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Effects of mandibular setback surgery using the surgery-first approach versus conventional orthognathic approach on upper airway change and sleep quality

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Abstract

Objectives To compare the effects of mandibular setback surgery on the upper airway and sleep quality using two approaches: the surgery-first approach (SFA) and the conventional orthognathic approach (COA).

Materials and methods A prospective, comparative clinical study was conducted in 20 patients, with 10 in each group undergoing isolated mandibular setback surgery. Three-dimensional upper airway analysis using cone-beam computed tomography and sleep quality assessments through questionnaires and sleep studies were performed preoperatively (T0), within 1 month postoperatively (T1), and six months postoperatively (T2).

Results The SFA group demonstrated greater mandibular setback and rotational changes compared to the COA group. Both groups exhibited postoperative reductions in airway volume and minimum cross-sectional area, with no significant intergroup differences. Significant differences in the change in airway length in the upper airway segment (0.9 ± 1.0 mm for SFA vs. -1.2 ± 3.4 mm for COA, $P = 0.002$) and total airway length (3.3 ± 1.8 mm for SFA vs. -0.1 ± 2.3 mm for COA, $P < 0.001$) were observed at T2 compared to the preoperative period. Subjective and objective sleep parameters were comparable between the groups. Objective sleep quality initially worsened but improved over time.

Conclusions Isolated mandibular setback surgery, whether performed using SFA or COA, resulted in comparable changes in upper airway dimensions and sleep quality.

Clinical relevance The choice between SFA and COA for isolated mandibular setback surgery does not significantly influence surgical decision-making regarding upper airway changes and sleep quality.

Keywords Orthognathic surgery, Airway, Sleep quality, Obstructive sleep apnea, Cone-beam computed tomography, Questionnaire

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Introduction

Orthognathic surgery is frequently utilized to correct various dentofacial deformities, including skeletal class III malocclusion, which may be characterized by mandibular protrusion, maxillary retrognathia, or a combination of both. Among the techniques used to correct a prognathic mandible, mandibular setback surgery is widely favored. However, changes in the patient's upper airway resulting from the posterior positioning of the mandible after mandibular setback have been reported. This change often results in a reduction of the upper airway space, which could lead to the occurrence of sleep-disordered breathing, specifically obstructive sleep apnea (OSA) [1–5].

For decades, orthognathic surgery has predominantly employed a conventional orthognathic approach (COA), involving pre-surgical orthodontics, surgical intervention, and post-surgical orthodontic treatment. The primary objectives of preoperative orthodontics include dental decompensation, arch alignment, and arch coordination, ensuring the proper positioning of teeth relative to the underlying skeletal structures. This phase unveils the true skeletal discrepancy and facilitates the establishment of a stable occlusion post-surgery. Subsequently, the maxilla and mandible can be repositioned correctly to achieve a stable occlusion [6]. Mandibular setback surgery performed with the COA typically yields predictable outcomes and significant postsurgical skeletal stability [7]. Nonetheless, the orthodontic preparatory phase is time-intensive, potentially leading to a temporary deterioration in occlusion and facial profile, and may reduce the patient's quality of life [8, 9].

In recent years, the surgery-first approach (SFA), which involves minimal or no preoperative orthodontic treatment, has emerged as an alternative to the COA. The SFA offers advantages such as shorter total treatment duration, immediate enhancement of facial appearance, and improved quality of life [10–14]. The postoperative skeletal stability of the SFA remains a topic of debate. On one hand, systematic reviews and meta-analyses suggest that the SFA provides post-surgical stability comparable to the COA [11, 15]. On the other hand, some studies indicate that the SFA may result in inferior stability, particularly in the mandible, where postoperative counterclockwise rotation has been observed [10, 16–18]. Agarwal et al. [19] conducted a retrospective study comparing airway changes using acoustic pharyngometry between the SFA and COA. They found that patients undergoing mandibular setback surgery in the SFA group experienced greater immediate postoperative airway reduction and greater relapse during the follow-up period. The forward and upward movement of the mandible can impact the upper airway, potentially influencing sleep quality.

To the best of our knowledge, no study has compared three-dimensional (3D) airway changes, including sleep quality, between the SFA and COA. The purpose of this study is to evaluate the effects of orthognathic surgery on the upper airway and sleep quality using different approaches.

Materials and methods

A prospective, comparative clinical study was conducted on patients undergoing isolated mandibular setback surgery with bilateral sagittal split ramus osteotomy (BSSRO) between October 2022 and October 2023 at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University. This study was registered with the Thai Clinical Trials Registry (www.thaiclinicaltrials.org– TCTR20230601002; retrospectively recorded on May 31, 2023). The study was designed and conducted in accordance with the guidelines of the Helsinki Declaration on human experimentation and good clinical practice, after obtaining ethical approval from the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2022-072). All participants provided written informed consent. The study divided participants into two groups:

- COA group: Patients who underwent isolated mandibular setback surgery using the conventional orthognathic approach (COA).
- SFA group: Patients who underwent isolated mandibular setback surgery using the surgery-first approach (SFA).

The sample size calculation was based on the preoperative mean airway volumes of the COA and SFA groups from a previous study [19], utilizing the G*Power 3.1.9.7 program. The mean airway volume for the COA group was 36.08 ± 3.6 cc, while for the SFA group it was 30.57 ± 4.89 cc. These values were incorporated into the calculation. A total of 20 subjects (10 per group) was determined to be necessary to achieve 85% power for detecting a significant difference in mean airway volume, with a type I error rate of 0.05, using an independent *t*-test.

