Mandibular advancement devices shorten desaturation duration in patients at high risk for obstructive sleep apnea syndrome during intravenous propofol sedation in the decubitus position

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Abstract

Background: The purpose of this study was to determine the efficacy of a mandibular advancement device (MAD) for increasing patient safety during sedated total knee arthroplasty (TKA) and total hip replacement (THR).

Methods: Forty patients undergoing TKA or THR surgery in the supine or lateral recumbent positions under spinal anesthesia were enrolled. Sedation and oxygenation were administered. The MAD (Sweet Sleep Anti-Snoring Device) was then placed after 15 minutes of observation. SpO_2, $PetCO_2$, blood pressure, and respiratory rate were recorded.

Results: Sedated patients in the decubitus position had higher saturation nadirs, shorter desaturation durations, shorter airway obstruction durations, and fewer rescue events than those in the supine position. In patients at a high risk of obstructive sleep apnea syndrome (OSAS), desaturation duration, obstruction duration, apnea duration, desaturation duration, and rescue events were significantly lower after MAD placement. However, the saturation nadir did not improve after MAD placement.

Conclusion: The MAD may shorten the duration of desaturation events during spontaneous breathing sedative procedures in the lateral recumbent position but not in the supine position. Breathing patterns did not change from nasal breathing to oral breathing or vice versa between pre- and postplacement of the MAD. Sedation score evaluation affects breathing pattern changes from oral breathing to nasal breathing and vice versa.

Keywords: Airway device; Intravenous sedation; Mandibular advancement device

1. INTRODUCTION

The purpose of intravenous sedation is to reduce pain and anxiety during surgical or examination procedures.[1] All sedative medications cause respiratory muscular depression and airway collapse, resulting in desaturation and increased cardiovascular risk, and may lead to serious complications.[2] Obstructive sleep apnea (OSA) is a condition characterized by repetitive and intermittent occlusion of the upper airway (UA) during sleep.[3] Airway management with high percentage oxygen, jaw thrust, or insertion of a nasopharyngeal airway by trained anesthetic personnel is required during upper airway obstruction emergencies. The nasopharyngeal airway is invasive and may cause soft tissue damage of the nasal mucosa, nasal bleeding, and other problems.[4] Jaw thrust requires training and is laborious for anesthetic personnel to perform.

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The mandibular advancement device (MAD) is recommended for the treatment mild-to-moderate obstructive sleep apnea syndrome (OSAS).[4] The American Sleep Disorders Association defines a MAD as a device that is introduced into the mouth and modifies the position of the jaw, the tongue, and other supporting structures of the upper airway for the treatment of chronic snoring and OSAS.[5] Currently, there are more than 50 types of devices used to treat snoring.[5] The Sweet Sleep Anti-Snoring Device is a new MAD designed to retain the mandible in a protrusive position and reduce the vibration or collapse of the tongue, soft palate, and other soft tissue in the oral cavity. It is integrally formed by plastic injection molding and connects the upper and lower splints into a single structure. When using this MAD, the mandible is retained in a protrusive position, while the movements of the lower jaw are limited. The purpose of this study was to evaluate the efficacy of a MAD in increasing patient safety during sedated total knee arthroplasty (TKA) and total hip replacement (THR).

2. METHODS

Forty patients undergoing TKA or THR surgery in the supine or lateral recumbent position under spinal anesthesia were enrolled. The protocol was approved by the Institutional Review Board, Taipei Veterans General Hospital (Protocol number 2017-06-002C). The exclusion criteria were as follows: body mass index (BMI) >35, age over 80 years, American Society of Anesthesiologists (ASA) class >II, room air oxygen saturation by

pulse oximetry (SpO_2) <90%, loose teeth, and previous oral or facial surgeries that altered the oropharyngeal anatomy. Baseline patient characteristics including sex, height, weight, and STOP-Bang score (which considers snoring, tiredness, observed apnea, high blood pressure, BMI, age, neck circumference, and male gender) were recorded. Patients with sensory blockade of spinal anesthesia exceeding T6 were excluded.

