pii: jc-19-00306 https://dx.doi.org/10.5664/jcsm.8126

JCSM | Journal of Clinical Sleep Medicine

SCIENTIFIC INVESTIGATIONS

The influence of position dependency on surgical success in patients with obstructive sleep apnea undergoing maxillomandibular advancement

Patty E. Vonk, MD[1,*]; Perry J. Rotteveel, MD[1,*]; Madeline J.L. Ravesloot, MD, PhD, MSc[1,2]; Jean-Pierre T.F. Ho, MD[3]; Jan de Lange, MD, PhD[3]; Nico de Vries, MD, PhD[1,4,5]

*[1]Department of Otorhinolaryngology - Head and Neck Surgery, OLVG, Amsterdam, the Netherlands; [2]Department of Otorhinolaryngology, Medical Centre Jan van Goyen, Amsterdam, the Netherlands; [3]Department of Oral and Maxillofacial Surgery, Amsterdam UMC/ACTA, Amsterdam, the Netherlands; [4]Department of Oral Kinesiology, ACTA, MOVE Research Institute Amsterdam, University of Amsterdam and VU University Amsterdam, Amsterdam, the Netherlands; [5]Faculty of Medicine and Health Sciences, Department of Otorhinolaryngology, Head and Neck Surgery Antwerp University Hospital, Antwerp, Belgium; *Contributed equally*

Study Objectives: (1) To evaluate surgical success in patients with obstructive sleep apnea undergoing maxillomandibular advancement (MMA) stratifying for the reduction of both the total apnea-hypopnea index (AHI) and the AHI in the supine and nonsupine position; (2) to evaluate the influence of position dependency on surgical outcome; and (3) to analyze the prevalence of residual position-dependent obstructive sleep apnea (OSA) in nonresponders after MMA.

Methods: A single-center retrospective study including a consecutive series of patients with OSA undergoing MMA between August 2011 and February 2019.

Results: In total, 57 patients were included. The overall surgical success was 52.6%. No significant difference in surgical success between nonpositional patients (NPP) and positional patients (PP) with OSA was found. Surgical success of the supine AHI was not significantly different between NPP and PP, but surgical success of the nonsupine AHI was significantly greater in NPP than in PP. Of the 17 preoperative NPP, 13 of them moved to being PP with less severe OSA postoperatively. In total, 21 out of 27 nonresponders (77.8%) were PP postoperatively.

Conclusions: No significant difference in surgical success between NPP and PP undergoing MMA was found. However, the improvement of total and nonsupine AHI in NPP was significantly greater compared to PP. In nonresponders, a postoperative shift from severe OSA in NPP to less severe OSA in PP was found, caused by a greater reduction of the nonsupine AHI than the supine AHI postoperatively. In patients with residual OSA in the supine position after MMA, additional treatment with positional therapy can be indicated.

Keywords: maxillomandibular advancement, obstructive sleep apnea, positional, position dependency, sleep-disordered breathing, surgical success

Citation: Vonk PE, Rotteveel PJ, Ravesloot MJL, Ho J-PTF, de Lange J, de Vries N. The influence of position dependency on surgical success in patients with obstructive sleep apnea undergoing maxillomandibular advancement. *J Clin Sleep Med.* 2020;16(1):73–80.

BRIEF SUMMARY

Current Knowledge/Study Rationale: Preoperative evaluation of possible predictors for surgical success is of paramount importance before initiating upper airway surgery. Currently, the influence of position dependency on surgical success in patients with obstructive sleep apnea (OSA) undergoing maxillomandibular advancement is unknown.

Study Impact: We found that surgical success was similar in patients with nonpositional (NPP) and positional (PP) OSA, but that the decrease in non-supine AHI was significantly greater in NPP than in PP, often resulting in a postoperative shift from severe OSA in NPP to less severe OSA in PP. Additional treatment with positional therapy can be of added value in nonresponders with residual OSA in the supine position.

Downloaded from jcsm.aasm.org by 49.145.234.186 on March 14, 2022. For personal use only. No other uses without permission. Copyright 2022 American Academy of Sleep Medicine. All rights reserved.

INTRODUCTION

In patients with moderate to severe obstructive sleep apnea (OSA), continuous positive airway pressure (CPAP) is considered the gold-standard therapy, but this therapy is often hampered by poor tolerance and low acceptance.[1–3] In patients with severe OSA (apnea-hypopnea index (AHI) > 30 events/h) and failure of CPAP treatment, several surgical therapies are available aiming to target structures related to upper airway (UA) collapse in order to reduce obstructions during sleep. One of these surgical techniques is maxillomandibular advancement (MMA). MMA consists of a combination of a Le Fort I osteotomy and a bilateral sagittal split osteotomy to enlarge the pharyngeal airway space. By advancement of the maxilla and mandible the medial-lateral and anteroposterior dimensions of the UA are enlarged.[4] This technique is highly effective in treating patients with severe OSA, with surgical success rates varying from 80% to 90%.[5–9] Compared to other surgical techniques, MMA is considered to be more invasive and in addition it has considerable morbidity. Therefore, patients are usually referred in cases of severe to extreme OSA, and when the chance of surgical success of less invasive forms of UA surgery is considered to be low.