The inclusion criteria consisted of patients with ASA physical status I or II who were diagnosed with mandibular prognathism or skeletal class III malocclusion and required isolated mandibular setback surgery with BSSRO. Exclusion criteria included patients with uncontrolled systemic diseases, those on medications that could affect sleep, individuals with craniofacial syndromes, and those with a history of previous orthognathic or naso-oropharyngeal surgery.

Demographic data, including age, sex, body mass index (BMI), and neck circumference, were collected. Skeletal and upper airway change were evaluated using cone-beam computed tomography (CBCT). Skeletal change due to surgery was determined by the amount of mandibular setback at B point and the change of sella–nasion-mandibular plane (SN-MP) angle, defined as the angle between the SN line and the menton (Me)-gonion (Go) line, which was assessed to evaluate mandibular rotation. Sleep quality data were collected using the Thai version of the screening OSA questionnaires and a sleep study. Data were evaluated at three time points: within one month before surgery (T0), within one month after surgery (T1), and six months after surgery (T2).

A CBCT scan was acquired utilizing the 3D Accuitomo 170 scanner (Morita, Kyoto, Japan). All images were captured with the subjects in an upright and natural head position. The subjects were instructed to align their teeth in occlusion, maintain light breathing, refrain from swallowing, and avoid any movement during the scanning process. The setting protocol included a voxel size of 0.25 mm, 16 bits per pixel, X-ray tube voltage at 90 kV, tube current ranging from 5 to 9 mA, a scanning duration of 30 s, and a field of view measuring 17 × 23 cm. All CBCT images were exported as DICOM extension files (Digital Imaging and Communications in Medicine) and processed and segmented using 3D Slicer 5.2.1 open-source software (available at: http://www.slicer.org). The measurements were taken relative to the natural head position in the mid-sagittal plane containing the incisive canal by one evaluator (W.K.). The anatomic boundaries of the pharyngeal airway were determined based on a previous study [20, 21]. The superior boundary of the airway was delineated at the level of the hard palate, corresponding to the plane parallel to the FHP passing through the level of the PNS. The inferior boundary of the airway was determined at the level of the superior margin of the hyoid, defined as the plane parallel to the FHP passing through the superior margin of the hyoid plane. The anterior boundary of the airway was established at the frontal plane perpendicular to the FHP, intersecting the PNS. The posterior boundary of the airway was identified at the soft tissue contour of the posterior pharyngeal wall. Additionally, the pharyngeal airway was partitioned into upper and lower segments, with the division marked by the tip of the uvula, to assess and illustrate differential responses of each segment to the surgical intervention.

The region of interest (ROI) was identified based on anatomical delineations. Employing segmentation techniques, the airway was isolated from the adjacent soft tissue and bony framework. A threshold range of -1,000 through 150 was applied specifically to the airway. Subsequently, extraneous air space and noise were eliminated to formulate 3D airway models. Ultimately, measurements and calculations were performed to analyze the morphological aspects of the airway. Airway length was measured using the Markups module, airway volume was computed using the Segment Statistics module, and the minimum cross-sectional area was calculated from axial slices using the Segment Cross-Section Area module, an extension of the 3D Slicer program.

Airway parameters, including total pharyngeal airway length (TAL; in millimeters, mm), minimum cross-sectional area of the total pharyngeal airway (minCSA; in square millimeters, mm^2), and total pharyngeal airway volume (TAV; in cubic centimeters, cm^3), were measured and calculated. Subsequently, airway parameters for both the upper (U) and lower (L) segments were analyzed.

The validated Thai versions of the OSA screening questionnaires, namely the Epworth Sleepiness Scale (ESS) [22] and STOP-Bang Questionnaire (SBQ) [23], were utilized to assess subjective sleep quality. A score equal to or exceeding 10 on the ESS signified the presence of excessive daytime sleepiness in the subjects. Additionally, in the SBQ, a score of 1 or 2 indicated a low risk of OSA, whereas scores of 3 or 4 suggested an intermediate risk, and a score of 5 or higher signified a high risk [24, 25].

A home sleep apnea testing (HSAT) device (WatchPAT™ 300; Itamar Medical Inc., Caesarea, Israel) was employed to assess objective sleep parameters. The recording channels comprised peripheral arterial tone (PAT), pulse rate, oximetry, actigraphy, snoring, and body positioning. The objective sleep parameters were automatically analyzed using the zzzPAT program. The results of the study were validated and confirmed by a certified sleep medicine physician who was blinded to the study's details or group assignment.

Sleep parameters included the total sleep time, total apnea-hypopnea index (AHI), which encompasses both central and obstructive events, the obstructive AHI (ObsAHI), derived from the AHI with central events excluded, oxygen desaturation index (ODI), oxygen saturation levels, pulse rate, body position, snoring level, percentage of sleep, and sleep stages.