After the completion of spinal anesthesia, the patient was positioned in the supine or lateral recumbent position for TKA or THR surgery, respectively. The effect site concentration of target-controlled infusion pumping (Agilia, SB Medica SRL, Italy) of propofol using Marsh mode was adjusted to achieve Modified Observer's Alertness/Sedation (MOAA/S) level 2. The patient's name was called, and they were mildly prodded and physically shaken every 5 minutes.[6] Oxygenation with nasal cannula 3 L/min was given as propofol target-controlled infusion started. The trends of exhaled nasal and oral end tidal carbon dioxide ($PetCO_2$) concentration, respiratory rate, and SpO_2 changes during sedation were recorded. The MAD (Sweet Sleep Anti-Snoring Device®, Fig. 1A) was then placed after 15 minutes of observation in the space between the upper and lower teeth and the upper splint fit the upper teeth as the lower splint fit the lower teeth. The study setup is shown in Fig. 1B. In the event of a saturation nadir lower than 85%, rescue face-mask ventilation would be performed to raise saturation up to 100%. Parameters including SpO_2, $PetCO_2$, blood pressure, and respiratory rate were recorded simultaneously via data acquisition systems (Datex/Omeda S/5 Collect, GE Corporate).

The primary outcome was desaturation duration before and after MAD placement. Desaturation was defined as SpO_2 lower than 90%.

The secondary outcomes were airway obstruction duration, SpO_2, apnea duration, and rescue events. Apnea duration was defined as the time during which the respiratory rate was lower than half of the baseline respiratory rate (the respiratory rate before sedation). Obstruction duration was defined as the time during which the respiratory rate was lower than half of the baseline respiratory rate and the $PetCO_2$ had decreased to lower than 10 mmHg. Rescue events were defined as the number of times face mask ventilation was performed.

Quantitative variables were compared with paired sample t-test. $p < 0.05$ was considered to be significant. Analysis was performed using SPSS v. 24 (SPSS Inc., Chicago, IL).

3. RESULTS

A total of 20 patients underwent TKA and 20 underwent THR from May 12, 2018, to February 27, 2019 (Fig. 2). Patient characteristics are shown in Table 1. Patients sedated in the decubitus position had higher saturation nadirs, shorter desaturation durations, shorter airway obstruction durations, and fewer rescue events than those in the supine position (Table 2). In patients at high risk for OSAS, desaturation duration, obstruction duration, apnea duration, desaturation duration, and rescue events were significantly decreased after MAD placement. However, the saturation nadir did not improve after MAD placement.

There were no significant differences in saturation nadir, obstruction duration, apnea duration, desaturation duration, and rescue events after placement of MAD in both the TKA and THR groups, or in patients at a moderate or low risk of OSAS.

Interchange of oral breathing to nasal breathing or vice versa that occurred during the process of checking MOAA/S scores was noted in 12 patients (30%) (Fig. 3), possibly influencing the accuracy of $PetCO_2$ measurement. $PetCO_2$ data within 60 seconds after checking MOAA/S scores were excluded to mitigate the interference of interchange between oral breathing and nasal breathing.

Tables 3, 4, and 5 show the oral and nasal $PetCO_2$ values before and after placement of the MAD in the different groups. The maximum oral $PetCO_2$ values differed significantly between pre- and postplacement of the MAD in the TKA ($p = 0.049$) and THR ($p = 0.015$) groups. $PetCO_2$ data during the 60 seconds post MOAA/S evaluation were excluded due to the interchange of oral breathing and nasal breathing. The maximum nasal $PetCO_2$ values was significantly different between pre- and postplacement of the MAD ($p = 0.015$) in the THR groups, after data within 60 seconds of checking the MOAA/S score.

4. DISCUSSION

This noninvasive, ready-to-use MAD improved the quality of airway protection and oxygenation for sedative patients, especially those with OSAS.