There are several known negative predictors for the surgical success of MMA. Older patients and those with an increased neck circumference are at a greater risk of surgical failure.[10] Another potential predictor is position dependency. In a small-scale study, results showed that in partially effective MMA (response but not cured), a shift was often seen from severe nonpositional OSA to less severe positional OSA. In such cases, there is a successful decrease of the AHI in the nonsupine position, but insufficient reduction of the AHI in the supine position.[11] Although this finding suggests a correlation between position dependency and surgical success, further evidence is needed.

Therefore, the aim of this study was to evaluate surgical success in patients with OSA undergoing MMA stratifying for the reduction of both the total AHI and the AHI in the supine and nonsupine positions. Also, we wanted to evaluate the influence of position dependency on surgical outcome. In addition, we wanted to analyze the prevalence of residual position-dependent OSA in nonresponders after MMA. Our hypothesis is that there is a difference in surgical success between patients with OSA who are nonpositional (NPP) and positional (PP). In addition, we hypothesize that surgical failure is caused by insufficient reduction of the AHI in the supine position rather than nonsupine AHI.

METHODS

Study participants

We performed a single-center retrospective study including a consecutive series of patients with OSA undergoing MMA between August 2011 and February 2019. Patients were only included if preoperative and postoperative polysomnography (PSG) data after 3 to 6 months of follow-up were available. When patients slept 0% of the total sleep time (TST) in the supine or nonsupine position, position dependency could not be adequately determined. In that case, patients were excluded from further analysis.

Cephalometric work-up and MMA procedure

Preoperative and postoperative cephalometric data were collected including the following skeletal landmarks: center of sella turnica (S), nasion (N), subspinal (A-point), and supramentale (B-point). Sella-nasion–A-point angle (SNA angle) indicates whether or not the maxilla is normal, prognatic, or retrognatic. Sella–nasion–B-point angle (SNB angle) assesses the mandible in a similar way and the A-point to B-point angle (ANB angle) describes the sagittal discrepancy between the maxilla and the mandible[12] (**Figure 1**).

All MMA procedures were performed by two dedicated maxillofacial surgeons and consisted of a Le Fort I osteotomy and a bilateral sagittal split osteotomy to advance the maxillary and mandibular facial skeleton. The maxilla was advanced to the preoperatively planned position (approximately 8–10 mm anteriorly) and an acrylic intermediate splint was used to guarantee correct alignment and fixation of the maxilla in the intended planned position.

Definitions

Surgical success was defined according to criteria by Sher et al, which means that MMA was considered to be successful when a postoperative reduction of more than 50% of the preoperative AHI was achieved combined with a postoperative AHI below 20 events/h.[13] To determine surgical success stratified to supine and nonsupine position a modified versions of criteria by Sher et al was applied using supine and nonsupine AHI instead of total AHI.

Patients not meeting Sher et al's criteria for surgical success were referred to as nonresponders. Surgical success for total AHI, supine AHI, and nonsupine AHI was determined in the total study population, NPP, PP, responders, and in nonresponders.

Patients were identified as being position-dependent using criteria by Cartwright et al, a supine AHI of at least twice as high as nonsupine AHI.[14]

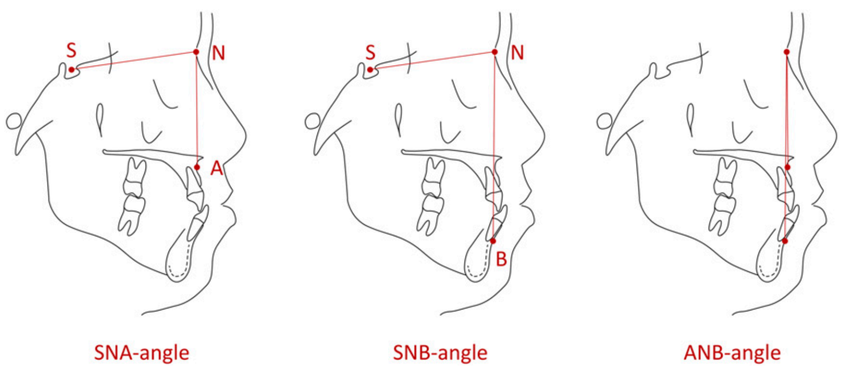
Ethical considerations

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the Declaration of Helsinki of 1975. Data on study participants were collected and stored encoded to protect personal information. For this type of study informed consent was not required.