Statistical analysis

Descriptive statistics (mean ± standard deviation for continuous variables; and frequency for categorical variables) were computed to provide an overview of the study sample. The normal distribution of each variable was evaluated by the Shapiro-Wilk test. Categorical variables were analyzed using the Chi-squared test, but the Fisher's Exact test was applied whenever the Chi-squared test assumptions were violated. To compare the baseline demographic, skeletal changes and preoperative parameters between groups, the independent *t*-test or Mann-Whitney *U*-test was used, as appropriate. To compare the changes in airway parameters, ESS, SBQ and sleep study results between groups, Analysis of Covariance (ANCOVA) was used with statistical adjustments for the amount of mandibular setback at B point and the change of SN-MP at T1.A *P*-values of < 0.05 was considered significant in two-tailed statistical tests. All statistical analyzes were performed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA).

To assess the reliability of airway measurements, CBCT images from a randomly selected sample of 10 patients were reanalyzed after a one-month interval. The intraclass correlation coefficients (ICC) were calculated to evaluate the intra-observer reliability of the measurements. The results, ranging from 0.93 to 1.0, indicate that the measurements have acceptable reliability for quality control purposes.

Results

Twenty participants were included in this study, with 10 participants in each group. The overall demographic data and skeletal changes are presented in Table 1. The SFA group had a significantly larger amount of mandibular setback and change of SN-MP compared to the COA group. At T1, the mandible in the SFA group exhibited greater clockwise rotation; however, it tended to rotate more counterclockwise at T2 (T2-T1) compared to the COA group.

Preoperatively, no differences were observed in demographic data, airway parameters, or sleep parameters between the groups. Postoperatively, both groups exhibited reduced airway volume and minCSA in the total, upper, and lower segments of the pharyngeal airway (Fig. 1; Table 2). However, these changes did not differ significantly between the groups at any time point. Significant differences in the changes to TAL and UAL between the groups were observed. At T2, the change in UAL in the SFA group was significantly greater than that in the COA group (0.9 ± 1 mm vs. -1.2 ± 3.4 mm, *P* = 0.002). From T1 to T2, the change in UAL in the SFA group was significantly smaller compared to the COA group (-0.1 ± 2.2 mm vs. -2.8 ± 3.2 mm, *P* = 0.016). Additionally, the change in TAL in the SFA group at T2, compared with preoperative values, was significantly greater than that in the COA group (3.3 ± 1.8 mm vs. -0.1 ± 2.3 mm, *P* < 0.001).

No significant differences in changes in subjective and objective sleep quality were observed between the groups. Objective sleep quality analysis revealed increases in total AHI, ObsAHI, ODI, and snoring levels within one month after surgery; however, these changes decreased over the study period (Table 3). Three participants in each group who had a preoperative ObsAHI of < 5 events/h showed an increase to > 5 events/h within one month postoperatively. Among these participants, an ESS score of ≥ 10 was observed in one COA participant and two SFA participants. However, their ObsAHI values decreased to < 5 events/h by six months after surgery, and none exhibited signs of excessive daytime sleepiness; therefore, a diagnosis of OSA was not established.

Discussion

Nowadays, the SFA has been increasingly adopted as an alternative to the COA. However, most studies have focused on evaluating the upper airway and sleep quality in patients undergoing COA. Lateral cephalometry has primarily been used to access changes in the sagittal dimension of the upper airway following COA [1, 3, 26–30]. Pharyngeal airway space (PAS) decreased, and the mandibular plane-to-hyoid bone distance increased after mandibular setback surgery, with or without maxillary surgery. PAS reduced immediately post-surgery, recovered partially within a month, and gradually improved but did not fully recover by 12 months after the surgery [29]. Immediate postoperative attention was necessary for potential airway reduction and respiratory function issues during sleep [28, 29]. On the other hand, Chen et al. [30] reported significant PAS reductions in the oropharynx and hypopharynx over both short (3–6 months) and long terms (up to 2 years) after isolated mandibular

Table 1 Baseline demographic and skeletal changes of patients in each group

Variables	COA (Mean ± SD)	SFA (Mean ± SD)	*P*-value[¶]
Age (years)	25.8 ± 4.4	23.9 ± 3.1	0.28
Sex	M = 3, F = 7	M = 4, F = 6	1.00[£]
BMI (kg/m^2)	21.6 ± 3.2	23.1 ± 4.3	0.36
Neck circumference (cm)	34.7 ± 2.8	35 ± 2.4	0.52
Amount of mandibular setback at B point (T1-T0, mm)	6.3 ± 1.6	9.4 ± 2.4	0.003*
Amount of mandibular setback at B point (T2-T0, mm)	5.9 ± 1.4	8.2 ± 2.3	0.015*
Change of mandibular setback at B point (T2-T1, mm)	-0.4 ± 0.7	-1.2 ± 0.6	0.017*
Change of SN-MP at T1 (T1-T0, degree)	-0.4 ± 2.2	1.9 ± 1.7	0.018*
Change of SN-MP at T2 (T2-T0, degree)	-0.3 ± 2.6	0.3 ± 1.8	0.60
Change of SN-MP at T2 (T2-T1, degree)	0.1 ± 1.5	-1.6 ± 1.2	0.008*