MADs are considered valid alternatives that can be the first choice in simple snorers, mild OSAS patients, mild-moderate OSAS with low body mass index, and patients suffering from the syndrome of increased resistance of the upper airway. It may also be a second choice in patients who do not improve or cannot tolerate positive pressure devices, those at high surgical risk, and those who react badly to surgical treatment.[5,7] Very few studies of MAD use in sedated patients have been performed. If apnea or desaturation occur during moderate sedation, airway repositioning (via head tilt, chin lift, or forward jaw thrust) may open the airway and inflict sufficient painful stimuli to prompt spontaneous breathing. If jaw thrust is not successful, we should

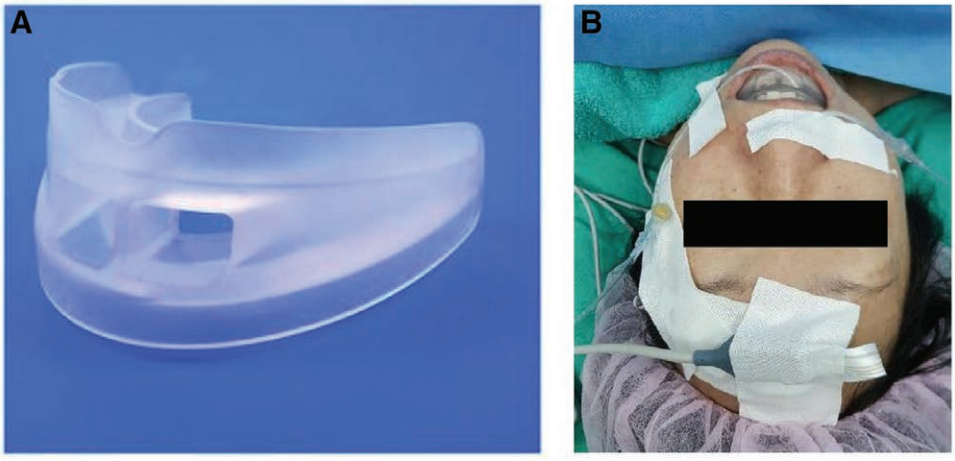

Fig. 1 Study setup. A, Mandibular advancement device (MAD). B, MAD placement on patient.