Statistical analysis

Statistical analysis was performed using SPSS (version 22, IBM Corp, Armonk, New York, United States). Quantitative data were reported as mean and standard deviation (SD) or as median

Figure 1—Skeletal landmarks.



A = A-point (subspinal), B = B-point (supramentale), N = nasion, S = center of sella turnica.

Downloaded from jcsm.aasm.org by 49.145.234.186 on March 14, 2022. For personal use only. No other uses without permission. Copyright 2022 American Academy of Sleep Medicine. All rights reserved.

and (Q1, Q3) when not normally distributed. To determine whether continuous variables were normally distributed, the Shapiro-Wilk Test was used. A value of $P < .05$ was considered to indicate statistical significance.

To compare baseline characteristics between NPP and PP the unpaired *t* test was used in case of normally distributed data and the Mann-Whitney *U* test when data were not normally distributed. A Pearson chi-square test was used to determine whether there was a correlation between position dependency and surgical success. To compare preoperative and postoperative values in total population, NPP, and PP a paired *t* test was used when data were normally distributed. In case of not normally distributed data a Wilcoxon signed-rank test was applied. When comparing differences in surgical outcome between groups an unpaired *t* test or the Mann-Whitney *U* test was used in case of normally or not normally distributed data, respectively. To correct for possible confounders a multivariate logistic regression analyses was performed. Descriptive statistics were used to analyze the occurrence of a shift in position dependency after MMA.

RESULTS

In total 68 patients underwent MMA for OSA. Eight patients were excluded because (partial) preoperative or postoperative PSG data were missing. In three patients position dependency could not be determined due to a TST of 0% in the supine position. Therefore, 57 patients were included for analysis. Forty-eight patients were male (84.2%). The mean age was 51.3 ± 8.6 years with a body mass index (BMI) of 28.6 ± 4.0 kg/m^2.

Twenty-four patients were daily smokers (42.1%) and 23 patients (40.4%) had a previous diagnosis of cardiovascular problems (myocardial infarction n = 9, hypertension n = 9, atrial fibrillation n = 2, other n = 2). Fifty-five patients (96.5%) had CPAP intolerance or failure and 23 patients (40.4%) received another form of UA surgery prior to MMA (eg, uvulopalatopharyngoplasty), thermotherapy of the tongue base or hyoidthyroidpexia).

Patients had a total mean AHI of 51.4 ± 22.2 events/h, a mean supine AHI of 68.1 ± 20.7 events/h, and a nonsupine AHI of 44.4 ± 24.5 events/h. The mean oxygen desaturation index (ODI ≥ 3%) was 46.9 ± 22.3 events/h and the median average was SpO_2 93.0% (92.0; 95.0). Of all patients, 38 were NPP preoperatively (66.7%). A detailed overview of baseline characteristics can be found in **Table 1**.

Baseline characteristics of NPP versus PP

When comparing baseline characteristics between NPP and PP, mean age, the distribution of sex, mean BMI and supine AHI did not significantly differ. Total AHI ($P < .001$), obstructive apnea index ($P < .001$), nonsupine AHI ($P < .001$), percentage of TST in the supine position ($P = .036$) and ODI ($P < .001$) were significantly higher in NPP. The median average SpO_2 did not significantly differ in NPP from that in PP ($P = .079$) (**Table 2**).

Preoperative and postoperative MMA results

The median advancement of the maxillomandibular complex was 10 mm (range 8 to 12 mm). The preoperative and postoperative skeletal relationship based on the SNA, SNB, and ANB are shown in **Table 3**.

The total mean AHI was significantly reduced from 51.4 ± 22.2 to 19.9 ± 15.3 events/h ($P < 0.001$). In NPP, the total mean AHI decreased from 61.9 ± 17.5 to 21.9 ± 16.8 events/h compared to a decrease from 30.4 ± 14.5 to 16.1 ± 11.0 events/h in PP.

In the total population, supine AHI was significantly reduced from 68.1 ± 20.7 to 35.2 ± 25.9 events/h ($P < .001$). In NPP, supine AHI was reduced from 70.6 ± 17.6 to 38.2 ± 28.9 events/h compared to 63.0 ± 25.6 to 29.2 ± 17.6 events/h in PP.

Table 1—Baseline characteristics of the total population, NPP and PP.