¶ Independent *t*-test or Mann-Whitney *U*-test was used as appropriate

£ Fisher's Exact test

*Significant difference between the groups

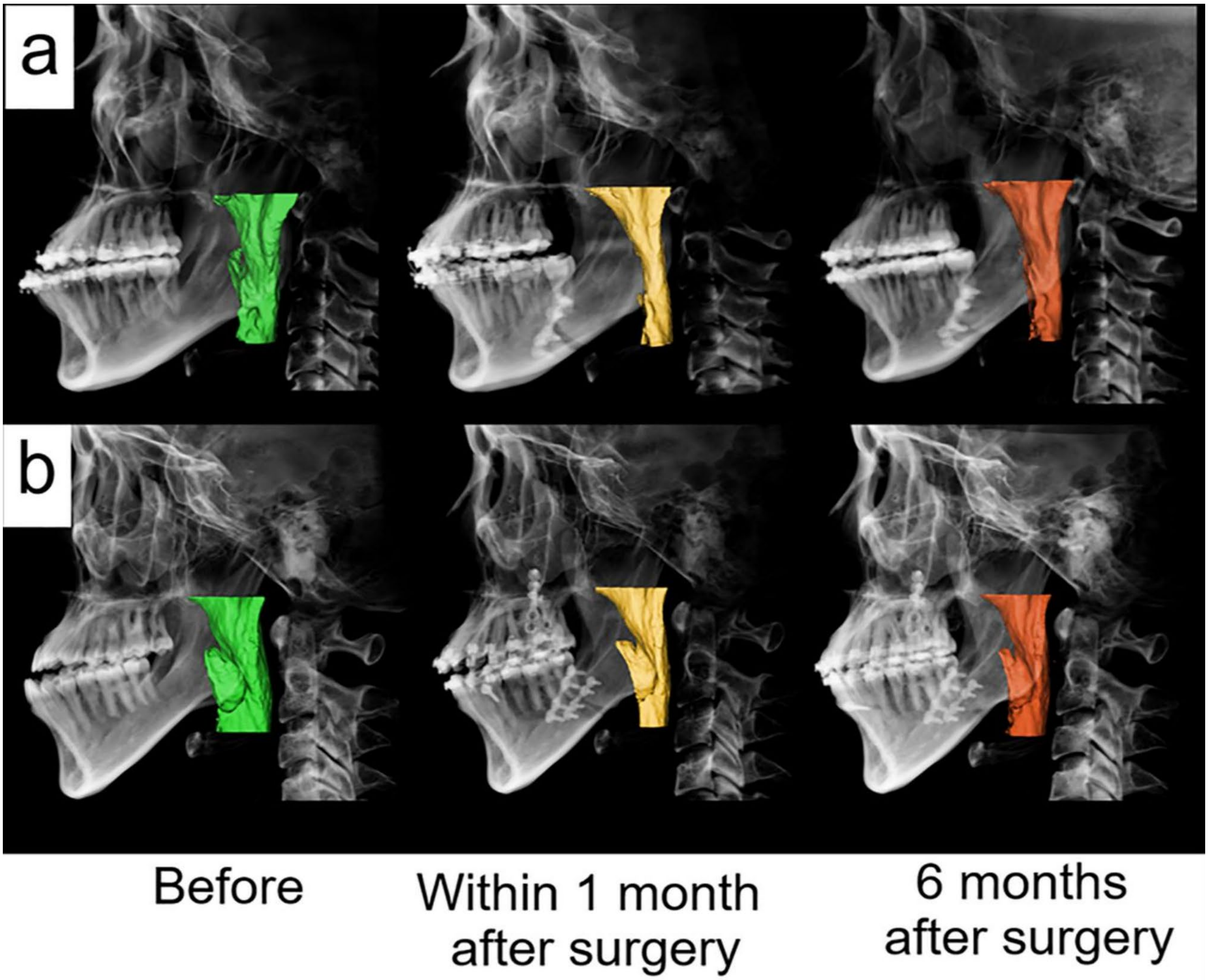

Fig. 1 Upper airway changes in a patient who underwent isolated mandibular setback surgery using COA **(a)** versus SFA **(b)**. Note: Titanium bone plates were applied to the maxilla in the patient who underwent mandibular setback surgery using SFA as temporary anchorage devices for orthodontic treatment

setback surgery. In contrast, PAS changes were significant only in the short term for patients undergoing mandibular setback combined with maxillary advancement. For 3D analysis using CBCT, studies reported increased airway length but significantly decreased cross-sectional area and pharyngeal airway volume, particularly after isolated mandibular setback osteotomy [31–37]. Park et al. [36] found that reduced airways did not recover over time. The present study demonstrated that patients who underwent isolated mandibular surgery using COA exhibited an increase in airway length and a decrease in minCSA and airway volume immediately after surgery, followed by partial recovery of minCSA and airway volume at 6 months postoperatively. However, the airway length of the lower airway segment continued to increase.

Limited research has investigated changes in the upper airway following mandibular setback, with or without maxillary surgery, using SFA. Kanwal et al. [38] retrospectively evaluated the PAS at the upper pharynx (soft palate level) and the lower pharynx (posterior tongue level) using lateral cephalometry. They reported that patients who underwent mandibular setback surgery alone experienced a significant reduction in the PAS at the lower pharynx, whereas those who underwent two-jaw surgery exhibited an insignificant change in the airway. The PAS at both the upper and lower pharynx decreased immediately after isolated mandibular setback surgery and continued to decrease from the immediate postoperative period to 3–12 months postoperatively. In contrary, Choi et al. [39] showed that the immediate results after the clockwise rotation of maxillomandibular complex using SFA, the PAS of the nasopharynx, oropharynx and hypopharynx decreased significantly when compared with before surgery. However, the negative