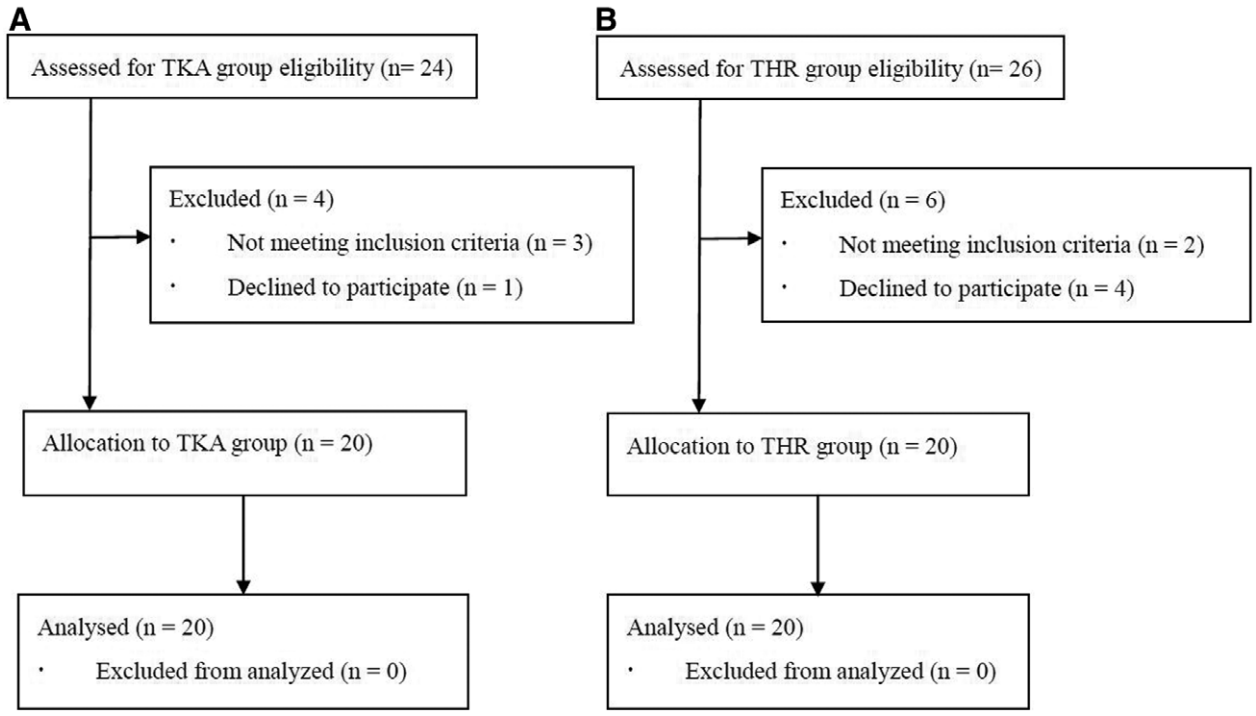

Fig. 2 Study flow diagram. TKA = total knee arthroplasty; THA = total hip arthroplasty.

Table 1.

Patient demographic and surgical data

Demographics	THR (n = 20)	TKA (n = 20)
Age (years)	66.35 ± 10.7	63.35 ± 10.5
Gender (male *n*/female *n*)	6/14	11/9
ASA (I *n*/ II *n*)	1/19	3/17
Weight (kg)	66.5 ± 9.1	68.6 ± 12.5
Height (cm)	155.4 ± 7.2	162.0 ± 6.8
STOP-Bang risk (low *n*/mod *n*/high *n*)	7/13/0	6/9/5
Time from start of TCI to MOAA/S 2 (min)	10.8 ± 7.0	10.8 ± 7.0
Time from start of TCI to placement of MAD	26.5 ± 8.0	26.5 ± 8.0
Time from start of TCI to end of TCI (min)	44.1 ± 10.9	44.1 ± 10.9
Time from end of TCI to MOAA/S 3 (min)	48.3 ± 10.9	48.3 ± 10.9
Propofol TCI Ce (ng/ml)	1.4 ± 0.7	1.2 ± 0.4
BIS	78.6 ± 5.7	75.7 ± 7.4

ASA = American Society of Anesthesiologists classification; BIS = bispectral index; BMI = body mass index; STOP-Bang = STOP-Bang questionnaire; TKA = total knee arthroplasty; THR = total hip replacement; TCI = target-controlled infusion; Propofol TCI Ce = effect site concentration for propofol target-controlled infusion.

consider bag-valve mask ventilation or nasopharyngeal airway.[8] However, a nasopharyngeal airway may cause soft tissue damage to the nasal mucosa; therefore, a MAD would be a less invasive alternative.

In patients at a high risk for OSAS, the desaturation duration was significantly shorter after MAD placement. However, there was no significant difference in saturation nadir, apnea duration, obstruction duration, desaturation duration, rescue events, and $PetCO_2$ between pre- and postplacement MAD in both the TKA and THR groups. MADs may be used as an airway patency tool in OSAS patients during moderate sedation before using more invasive airway management maneuvers, such as nasal airways.

The THR group had higher saturation nadirs than the TKA group, as well as shorter apnea durations, no airway obstruction, fewer rescue events, and no desaturation. This may be because changing from the supine to the lateral position enlarges both the retropalatal and retroglossal airways. The decubitus position structurally improves the maintenance of the passive pharyngeal airway in patients with OSAS.[9] In the retroglossal region, significant increases in the cross-sectional area and volume were observed in the lateral recumbent position compared

Table 2.

Comparison between pre-placement and post-placement of MAD

	Total knee arthroplasty (n = 20)			Total hip replacement (n = 20)			High risk for OSAS (n = 5)		
	Pre	Post	*p*	Pre	Post	*p*	Pre	Post	*p*
Saturation nadir	90.4 ± 8.3	91.5 ± 7.8	0.223	96.4 ± 6.7	95.8 ± 6.2	0.183	84.7 ± 6.34	84.4 ± 8.3	0.779
Obstruction duration (sec)	10.0 ± 23.2	4.0 ± 12.3	0.235	0	0	-	38 ± 34.9	8 ± 17.9	0.113
Apnea duration (sec)	16.0 ± 39.4	13.0 ± 39.1	0.748	2.0 ± 8.9	0.5 ± 2.2	0.330	64 ± 59.4	32 ± 71.6	0.368
SpO2 < 90% duration (sec)	162.1 ± 230.1	185.3 ± 287.6	0.251	0	0	-	138 ± 123.4	34 ± 38.5	0.050*
Rescue events	5	2		0	0		3	0	

Data are represented as mean ± standard deviation;
*$p < 0.05$.
MAD = mandibular advancement device; OSAS = obstructive sleep apnea syndrome; pre = preplacement; post = postplacement.