	Total (n = 57)	NPP (n = 38)	PP (n = 19)	*P*
Male:female	48:9	32:6	16:3	> .999
Age (years)	51.3 ± 8.6	51.2 ± 9.1	51.6 ± 7.8	.872
BMI (kg/m^2)	28.6 ± 4.0	29.0 ± 3.9	27.8 ± 4.2	.302
Total AHI (events/h)	51.4 ± 22.2	61.9 ± 17.5	30.4 ± 14.5	< .001
Obstructive AI (events/h)	21.7 [10.4, 44.3]	33.5 [19.5, 54.8]	11.0 [3.8, 18.2]	< .001
Mixed AI (events/h)	3.9 [0.3, 15.3]	4.4 [1.5, 21.9]	1.3 [0.3, 10.3]	.257
Central AI (events/h)	0.8 [0.2, 3.0]	0.8 [0.2, 2.5]	0.9 [0.1, 3.3]	.739
Supine AHI (events/h)	68.1 ± 20.7	70.7 ± 17.6	63.0 ± 25.6	.188
Nonsupine AHI (events/h)	44.4 ± 24.5	57.0 ± 19.1	19.3 ± 10.9	< .001
Supine position (% TST)	35.2 ± 19.6	39.2 ± 18.2	27.4 ± 20.5	.031
ODI (events/h)	46.9 ± 22.3	56.4 ± 19.1	28.5 ± 15.9	< .001
Median average SpO_2 (%)	93.0 [92.0, 95.0]	95.0[91.0, 94.5]	94.0[93.0, 95.3]	.079

Data presented as mean ± standard deviation or median [Q1, Q3]. *P* values compare NPP and PP; $P < .05$ considered statistically significant. AHI = apnea-hypopnea index, AI = apnea index, BMI = body mass index, NPP = nonpositional patients, ODI = oxygen desaturation index, PP = positional patients, SpO_2 = saturation of peripheral oxygen, TST = total sleep time.

Downloaded from jcsm.aasm.org by 49.145.234.186 on March 14, 2022. For personal use only. No other uses without permission.
Copyright 2022 American Academy of Sleep Medicine. All rights reserved.

Table 2—Results before and after maxillomandibular advancement in total population (n = 57).

	Preoperative	Postoperative	*P*
BMI (kg/m^2)	28.6 ± 4.0	28.1 ± 3.8	.125
Total AHI (events/h)	51.4 ± 22.2	19.9 ± 15.3	< .001
Obstructive AI (events/h)	21.7 [10.4, 44.3]	5.0 [1.4, 10.1]	< .001
Mixed AI (events/h)	3.9 [0.3, 15.3]	0.6 [0.1, 4.1]	.004
Central AI (events/h)	0.8 [0.2, 3.0]	0.3 [0.1, 1.1]	.021
Supine AHI (events/h)	68.1 ± 20.7	35.2 ± 25.9	< .001
Nonsupine AHI (events/h)	44.4 ± 24.5	11.2 ± 11.8	< .001
Supine position (% TST)	35.2 ± 19.6	38.3 ± 21.8	.236
ODI (events/h)	46.9 ± 22.3	25.1 ± 15.8	< .001
Median average SpO_2(%)	93.0 [92.0, 95.0]	95.0 [93.0, 96.0]	< .001

Data presented as mean ± standard deviation or median [Q1, Q3]. $P < .05$ considered statistically significant. AHI = apnea-hypopnea index, AI = apnea index, BMI = body mass index, ODI = oxygen desaturation index, SpO_2 = saturation of peripheral oxygen, TST = total sleep time.

Table 3—Cephalometric analysis

	SNA	SNB	ANB
Preoperative	81.0 (79.5–85.2)	77.4 (73.1–81.8)	5.0 (2.7–7.7)
Postoperative	87.0 (84.2–91.7)	80.2 (76.7–85.6)	6.8 (5.1–11.1)

Data presented as median (interquartile range). ANB = A-point to B-point angle, SNA = S-N line and A-point, SNB = S-N line and B-point.

The nonsupine AHI in all patients significantly decreased from 44.4 ± 24.5 to 11.2 ± 11.8 events/h ($P < .001$). A reduction in nonsupine AHI from 57.0 ± 19.1 to 12.0 ± 13.0 events/h and 19.3 ± 10.9 to 9.7 ± 9.3 events/h was found in NPP and PP, respectively (**Figure 2**). An overview of preoperative and postoperative PSG parameters in the total population, and in both NPP and PP can be found in **Table 2** and **Table 4**.