Table 2 Comparison of airway parameters between groups, adjusting for amount of mandibular setback at B point and change of SN-MP at T1

Variables	COA (Mean ± SD)				SFA (Mean ± SD)				*P*-value			
	T0	T1-T0	T2-T0	T2-T1	T0	T1-T0	T2-T0	T2-T1	T0[¶]	T1-T0[£]	T2-T0[£]	T2-T1[£]
TAL (mm)	55.8 ± 7.7	2.1 ± 3	-0.1 ± 2.3	-2.2 ± 2.6	53.8 ± 7.1	4.5 ± 3.4	3.3 ± 1.8	-1.2 ± 4.2	0.94	0.11	< 0.001[*]	0.44
minCSA (mm^2)	224.6 ± 56	-74.6 ± 39.3	-45.7 ± 57	28.9 ± 53.1	200.1 ± 85.3	-69.9 ± 77.5	-48.3 ± 71	21.6 ± 26.7	0.46	0.74	0.42	0.43
TAV (cm^3)	20 ± 7.3	-4.7 ± 3.3	-3.1 ± 4.6	1.6 ± 2.8	17.9 ± 7.5	-4.6 ± 4.6	-2.6 ± 2.9	2 ± 2.6	0.53	0.50	0.23	0.50
UAL (mm)	29.5 ± 4.7	1.6 ± 2.2	-1.2 ± 3.4	-2.8 ± 3.2	29.2 ± 3.8	1.1 ± 2.5	0.9 ± 1	-0.1 ± 2.2	0.90	0.78	0.002[*]	0.016[*]
UminCSA (mm^2)	305.7 ± 108.6	-115.7 ± 79.1	-68.6 ± 92.2	47.2 ± 62.6	259.9 ± 146.6	-86.5 ± 68.1	-70.5 ± 59.7	16 ± 32.3	0.47	0.41	0.52	0.80
UAV (cm^3)	11.9 ± 3.8	-2.8 ± 1.9	-1.4 ± 2.3	1.4 ± 1.4	10.1 ± 4.7	-2.4 ± 2.7	-1.4 ± 1.9	1 ± 1.3	0.38	0.30	0.35	0.76
LAL (mm)	26.3 ± 7.1	0.5 ± 2.4	1.1 ± 2.5	0.6 ± 3.3	24.5 ± 5.2	3.4 ± 2.8	2.3 ± 2	-1.1 ± 3.8	0.54	0.08	0.63	0.30
LminCSA (mm^2)	226.5 ± 56.9	-66.5 ± 49.3	-40.2 ± 68.1	26.3 ± 61.2	202.5 ± 84	-64.1 ± 81.2	-34.5 ± 74.8	29.5 ± 37.3	0.46	0.83	0.38	0.32
LAV (cm^3)	8.1 ± 4.7	-1.9 ± 1.8	-1.7 ± 2.6	0.2 ± 1.7	7.7 ± 3.4	-2.2 ± 2.6	-1.2 ± 1.1	1 ± 1.8	0.83	0.88	0.18	0.20

[¶] Independent *t*-test or Mann-Whitney *U*-test was used as appropriate

[£] Analysis of Covariance (ANCOVA)

[*] Significant difference between the groups

impact on the PAS was restored after 6 months postoperatively because of the soft-tissue adaptation and subsidence of swelling. Moreover, the 6-month postoperative data were similar to those of normal a person's data. The current study found that patients undergoing isolated mandibular surgery with SFA displayed an immediate postoperative increase in airway length, accompanied by reductions in minCSA and airway volume, with partial recovery of the upper airway observed at 6 months after surgery.

In comparing upper airway changes between SFA and COA, Agarwal et al. [19] utilized acoustic pharyngometry for evaluation. They found greater airway reduction immediately postoperatively and greater relapse at the 1-year follow-up in the SFA group undergoing mandibular setback surgery. At 1-month post-surgery, the airway volume reduction was 0.56 mm/mm setback in COA and 1.06 mm/mm setback in SFA. By 1 year, the airway volume relapse was 0.15 mm/mm setback in COA and 0.25 mm/mm setback in SFA. They suggested that the airway relapse corresponds to skeletal relapse. In the present study, the SFA group underwent greater mandibular setback with clockwise rotation due to non-decompensated arches. Postoperatively, a greater relapse in the form of counterclockwise rotation was observed at 6 months in the SFA group compared to the COA group, indicating differences in mandibular position between the two approaches. However, no significant differences in minCSA or airway volume were noted between groups, except for airway length. A decrease in airway length in the upper airway segment and an increase in airway length in the lower airway segment from T1 to T2 were observed in the COA group, whereas both upper and lower airway segments showed a decrease in airway length from T1 to T2 in the SFA group, likely due to more pronounced counterclockwise rotation. This increased counterclockwise rotation of the mandible in the SFA group aligns with findings from previous studies [10, 16–18].