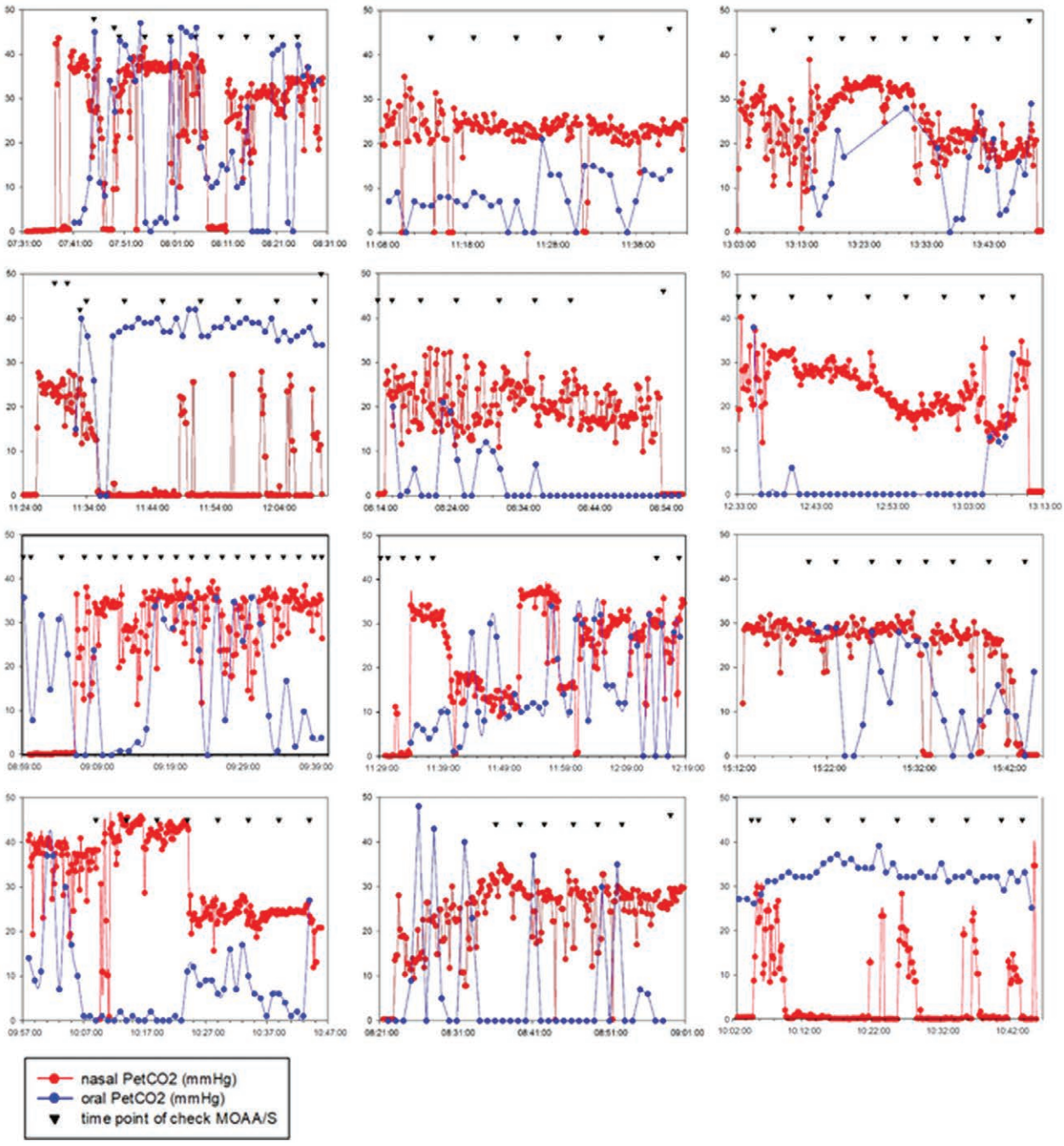

Fig. 3 Correlation of oral and nasal $PetCO_2$ measurements of the 12 patients with interchanging breathing pattern during checking of the MOAA/S score. MOAA/S score = Modified Observer's Alertness/Sedation; OSAS = obstructive sleep apnea syndrome.

