidism, polycystic ovary syndrome, a history of previous orthognathic or throat surgery, pregnancy, and a body mass index (BMI) greater than 35 kg/m².

OSA-related parameters were collected in two stages: pre-orthognathic surgical assessment (T1) and six months after surgery (T2). The parameters assessed included the AHI, 3% oxygen desaturation index (3% ODI), average blood oxygen levels (average SpO_2), minimum blood oxygen levels (min SpO_2), and snore percentage. Data were collected using Nox medical sleep monitoring device (Nox-T3, Nox Medical Inc. Reykjavik, Iceland). In addition, demographic variables, along with BMI, neck circumference, and waist circumference, were recorded.

The measurements of the distance of surgical jaw movement were obtained from the virtual surgical plans created in Dolphin Imaging 11.95 Premium® (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA). These measurements were taken in the antero-posterior (A-P) direction, with the Frankfurt horizontal plane serving as the reference line. The distances measured included maxillary movement (A), upper incisor movement (UI), mandibular movement (B), and lower incisor movement (LI). Participants were categorized into two groups based on the mean mandibular movement of participants with AHI < 5 events/hour post-surgery, and the incidence of OSA was subsequently compared between these two groups.

Statistical analysis was performed using the software PASW Statistics for Windows, Version 18.0 (SPSS Inc., Chicago, USA). To investigate the differences in OSA-related parameters before and after surgery (T1-T2), the data distribution was first tested using the Shapiro-Wilk test. A paired sample t-test was used for normally distributed data, including ODI in the one-jaw group, average SpO_2 in the two-jaw group, and AHI for both groups. The Wilcoxon signed-rank test was applied to all other variables that did not follow a normal distribution. The effect of different orthognathic procedures and mandibular setback distances on the presence of OSA was assessed using the Fisher exact test due to the small sample size. An independent T-test was conducted to compare the variations in jaw movement based on data distribution. The significance level for all analyses was set at a *p*-value of 0.05.

Results

No statistically significant differences were observed between participants in the one-jaw and two-jaw groups in terms of BMI, neck circumference, or waist circumference before surgery. In two-jaw surgery, the maxilla was advanced by 3.20 ± 1.39 mm, while the mandible was setback by 7.97 ± 4.46 mm. The one-jaw surgery group showed an average mandibular setback of 6.52 ± 3.01 mm.

All OSA-related parameters demonstrated non-significant changes following surgery for both one-jaw and two-jaw procedures. In the one-jaw surgery group (Table 1), a decrease in min SpO_2 levels was observed. Conversely, an increase was noted in AHI, ODI, average SpO_2, and snore percentage. In the two-jaw surgery group (Table 1), reductions were observed in ODI. The snore percentage remained unchanged. Meanwhile, non-significant increases were reported for AHI, average SpO_2, and min SpO_2.

Table 1 The difference in OSA-related parameters before and after surgery

Parameter	One-jaw surgery				Two-jaw surgery			
	Pre-surgery (T1)	Post-surgery (T2)	Different (T2-T1)	*p*-value	Pre-surgery (T1)	Post-surgery (T2)	Different (T2-T1)	*p*-value
AHI (events/hour)	1.98 (1.65)	3.31 (2.01)	1.33 (2.17)	0.125	2.41 (1.59)	2.65 (2.18)	0.24 (2.78)	0.769
ODI (events/hour)	2.21 (2.23)	2.56 (1.87)	0.35 (2.04)	0.643	2.25 (0.30,4.00)	2.00 (0.50,16.20)	-0.25	0.327
Average SpO_2 (%)	96.60 (95.00,98.00)	96.70 (94.50,97.20)	0.10	0.889	96.47 (0.76)	96.73 (0.66)	0.26 (0.81)	0.293
Min SpO_2 (%)	90.00 (81.00,94.00)	87.00 (82.00,94.00)	-3.00	0.799	83.00 (79.00,95.00)	84.00 (52.00,92.00)	1.00	0.327
Snore percentage (%)	0.00 (0.00,0.10)	0.55 (0.00,3.88)	0.55	0.352	0.20 (0.00,4.30)	0.20 (0.00,6.10)	0.00	0.919

Data analyzed using paired sample t-test (Mean ± SD) for normal distribution; Wilcoxon signed-rank test (Median [Min, Max]) for non-normal distribution.

AHI: apnea-hypopnea index

ODI: 3% oxygen desaturation index

Average SpO_2: average blood oxygen levels

Min SpO_2: minimum blood oxygen levels

The number of participants for each of surgery type concerning AHI changes is presented in Table 2. Twenty-five percent of patients developed AHI ≥ 5 events/hour in both surgical types after six months post-surgery.

A comparison of mean surgical movements revealed that participants with an AHI of fewer than 5 events/hour post-surgery exhibited greater maxillary and upper incisor advancements and smaller mandibular and lower incisor setbacks compared to those with an AHI of 5 or more events/hour. However, these differences were not statistically significant (Table 3).