The literature on the effects of orthognathic surgery on sleep quality remains controversial. Numerous studies have investigated the impact of mandibular setback surgery using COA on sleep quality. While the majority of patients do not develop post-surgical OSA [2, 3, 5, 34, 40], some have reported the occurrence of OSA following mandibular setback surgery, with or without maxillary advancement [26, 27, 31, 41–44]. To the best of our knowledge, no prior study has compared sleep quality between the SFA and COA groups. Choi et al. [39] reported that among 35 patients who underwent clockwise rotation of the maxillomandibular complex using SFA, five experienced a mild increase in snoring, as observed by their spouse or parents six months postoperatively. Additionally, no breathing difficulties were

Table 3 Comparison of sleep parameters between groups, adjusting for amount of mandibular setback at B point and change of SN-MP at T1

Variables	COA (Mean ± SD)				SFA (Mean ± SD)				*P*-value			
	T0	T1-T0	T2-T0	T2-T1	T0	T1-T0	T2-T0	T2-T1	T0[¶]	T1-T0[£]	T2-T0[£]	T2-T1[£]
ESS	6.5 ± 3	1.7 ± 2.5	0.1 ± 3.3	-1.6 ± 4.6	8.3 ± 1.9	0.1 ± 2.7	-0.1 ± 3.3	-0.2 ± 3.3	0.13	0.35	0.26	0.79
SBQ	0.7 ± 0.8	0.1 ± 0.6	0.3 ± 0.5	0.1 ± 0.6	1 ± 0.5	-0.2 ± 0.4	-0.3 ± 0.7	-0.2 ± 0.4	0.26	0.71	0.21	0.71
Total sleep time (minutes)	397.4 ± 51.6	2.2 ± 130.6	-8.1 ± 50.5	-10.3 ± 126.6	398.3 ± 49.9	-18.9 ± 48	-53.6 ± 67.6	-34.7 ± 52.9	0.97	0.85	0.09	0.34
Total AHI (events/h)												
All	3 ± 1.9	1.6 ± 2.5	0.2 ± 1.3	-1.3 ± 2.8	3.9 ± 1.7	2.5 ± 4.2	0.3 ± 1.9	-2.2 ± 4.6	0.20	0.18	0.16	0.43
REM	5.2 ± 2.1	1.5 ± 3.6	1 ± 4	-1.5 ± 5.6	5.7 ± 3.4	3.6 ± 9.3	0.1 ± 3.1	-3.3 ± 8.2	0.68	0.90	0.55	0.79
NREM	2.4 ± 1.9	2 ± 2.2	-0.2 ± 1.6	-2.3 ± 2.6	3.1 ± 2	1.3 ± 3.1	0.3 ± 2.1	-0.9 ± 3.5	0.40	0.97	0.37	0.83
ObsAHI (events/h)												
All	3 ± 2	1.2 ± 2.4	0.2 ± 1.3	-1.1 ± 2.7	3.5 ± 1.7	2.5 ± 3.8	0.1 ± 1.7	-2.4 ± 4.2	0.29	0.21	0.28	0.08
REM	5.2 ± 2.2	1.1 ± 3.5	0.9 ± 4.3	-1.3 ± 6.1	5 ± 3.5	4 ± 9.4	-0.2 ± 3.4	-4.3 ± 8.1	0.92	0.90	0.77	0.84
NREM	2.4 ± 2	1.7 ± 2	-0.3 ± 1.4	-2 ± 2.2	2.9 ± 1.9	1.2 ± 2.5	0.3 ± 1.9	-0.9 ± 3.2	0.50	0.90	0.52	0.99
ODI (events/h)												
All	0.8 ± 0.8	0.6 ± 1.3	0.5 ± 1.7	-0.1 ± 1.7	2.4 ± 3.7	0.5 ± 1.9	-0.3 ± 0.7	-0.8 ± 1.5	0.22	0.26	0.57	0.15
REM	1.7 ± 2	0.8 ± 2.3	1.1 ± 3.8	0.3 ± 2.7	4.3 ± 8.3	3.6 ± 4.6	-2 ± 3.7	-5.3 ± 7.2	0.47	0.65	0.67	0.66
NREM	0.7 ± 0.6	0.8 ± 1.3	0.1 ± 1.5	-0.6 ± 1.5	1.8 ± 2.6	-0.3 ± 1.8	0.1 ± 0.8	0.4 ± 2	0.20	0.58	0.58	0.84
Oxygen saturation (%)												
Mean	96.4 ± 0.8	-0.3 ± 0.7	-0.1 ± 0.7	0.2 ± 0.6	96.3 ± 1.2	-0.4 ± 1.1	0.1 ± 1.5	0.5 ± 1.5	0.60	0.61	0.10	0.16
Minimum	90 ± 3	-4.6 ± 6.7	-1.7 ± 3.5	2.9 ± 7.9	90.8 ± 3.6	-4.5 ± 6.5	-0.8 ± 4.7	3.7 ± 6.5	0.59	0.80	0.41	0.90
<90	0 ± 0	0 ± 0	0 ± 0.1	0 ± 0.1	0 ± 0.1	0 ± 0.1	0 ± 0.1	0 ± 0.2	0.51	0.92	0.99	0.96
<88	0 ± 0	0 ± 0	0 ± 0.1	0 ± 0	0 ± 0.1	0 ± 0.1	0 ± 0	0 ± 0.1	0.32	0.79	0.88	0.90
Pulse rate (bpm)												
Mean	63.3 ± 7.9	6.5 ± 8.6	-0.3 ± 3.6	-6.8 ± 9.1	60 ± 8.8	3 ± 4.9	4.1 ± 3.8	1.1 ± 6.3	0.39	0.85	0. 10	0.34
Minimum	45.3 ± 9	6.1 ± 8.2	1.3 ± 5.9	-4.8 ± 7.7	46.1 ± 8.9	0.8 ± 9.4	-2.4 ± 8.6	-3.2 ± 7.8	0.84	0.19	0.17	0.79
Maximum	105.9 ± 12.4	3.2 ± 12.7	-1.6 ± 14	-4.8 ± 10.7	98.4 ± 8	5.7 ± 11.2	4.9 ± 8.2	-0.8 ± 8.9	0.12	0.66	0.50	0.80
Position (Sleep%)												
Supine	63.7 ± 27.1	16.6 ± 15.3	3.6 ± 30.3	-13 ± 32.6	60 ± 40.4	15.3 ± 23.2	-4.2 ± 48.4	-18.6 ± 50	0.82	0.70	0.99	0.88
Non-supine	35.6 ± 27.4	-16.3 ± 15.8	-3.4 ± 30.6	13 ± 33	39.4 ± 40.6	-14.9 ± 23.3	4.1 ± 49.1	18 ± 49.9	0.82	0.67	0.93	0.92
AHI (events/h)												
Supine	2.5 ± 1.8	2 ± 2.8	0.9 ± 3.3	-1.1 ± 4.5	2.6 ± 2.3	2.8 ± 4.2	0.6 ± 2.7	-2.6 ± 5.1	0.89	0.21	0.76	0.25
Non-supine	2.2 ± 1.9	0.4 ± 4.1	1 ± 3.9	0.6 ± 5.7	3.4 ± 3	-2.7 ± 3.2	-1 ± 3.2	1.5 ± 3.1	0.30	0.49	0.26	0.72
ODI (events/h)												
Supine	0.7 ± 0.6	0.7 ± 1.6	1 ± 2.5	0.3 ± 2.6	2.7 ± 4.7	-0.1 ± 2.3	-1.7 ± 5.1	-2 ± 3	0.14	0.50	0.88	0.83
Non-supine	0.7 ± 1	0.2 ± 1.1	0.3 ± 2	0.2 ± 2.2	1.9 ± 2.6	-1.7 ± 2.7	0 ± 1.6	1.3 ± 3.6	0.12	0.81	0.16	0.37
Snoring Level (dB)												
>40 (Sleep%)	22.6 ± 26.6	21.6 ± 25.9	-5.4 ± 23.8	-27 ± 27.4	34.8 ± 36.7	2.8 ± 13.1	-7.1 ± 46.8	-6.3 ± 51.8	0.43	0.19	0.76	0.62
>50 (Sleep%)	1.8 ± 1.3	0.7 ± 1.7	-0.5 ± 1.2	-1.2 ± 1.8	1.7 ± 0.9	0.9 ± 2.7	0.5 ± 1.1	-0.3 ± 3.3	1.00	0.90	0.32	0.54
>60 (Sleep%)	0.4 ± 0.2	0.1 ± 0.3	0.1 ± 0.3	0 ± 0.5	0.4 ± 0.3	-0.1 ± 0.3	0.2 ± 0.3	0.2 ± 0.3	0.93	0.19	0.70	0.33
TS (Sleep%)[*]	3.4 ± 2.8	6.2 ± 10.7	-0.9 ± 2.8	-7.1 ± 11	3.4 ± 2.2	5.6 ± 9.6	1 ± 4.5	-3.6 ± 12.3	0.73	0.24	0.32	0.57