with the supine position.[10] The gravitational force may also play a role. The MAD may not exert a sufficient force to hold the mandible in the supine position. Therefore, these changes in upper airway volume and gravitational factors may result in easier maintenance of airway patency with MADs in the decubitus position.[11,12]

Patients undergoing sedated esophagogastroduodenoscopy may exhibit inaccurate nasal $PetCO_2$ values during respiratory monitoring via capnography. $PetCO_2$ measurement via oral cannulas increases the accuracy and efficacy of capnographic monitoring. The lack of capnographic measurement via the nasal route indicated a lack of nasal airway patency during open mouth endoscopic examinations. In our previous study, patients breathed almost solely through the oral route during open mouth upper gastrointestinal examinations.[13] However, in the present study, the sedated patients did not exhibit clear patterns of nasal or oral breathing. Although the breathing patterns in this study did not show a predominant pattern of nasal or oral breathing, they did shift from nasal to oral breathing or vice versa occurred during the stimulation for MOAA/S evaluation. After placement of a MAD, lower oral $PetCO_2$ was detected in the THR group. This may mean that, after placement of a MAD, there was more exhalation from the nose in the THR group. Because we cannot predict those patients who would mostly

Table 3.

Comparison of $PetCO_2$ between preplacement and postplacement of MAD device

	Oral (n = 40)			Nasal (n = 40)		
TKA and THR groups	**Preplacement**	**Postplacement**	***p***	**Preplacement**	**Postplacement**	***p***
Max $PetCO_2$(mmHg)	31.6 ± 11.2	27.7 ± 12.3	0.049*	35.1 ± 7.4	34.9 ± 7.1	0.894
Mini $PetCO_2$(mmHg)	8.1 ± 11.2	8.9 ± 11.3	0.617	8.6 ± 11.5	9.4 ± 10.5	0.592
	Oral (n = 20)			**Nasal (n = 20)**		
TKA group	**Pre-placement**	**Post-Placement**	***p***	**Pre-placement**	**Post-placement**	***p***
Max $PetCO_2$ (mmHg)	35.8 ± 9.8	32.4 ± 11.2	0.157	33.6 ± 7.9	35.3 ± 7.5	0.378
Mini $PetCO_2$ (mmHg)	9.1 ± 12.4	13.2 ± 13.6	0.168	5.9 ± 10.6	8.3 ± 11.1	0.214
	Oral (n = 20)			**Nasal (n = 20)**		
THR group	**Pre-placement**	**Post-Placement**	***p***	**Pre-placement**	**Post-placement**	***p***
Max $PetCO_2$ (mmHg)	27.5 ± 11.2	23.5 ± 11.7	0.174	36.6 ± 6.8	34.7 ± 6.8	0.015*
Mini $PetCO_2$ (mmHg)	7 ± 10.1	4.7 ± 6.3	0.196	11.4 ± 12	10.6 ± 9.9	0.741

Data are represented as mean ± standard deviation.

* $p < 0.05$.

Max = maximum; Mini = minimum; MAD = mandibular advancement device; TKA = total knee arthroplasty; THR = total hip arthroplasty.

Table 4.

Comparison of $PetCO_2$ between preplacement and postplacement of MAD device excluding data within 60 s of checking MOAA/S score