Table 2 Distribution of subjects by surgical type and changes in AHI post-surgery

Changes of AHI post-surgery	Type of orthognathic surgery, n (%)		*p*-value
	One-jaw surgery	Two-jaw surgery	
AHI < 5 events/hour (n=15)	6 (75.00)	9 (75.00)	> 0.05
AHI ≥ 5 events/hour (n = 5)	2 (25.00)	3 (25.00)	

Data analyzed using Fisher exact test.

AHI: apnea-hypopnea index

Table 3 Comparison of surgical jaw movement distance and post-surgery AHI

Cephalometric landmarks	Jaw movement (mm), Mean (SD)				*p*-value
	n	AHI < 5 events/hour	n	AHI ≥ 5 events/hour	
A	9	3.41 (1.47)	3	2.57 (1.10)	0.386
UI	9	2.74 (1.31)	3	2.32 (0.55)	0.603
B	15	6.96 (3.45)	5	8.69 (5.35)	0.407
LI	15	7.02 (2.86)	5	8.71 (4.28)	0.324

Data analyzed using independent T-test.

AHI: apnea-hypopnea index

A: antero-posterior distance of maxillary movement between pre-surgery and six months post-surgery

B: represents antero-posterior distance of mandibular movement between pre-surgery and six months post-surgery

UI: represents antero-posterior distance of upper incisor movement between pre-surgery and six months post-surgery

LI: represents antero-posterior distance of lower incisor movement between pre-surgery and six months post-surgery

The mean mandibular setback for participants whose AHI remained below 5 events/hour post-surgery (B = 6.96 mm) was used as a reference to categorize participants into two groups. Therefore, the relationship between the extent of surgical jaw movement, using a 7 mm cutoff, and subsequent changes in AHI at a 5-events/hour threshold post-surgery is detailed in Table 4. Among participants who underwent mandibular setback of less than 7 mm, 11.11% developed an AHI of ≥ 5 events/hour post-surgery, compared to 36.36% in those with setbacks ≥ 7 mm. However, the difference between these two groups was not statistically significant.

Discussion

Our findings indicated increased AHI following both one-jaw and two-jaw orthognathic surgeries; however, these changes did not reach statistical significance. The observed non-significant increase in the AHI following both types of skeletal Class III orthognathic surgery is consistent with previous research [8, 10, 12, 13, 16, 17]. Schilbred *et al.* [17] revealed an insignificant change in neither AHI, ODI, SpO_2, nor snore index after single-jaw surgery with a mean mandibular setback of 4.3 mm. Similarly, Abbasi *et al.* [12] used home sleep tests to assess AHI and SpO_2 after two-jaw surgery, revealing non-significant increases in

Table 4 Distribution of subjects by mandibular movement distance and changes in AHI post-surgery

Changes of AHI post- surgery	Mandibular movement distance, n (%)		*p*-value
	< 7 mm	≥ 7 mm	
AHI < 5 events/hour (n=15)	8 (88.89)	7 (63.64)	0.319
AHI ≥ 5 events/hour (n = 5)	1 (11.11)	4 (36.36)	

Data analyzed using Fisher exact test.

AHI: apnea-hypopnea index

both parameters at 6 months post-surgery. In their investigation, the mean amount of maxillary advancement was 2.9 ± 1.2 mm, and the mean amount of mandibular setback was 4.5 ± 1.1 mm. The study also demonstrated a statistically significant and direct correlation between AHI and the amount of posterior mandibular displacement. The impact of surgery on AHI appeared to vary depending on the pattern of jaw movement. Yang *et al.* [18] reported a significant increase in AHI following two-jaw surgery characterized by a maxillary advancement of 0.65 mm and a substantial mandibular setback of 11.08 mm. Conversely, Gokce *et al.* [9] discovered a significant reduction in AHI after two-jaw surgery involving a notable maxillary advancement of 5.0 ± 2.2 mm and a moderate mandibular setback of 6.5 ± 2.7 mm. These findings could emphasize the relationship between distance of surgical jaw movement and OSA-related parameters changes in patients with skeletal Class III correction.

The occurrence of OSA after surgery may vary depending on the surgical type and extent of surgical movement. In our study, the comparable 25% incidence of OSA (defined as a post-operative AHI ≥ 5 events/hour) observed in both one-jaw and two-jaw surgeries may be specifically attributed to the relatively limited degree of maxillary advancement and significant mandibular setback. Specifically, the average mandibular setback in one-jaw surgery was 6.52 ± 3.01 mm, whereas in two-jaw surgery, the mandible underwent an even greater setback of 7.97 ± 4.46 mm, accompanied by a maxillary advancement of 3.20 ± 1.39 mm. This greater extent of mandibular setback may have contributed to the similar OSA incidence in both surgical groups, as presented in Table 2.