Table 3 (continued)

Variables	COA (Mean ± SD)				SFA (Mean ± SD)				*P*-value			
	T0	T1-T0	T2-T0	T2-T1	T0	T1-T0	T2-T0	T2-T1	T0[¶]	T1-T0[£]	T2-T0[£]	T2-T1[£]
Mean	40.6 ± 0.7	0.9 ± 0.9	-0.1 ± 0.7	-1 ± 1.3	40.8 ± 1	0.7 ± 1.3	0.3 ± 1.1	-0.4 ± 2	0.80	0.84	0.92	0.94
Sleep (%)	84.4 ± 5.5	-3.3 ± 9.7	2.5 ± 6.9	5.8 ± 10.2	88.2 ± 6	-4.2 ± 7.2	-0.3 ± 5.5	4 ± 4.7	0.15	0.75	0.19	0.12
Sleep latency (minutes)	18.2 ± 12.1	4 ± 17.8	0.9 ± 19.3	-3.1 ± 18.5	18.7 ± 13.7	5.6 ± 29.6	1.1 ± 14.6	-4.5 ± 22.1	0.93	0.64	0.88	0.66
REM latency (minutes)	119.9 ± 74.6	1.3 ± 103.8	-36.8 ± 77.6	-38.1 ± 75.1	101.3 ± 52	2.9 ± 65.6	-32.7 ± 57.4	-35.6 ± 42.4	0.53	0.62	0.88	0.55
Number of wakes	6.9 ± 3.3	0.9 ± 6.6	-0.9 ± 4.7	-1.8 ± 5.3	5.4 ± 5.1	1.5 ± 6.5	0.5 ± 3.2	-1 ± 4.7	0.12	0.79	0.39	0.28
Sleep stage												
REM (%)	25.7 ± 6	-4 ± 13.2	0.7 ± 5	4.6 ± 10.4	25.7 ± 4.8	-4.4 ± 8.9	4.7 ± 6.6	9.1 ± 5.5	0.97	0.69	0.38	0.95
Light (%)	52.8 ± 7.2	4.3 ± 15.3	-2.5 ± 7.4	-6.8 ± 12.1	54.9 ± 5.6	2 ± 6	-7.7 ± 9.6	-9.7 ± 7	0.47	0.50	0.44	0.39
Deep (%)	21.6 ± 3.4	-0.4 ± 6.5	1.8 ± 4.9	2.2 ± 7.8	19.3 ± 5.2	2.4 ± 6.4	2.2 ± 7.5	-0.2 ± 7.5	0.28	0.59	0.13	0.49