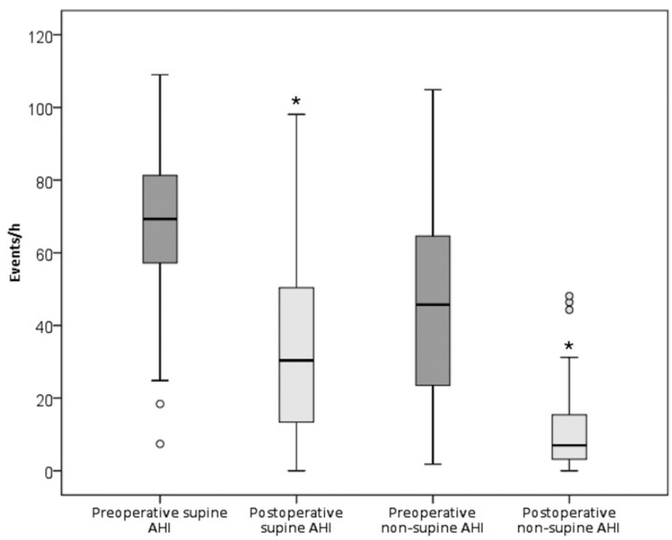
Surgical success of the total AHI, supine AHI, and nonsupine AHI

Surgical success was achieved in 30 of 57 patients (52.6%); 55.3% (n = 21) in NPP and 47.4% (n = 9) in PP. This difference was not statistically significant ($P = .574$). Multivariate logistic regression analysis showed no significant correlation between surgical success and age (odds ratio [OR] 0.96, 95% confidence interval [CI] 0.90–1.02; $P = .198$), preoperative BMI (OR 1.0, 95% CI 0.90–1.20; $P = .561$) or preoperative total AHI (OR 0.99, 95% CI 0.97–1.01); $P = .630$).

Surgical success in the supine position was achieved in 19 patients (33.3%) of the total population, in 13 NPP (34.2%) and in 6 PP (31.6%). No significant difference was found between the surgical success in the supine position comparing preoperative NPP and PP ($P = .843$).

In the nonsupine position surgical success was achieved in 41 patients (71.9%) of the total population, in 31 NPP (81.6%) and in 10 PP (52.6%). Surgical success in the nonsupine positions was significantly greater in NPP than in PP ($P = .022$). **Table 5** provides an overview of surgical success percentages stratified for the total AHI, the supine AHI, and the nonsupine AHI in the total population and comparing NPP with PP.

Figure 2—Boxplot of the preoperative and postoperative MMA supine and nonsupine AHI in total population.



*Value of $P < .05$ comparing the preoperative and postoperative supine and nonsupine AHI. AHI = apnea-hypopnea index, MMA = maxillomandibular advancement.

Postoperative shift in position dependency

Of all patients, 38 (66.7%) were NPP preoperatively. Twenty-five NPP shifted to PP postoperatively (65.8%). Nineteen patients (33.3%) were PP preoperatively. After MMA 14 patients remained PP, 5 shifted to NPP (26.3%) (**Figure 3**). In total, 39 of 57 patients were PP postoperatively (68.4%).

Downloaded from jcsm.aasm.org by 49.145.234.186 on March 14, 2022. For personal use only. No other uses without permission. Copyright 2022 American Academy of Sleep Medicine. All rights reserved.

Table 4—Preoperative and postoperative polysomnography values comparing NPP and PP.

	NPP (n = 38)				NPP vs PP
	Preoperative	Postoperative	*P**	Δ	*P*†
BMI (kg/m^2)	29.0 ± 3.9	28.6 ± 3.7	.401	0.3 ± 2.4	.577
Total AHI (events/h)	61.9 ± 17.5	21.9 ± 16.8	< .001	40.0 ± 20.3	< .001
Obstructive AI (events/h)	33.5 [19.5, 54.8]	6.3 [2.1, 10.7]	< .001	23.1 [11.3, 45.2]	.001
Mixed AI (events/h)	4.4 [1.5, 21.9]	0.8 [0.0, 7.0]	.017	2.0 [−1.5, 18.2]	.865
Central AI (events/h)	0.8 [0.2, 2.5]	0.3 [0.0, 1.0]	.033	0.3 [−0.3, 2.4]	.182
Supine AHI (events/h)	70.6 ± 17.6	38.2 ± 28.9	< .001	32.5 ± 30.9	.884
Nonsupine AHI (events/h)	57.0 ± 19.1	12.0 ± 13.0	< .001	44.9 ± 20.6	< .001
Supine position (% TST)	39.2 ± 18.2	41.0 ± 22.6	< .001	1.8 ± 21.5	.509
ODI (events/h)	56.4 ± 19.1	27.4 ± 17.4	.608	28.9 ± 20.0	< .001
Median average SpO_2 (%)	93.0 [91.0, 94.5]	95.0 [93.0, 96.0]	< .001	1.0 0.0, 2.0]	.119
	PP (n = 19)				NPP vs PP
	Preoperative	Postoperative	*P**	Δ	*P*†
BMI (kg/m^2)	27.8 ± 4.2	27.1 ± 3.9	.082	0.7 ± 1.6	.577
Total AHI (events/h)	30.4 ± 14.5	16.1 ± 11.0	.002	14.3 ± 17.7	< .001
Obstructive AI (events/h)	11.0 [3.8, 18.2]	3.3 [0.3, 7.5]	.017	7.0 [−1.0, 14.0]	.001
Mixed AI (events/h)	1.3 [0.3, 10.3]	0.6 [0.1, 1.8]	.044	0.6 [−0.2, 9.7]	.865
Central AI (events/h)	0.9 [0.1, 3.3]	0.4 [0.1, 1.3]	.434	0.1 [−0.3, 2.3]	.182
Supine AHI (events/h)	63.0 ± 25.6	29.2 ± 17.6	< .001	33.8 ± 32.2	.884
Nonsupine AHI (events/h)	19.3 ± 10.9	9.7 ± 9.3	.020	9.6 ± 16.4	< .001
Supine position (% TST)	27.4 ± 20.5	32.9 ± 19.6	.104	5.4 ± 14.3	.509
ODI (events/h)	28.5 ± 15.9	20.5 ± 11.1	.073	7.9 ± 18.2	< .001
Median average SpO_2 (%)	94.0 [93.0, 95.3]	95.0 [94.0, 96.0]	.018	0.5 [0.0, 2.0]	.119