	Oral (n = 40)			Nasal (n = 40)		
TKA and THR groups	**Preplacement**	**Postplacement**	***p***	**Preplacement**	**Postplacement**	***p***
Mean $PetCO_2$ (mmHg)	19.4 ± 11.6	16.6 ± 11.4	0.063	24.0 ± 9.9	23.4 ± 9.4	0.598
Max $PetCO_2$ (mmHg)	28.4 ± 13.4	26.3 ± 13.1	0.318	28.4 ± 13.4	26.3 ± 13.1	0.364
Mini $PetCO_2$ (mmHg)	9.2 ± 11.5	8.9 ± 11.2	0.866	9.7 ± 12.2	10.6 ± 11.5	0.559
	Oral (n = 20)			**Nasal (n = 20)**		
TKA group	**Preplacement**	**Postplacement**	***p***	**Preplacement**	**Postplacement**	***p***
Mean $PetCO_2$ (mmHg)	23.0 ± 11.6	20.8 ± 12.9	0.323	20.5 ± 10.7	22.2 ± 10.2	0.331
Max $PetCO_2$ (mmHg)	33.9 ± 10.8	31.7 ± 12.1	0.428	34.5 ± 7.1	35.7 ± 6.9	0.506
Mini $PetCO_2$ (mmHg)	10.9 ± 12.9	12.6 ± 13.8	0.579	7.2 ± 11.8	8.9 ± 12.0	0.385
	Oral (n = 20)			**Nasal (n = 20)**		
THR group	**Preplacement**	**Postplacement**	***p***	**Preplacement**	**Postplacement**	***p***
Mean $PetCO_2$ (mmHg)	15.8 ± 10.6	12.3 ± 8.0	0.108	27.6 ± 7.7	24.6 ± 8.4	0.073
Max $PetCO_2$ (mmHg)	22.9 ± 13.8	21.0 ± 12.0	0.542	36.2 ± 6.7	32.9 ± 6.8	0.015*
Mini $PetCO_2$ (mmHg)	7.5 ± 10	5.2 ± 6.2	0.225	12.1 ± 12.4	12.4 ± 11.2	0.926

Data are represented as mean ± standard deviation.

*$p < 0.05$

Max = maximum; Mini = minimum; MAD = mandibular advancement device; TKA = total knee arthroplasty; THR = total hip arthroplasty; MOAA/S score = Modified Observer's Alertness/Sedation.

Table 5.

Comparison of $PetCO_2$ between preplacement and postplacement of MAD device in the high OSAS risk group, excluding data within 60 seconds of checking MOAA/S score

	Oral (n = 5)			Nasal (n = 5)		
	Preplacement	**Postplacement**	***p***	**Preplacement**	**Postplacement**	***p***
Mean $PetCO_2$ (mmHg)	29.8 ± 10.4	31.6 ± 8.9	0.307	19.8 ± 13.8	20.2 ± 13.4	0.941
Max $PetCO_2$ (mmHg)	38.3 ± 6.2	37.5 ± 4.1	0.798	36.3 ± 6.7	35.7 ± 6.0	0.806
Mini $PetCO_2$ (mmHg)	16.4 ± 15.1	24.8 ± 14.5	0.282	7.6 ± 17.0	9.5 ± 14.3	0.574

Data are represented as mean ± standard deviation.

Max = maximum; Mini = minimum; MAD = mandibular advancement device; TKA = total knee arthroplasty; THR = total hip arthroplasty; MOAA/S score = Modified Observer's Alertness/Sedation; OSAS = obstructive sleep apnea syndrome.

breathe via the oral or nasal routes, respiratory monitoring with capnography via both nasal and oral routes would be more accurate. Furthermore, because capnographic readings indicate airway patency, delivery of oxygen via both the oral and nasal cavities may be more efficient than only nasal delivery during moderate sedation.

This study has several limitations. The role of capnography in nonintubated patients is controversial. The sedated patient may

be in a respiratory depressed state, and therefore, has higher end tidal carbon dioxide readings. Ventilatory drive and minute ventilation volume were not measured. The capnography was performed under an open system, which cannot produce accurate measurements. Further studies are needed using closed respiratory systems to correctly evaluate airway patency. In addition, the use of MADs may not be suitable in patients with poor dental status. Further studies are needed to elucidate the functional outcomes and complications rate according to dental status. BMI > 35 was an exclusion criterion in this study; thus, further studies on obese patients are needed.

In conclusion, the MAD may shorten desaturation duration during spontaneous breathing sedative procedures in the decubitus position but not in the supine position. Breathing patterns did not change between pre- and postplacement of the MAD. Sedation score evaluation affects breathing pattern changes from oral breathing to nasal breathing and vice-versa. Further airway imaging studies in patients under sedation are needed.

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