[¶] Independent *t*-test or Mann-Whitney *U*-test was used as appropriate

[£] Analysis of Covariance (ANCOVA)

[*] Threshold = snoring level more than 45 dB

reported. However, the study lacked a comparison group and did not employ tools to evaluate these outcomes objectively. In contrast, the present study assessed both subjective and objective sleep quality. Subjective assessments using the ESS and SBQ revealed no significant change between the groups, and no patients were identified as being at intermediate or high risk for OSA after surgery.

Objective assessments using HSAT revealed increased in total AHI, ObsAHI, ODI, and snoring levels within the first month after surgery in both groups. However, these metrics progressively declined between the immediate postoperative period and 6 months post-surgery. These findings are consistent with previous studies that reported a marked deterioration in AHI, ODI, and snoring immediately following orthognathic mandibular setback surgery, with gradual recovery observed by the 3- to 6-month follow-up [28, 42, 43, 45–47]. Airway obstruction during the first month after surgery may affect sleep quality due to factors such as postoperative bleeding, swelling, mucus accumulation, nasopharyngeal exudates, posterior displacement of the tongue, and narrowing of the pharyngeal airway. Additionally, an increase in airway length and a decrease in the cross-sectional area immediately following mandibular setback surgery result in increased upper airway resistance to airflow, as described by Poiseuille's law. According to this principle, resistance is directly proportional to airway length and inversely proportional to the radius raised to the fourth power. These anatomical changes contribute to increased upper airway resistance. Over time, muscular and soft tissue adaptation occurs, and respiratory function during sleep adjusts to these changes, leading to the resolution of OSA symptoms by 6 months postoperatively [28, 45, 47, 48].

The present prospective comparative clinical study provided insights into changes in upper airway morphology and sleep quality between the SFA and COA groups, incorporating multiple postoperative time points, including assessments within 1 and at 6 months. Nevertheless, the study had some limitations that should be considered. First, CBCT does not replicate the actual conditions during sleep, as this static technique captures images while the patient is awake and in an upright position. As a result, variations in airway morphology may occur. However, when high-quality CBCT scans are used, anatomical landmarks are accurately identified, and standardized measurement protocols with consistent threshold sensitivity are applied, making CBCT a dependable method for airway analysis [49, 50]. Second, the selection of the inferior boundary of the upper airway remains a subject of debate, as no consensus exists on the most appropriate anatomical reference for upper airway subdivision. A systematic review identified 14 different upper airway terminologies and various inferior boundary landmarks, including the tip or base of the epiglottis, hyoid bone, C2, C3, mental point, and retrognathion (RGn). Soft tissue structures such as the epiglottis undergo significant movement during respiration and swallowing, potentially altering upper airway morphology. This variability makes hard tissue landmarks preferable for more consistent and accurate evaluation [50]. Despite being influenced by neuromuscular activity, surgical intervention, or posture, the hyoid bone remains a reliable and reproducible landmark for upper airway assessment. When standardized positioning and imaging protocols are applied, it serves as a relatively stable reference point. Its clear visibility on CBCT and other imaging modalities allows for consistent measurements across studies. Moreover, the hyoid bone's position reflects functional airway dynamics, making it a valuable indicator of changes following orthognathic surgery. Notably, inferior and posterior displacement of the hyoid bone has been associated with OSA, a key concern in our study [25]. Furthermore, an inferiorly positioned hyoid bone may contribute to an increase in airway length. Finally, a type III HSAT device was used instead of polysomnography (PSG). Although PSG is the gold standard for diagnosing OSA, it requires subjects to stay overnight in a sleep laboratory and involves higher costs. In contrast, type III HSAT is more affordable, can be conducted at home, and provides sufficient results for diagnosing OSA. Nevertheless, HSAT is not recommended for general screening of asymptomatic clinical populations [25, 51]. Further studies using PSG are warranted to evaluate the effects of mandibular changes following different orthognathic surgery approaches.

Conclusion

In conclusion, isolated mandibular setback surgery, whether performed using SFA or COA, resulted in comparable changes in upper airway dimensions and sleep quality. Attention should be given to the potential for temporary airway obstructions immediately after surgery.

Author contributions

All authors contributed to the study conception and design. Material, data collection and validation were preformed by W.K., P.S., and N.C. Analysis and interpretation of results were performed by W.K., S.R., and C.C. The first draft of the manuscript was written by W.K. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The ethical approval was obtained by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2022-072). All individual participants enrolled for the study signed an informed consent.

Consent for publication

The authors adhered to ethical guidelines by obtaining approval from the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2022-072). All participants were given a detailed explanation of the study's objectives and signed informed consent forms before enrollment, ensuring voluntary participation and confidentiality.

Competing interests

The authors declare no competing interests.

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