Data presented as mean ± standard deviation or median [Q1, Q3]. $P < .05$ considered statistically significant. **P* values compare preoperative and postoperative polysomnography values. †*P* values compare Δ (preoperative and postoperative change) in NPP and PP. AHI = apnea-hypopnea index, AI = apnea index, BMI = body mass index, NPP = nonpositional patients, ODI = oxygen desaturation index, PP = positional patients, SpO_2 = saturation of peripheral oxygen, TST = total sleep time.

Table 5—Surgical success of AHI, supine AHI, and nonsupine AHI in total population, NPP, and PP.

Surgical Success	Total Population (n = 57)	NPP (n = 38)	PP (n = 19)	*P*
Total AHI	52.6%	55.3%	47.4%	.574
Supine AHI	50.9%	34.2%	31.6%	.843
Nonsupine AHI	75.4%	81.6%	52.6%	.022

P values compare NPP and PP; $P < .05$ considered statistically significant. AHI = apnea-hypopnea index, NPP = nonpositional patients, PP = positional patients.

Responders versus nonresponders

In the nonresponder group, 10 of 27 patients (37.0%) were PP preoperatively. Eight preoperative PP remained position dependent. Of the 17 preoperative NPP, 13 patients moved to the less severe PP group postoperatively. In total, 21 of 27 nonresponders (77.8%) were PP postoperatively. The surgical success of the supine AHI was 83.3% in responders versus 14.8% in nonresponders ($P < .001$). When comparing the surgical success of the nonsupine AHI we found a surgical success of 93.3% compared to 55.6% in responders and nonresponders, respectively ($P < .001$). **Table 6** provides an overview of surgical success percentages of the total, supine and nonsupine AHI comparing responders with nonresponders.

DISCUSSION

Most studies on MMA show success rates of approximately 85%.[15] This is the first series that focuses on nonresponders to MMA. In contrast with what was expected, our results did not show a significant difference in surgical success between NPP and PP, suggesting the absence of a correlation between position dependency and surgical outcome in patients undergoing MMA. When stratifying for surgical success of the supine and nonsupine AHI no significant difference was found in the surgical success of the supine AHI, but surgical success of the nonsupine AHI was significantly greater in NPP than in PP. In most nonresponders, a shift from severe OSA in NPP to less severe OSA in

Downloaded from jcsm.aasm.org by 49.145.234.186 on March 14, 2022. For personal use only. No other uses without permission. Copyright 2022 American Academy of Sleep Medicine. All rights reserved.

PP was caused by a more pronounced reduction of the nonsupine AHI than the supine AHI.