Although the total combined correction of the maxilla and mandible in both Gokce *et al.* [9] and our research was approximately 10-11 mm, there was a noticeably different amount in each jaw movement between the two trials. In the study conducted by Gokce *et al.*, a substantial maxillary advancement of 5.0 ± 2.2 mm was implemented. This pronounced maxillary advancement played a role in reducing the magnitude of mandibular setback to 6.5 ± 2.7 mm, potentially contributing to a reduction in the AHI. Comparing to our study the mandibular setback distance was larger (7.97 ± 4.46 mm), while the maxilla was less advanced (3.20 ± 1.39 mm) which might have resulted in the increase in AHI.

When comparing jaw movement differences between participants who remained AHI < 5 events/hour and those who developed OSA after surgery, an average mandibular setback was 6.96 ± 3.45 mm in normal participants and 8.69 ± 5.35 mm in patients developed OSA. Even though statistics show no significant difference, our research found only one case (11.11%) where OSA developed following < 7 mm mandibular setback, compared to 36.36% after a mandibular setback of ≥ 7 mm (Table 4). This outcome was correlated with the observation of Abbasi *et al.* [12] that OSA incidence was not increased by bimaxillary orthognathic surgery when the mandibular setback was less than 7 mm.

Considering treatment stability, there is a positive correlation between mandibular setback distance and relapse [19]. The study reported differing relapse rates based on the extent of mandibular repositioning, with a 23% relapse rate observed following a 6–10 mm setback, compared to a 39% relapse rate after a 10–14 mm setback. To reduce sleep-related risks and improve stability, restricting the mandibular setback distance to less than 7 mm may be recommended. This can be achieved by contemplating two-jaw surgery with an increased degree of maxillary advancement,

which is known for superior stability [20], However, the extent of jaw surgery should be carefully evaluated against the aesthetic outcome and discussed individually.

The development of OSA after one-jaw surgery, the correlation between amount of jaw movement and AHI, and the amount of mandibular setback that may affect OSA occurrence remain subjects of ongoing debate [8, 13, 18]. While there is no conclusive evidence demonstrating a direct causative link between mandibular setback surgery and OSA, several studies suggest that it may act as a predisposing factor that affects patients in the long term, especially those with particular risks such as obesity, advanced age [8, 10].

Several aspects were considered when conducting our research. Due to the implementation of a strict exclusion criterion, which excluded participants whose sleep tests revealed an AHI ≥ 5 events/hour, the number of participants in our study was limited. Although the sample size is comparable to that of several previous studies [10, 13, 16-18, 21], the relatively small sample size may raise concerns regarding the statistical power of our findings. Nox-T3, type III portable sleep monitoring device, was used instead of gold-standard polysomnography (PSG). The AHI derived from Nox-T3, using an autoscore system, strongly correlates with PSG values [22]. This device has received approval for the diagnosis of OSA in adult patients presenting with uncomplicated cases, specifically those without an elevated risk of non-obstructive sleep-disordered breathing [1]. Nonetheless, disparities exist between Nox-T3 and PSG. PSG calculates AHI based on actual sleep hours, while Nox-T3 uses predetermined recording time [23, 24], potentially underestimating AHI if patients awaken earlier than the time specified. Our study was designed to collect jaw movement distances from virtual surgical plans rather than radiographic superimposition, as consistent radiographic imaging modalities were not available before and after surgery. While most patients underwent Cone Beam Computed Tomography (CBCT) during the pre-surgical phase, post-treatment evaluations were typically conducted using 2D radiographs. Due to the limited concordance observed between these two distinct imaging modalities [25, 26], direct comparisons of treatment outcomes using differing image superimposition methods are not recommended [25]. Notably, previous studies have demonstrated no statistically significant differences between virtual surgical plans and post-operative results [27, 28], supporting the reliability of virtual planning as an alternative approach.

A larger cohort study with precise sample size calculation is necessary to ensure sufficient statistical power in future research. A longer follow-up period should also be included, as soft tissue thickness continues to adapt and change for up to one year following mandibular setback [29]. Nowadays, there is a new concept called “precision-based approaches”, which take an interest in the OSA genotypes, endotypes, and phenotypes, as well as their relationships to treatment outcomes in individual patients. This approach focuses on non-anatomical traits that are also important contributors to OSA [30, 31] and could be the cause of variable treatment results. Their association with orthognathic surgery should also be further investigated to provide information about which patients are more likely to acquire OSA or benefit from this treatment intervention.

Conclusion

This study found no statistically significant differences in the incidence of OSA between one-jaw and two-jaw surgeries or between surgical distances using a 7 mm cutoff. However, OSA was observed in 25% of patients following both one-jaw and two-jaw procedures, highlighting the importance of evaluating the risk of sleep-related breathing disorders in skeletal Class III patients undergoing orthognathic surgery. To reduce the potential risks of OSA associated with orthognathic surgery, it is advisable to increase maxillary advancement and minimize the mandibular setback distance to less than 7 mm in the surgical plan, with careful consideration and individualized discussion.

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