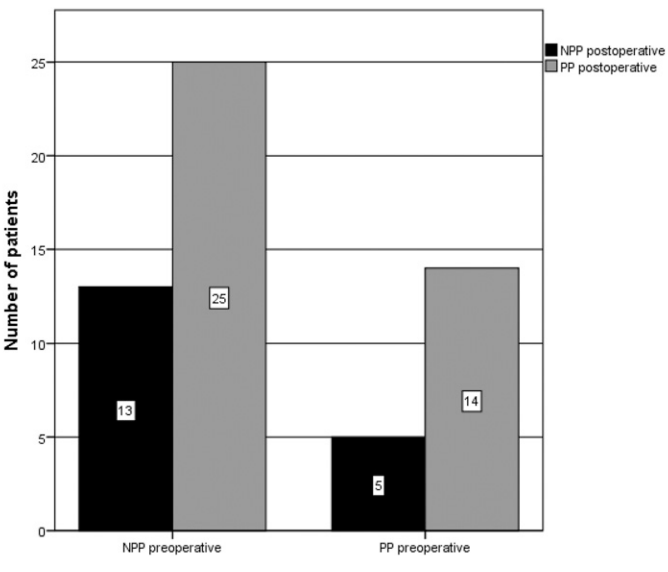
When interpreting the results, there are several factors that must be taken into consideration. Our overall success rate is lower than reported in the literature.[15] This is probably because MMA in our institute is strictly reserved for severe to extreme OSA (mean AHI of 51.5 events/h), whereas many other series also include moderate and even mild pathology. Forty percent of our patients who have undergone MMA underwent previous, unsuccessful UA surgery, or were considered poor candidates for standard UA surgery or UA stimulation for a variety of reasons (eg, unfavorable findings during drug-induced sleep endoscopy, such as complete concentric palatal collapse or multilevel total collapse), which might have interfered with a positive surgical outcome. Last, the average age in this study was higher than in other studies reporting on the surgical outcome of MMA. It is known that a higher age has a negative effect on the surgical success of UA surgery and MMA.[10]

Nevertheless, we did not find a significant correlation between age and surgical success in our study population. When evaluating the possible relation of rapid eye movement (REM)-related OSA and the increase of the percentage of REM sleep postoperatively, we did not find a significant correlation between the presence of REM-related OSA and surgical success (P = .136) Furthermore, the high percentage of NPP is not surprising, because the prevalence of positional OSA decreases when OSA severity increases.[16–20]

A significant decrease of the total AHI, supine AHI, and nonsupine AHI was found in both NPP and PP after MMA. ODI and average SpO_2 also significantly improved in NPP, but not in PP. Although total and nonsupine AHI significantly decreased in both NPP and PP, the decrease was significantly greater in NPP than in PP. No significant difference was found in the decrease of the supine AHI. This finding might be explained by the fact that the preoperative total AHI and nonsupine AHI in NPP were significantly higher. As a result, a greater reduction in nonsupine AHI was possible.

The finding of a postoperative shift from severe NPP to less severe PP is not new. In previously published studies, similar results were found in patients undergoing uvulopalatopharyngoplasty or Z-palatoplasty with or without radiofrequency thermotherapy of the tongue base and multilevel surgery.[21–24] This phenomenon also occurs in the case of extensive weight loss after bariatric surgery in patients with OSA,[25] whereas unpublished data suggest that treatment with mandibular advancement devices can also lead to more reduction of the lateral AHI than the supine AHI.

Figure 3—Postoperative shift in position dependency.



NPP = nonpositional patients, PP = positional patients.

Clinical relevance

Because MMA is often positioned as a last resort and taking into account its considerable morbidity, surgical failure is a very disappointing outcome. It is often seen that the AHI in nonsupine positions is successfully reduced, this in contrast with the supine AHI. As a result, apneic events may still occur in the supine position, which can have a negative effect on the outcome of MMA. However, additional positional therapy using either the so-called tennis ball technique, in which a bulky mass is attached to the back, or with new-generation vibrotactile devices attached to the chest or trunk aiming to prevent patients from lying in the supine position. In that case, positional therapy can be of added value in nonresponders with residual OSA in the supine position.[23,26,27] Furthermore, hypoglossal nerve stimulation has been added as a treatment option for OSA. Several patients treated with MMA could in theory also have benefitted from this form of UA surgery, which may explain the decrease in the number of MMA procedures over the past few years. Nevertheless, hypoglossal nerve stimulation is currently only performed in patients with an AHI between 15 and 65 events/h; therefore, almost half of our study population would not have been selected for this therapeutic option.

Table 6—Surgical success in total AHI, supine AHI, and nonsupine AHI comparing responders and nonresponders.

Surgical Success	Responders (n = 30)	Nonresponders (n = 27)	*P*
Total AHI	100%	N/A	–
Supine AHI	83.3%	14.8%	< .001
Nonsupine AHI	93.3%	55.6%	< .001

P values compares surgical success of the supine and nonsupine AHI in responders and nonresponders. AHI = apnea-hypopnea index.

Downloaded from jcsm.aasm.org by 49.145.234.186 on March 14, 2022. For personal use only. No other uses without permission. Copyright 2022 American Academy of Sleep Medicine. All rights reserved.

Limitations

This study is not without limitations. First, a retrospective study design was used, where a prospective study would have been preferred. Second, when comparing NPP and PP one must take several confounders into consideration. PP tend to have lower total AHI, lower BMI, and are usually younger as compared to NPP. These factors are also related to surgical outcome.[15,28,29] Nevertheless, after correcting for confounders such as age, preoperative total AHI, and BMI, no significant difference in surgical success between NPP and PP was found. Third, especially in PP, total AHI is influenced by the time spent in the supine position. Although this could have influenced differences in surgical success when comparing NPP and PP, we did not find a significant difference in percentage of TST in the supine position. Therefore, in our opinion the effect of this limitation was negligible.

CONCLUSIONS

No significant difference in surgical success between NPP and PP undergoing MMA was found. However, the improvement of total and nonsupine AHI in NPP was significantly greater compared to PP. In nonresponders, a postoperative shift from severe OSA in NPP to less severe OSA in PP was seen, caused by a greater reduction of the nonsupine AHI than the supine AHI. In patients with residual OSA in the supine position after MMA, additional treatment with PT can be indicated.

ABBREVIATIONS

AHI, apnea-hypopnea index
BMI, body mass index
CPAP, continuous positive airway pressure
MMA, maxillomandibular advancement
NPP, nonpositional patients
ODI, oxygen desaturation index
OR, odds ratio
OSA, obstructive sleep apnea
PP, positional patients
PSG, polysomnography
SpO_2, saturation of peripheral oxygen
TST, total sleeping time
UA, upper airway

REFERENCES

1. Haniffa M, Lasserson TJ, Smith I. Interventions to improve compliance with continuous positive airway pressure for obstructive sleep apnoea. *Cochrane Database Syst Rev.* 2004;CD003531.
2. Richard W, Venker J, den Herder C, et al. Acceptance and long-term compliance of nCPAP in obstructive sleep apnea. *Eur Arch Otorhinolaryngol*. 2007;264(9):1081–1086.
3. Weaver TE, Grunstein RR. Adherence to continuous positive airway pressure therapy: the challenge to effective treatment. *Proc Am Thorac Soc*. 2008;5(2):173–178.
4. Gokce SM, Gorgulu S, Gokce HS, Bengi AO, Karacayli U, Ors F. Evaluation of pharyngeal airway space changes after bimaxillary orthognathic surgery with a 3-dimensional simulation and modeling program. *Am J Orthod Dentofacial Orthop*. 2014;146(4):477–492.
5. Holty JE, Guilleminault C. Maxillomandibular advancement for the treatment of obstructive sleep apnea: a systematic review and meta-analysis. *Sleep Med Rev*. 2010;14(5):287–297.
6. Prinsell JR. Maxillomandibular advancement surgery for obstructive sleep apnea syndrome. *J Am Dent Assoc*. 2002;133(11):1489–1497; quiz 539-540.
7. Prinsell JR. Maxillomandibular advancement surgery in a site-specific treatment approach for obstructive sleep apnea in 50 consecutive patients. *Chest*. 1999;116(6):1519–1529.
8. Hoekema A, de Lange J, Stegenga B, de Bont LG. Oral appliances and maxillomandibular advancement surgery: an alternative treatment protocol for the obstructive sleep apnea-hypopnea syndrome. *J Oral Maxillofac Surg*. 2006;64(6):886–891.
9. Goh YH, Lim KA. Modified maxillomandibular advancement for the treatment of obstructive sleep apnea: a preliminary report. *Laryngoscope*. 2003;113(9):1577–1582.
10. de Ruiter MHT, Apperloo RC, Milstein DMJ, de Lange J. Assessment of obstructive sleep apnoea treatment success or failure after maxillomandibular advancement. *Int J Oral Maxillofac Surg*. 2017;46(11):1357–1362.
11. Benoist LBL, de Ruiter MHT, de Lange J, de Vries N. Residual POSA After Maxillomandibular Advancement in Patients with Severe OSA. In: de Vries N, Ravesloot M, van Maanen J, eds. *Positional Therapy in Obstructive Sleep Apnea*. Cham, Switzerland: Springer, Cham; 2015:321-329.
12. Paoli JR, Lauwers F, Lacassagne L, Tiberge M, Dodart L, Boutault F. Craniofacial differences according to the body mass index of patients with obstructive sleep apnoea syndrome: cephalometric study in 85 patients. *Br J Oral Maxillofac Surg*. 2001;39(1):40–45.
13. Sher AE, Schechtman KB, Piccirillo JF. The efficacy of surgical modifications of the upper airway in adults with obstructive sleep apnea syndrome. *Sleep*. 1996;19(2):156–177.
14. Cartwright RD, Diaz F, Lloyd S. The effects of sleep posture and sleep stage on apnea frequency. *Sleep*. 1991;14(4):351–353.
15. Zaghi S, Holty JE, Certal V, et al. Maxillomandibular Advancement for Treatment of Obstructive Sleep Apnea: A Meta-analysis. *JAMA Otolaryngol Head Neck Surg*. 2016;142(1):58–66.
16. Frank MH, Ravesloot MJ, van Maanen JP, Verhagen E, de Lange J, de Vries N. Positional OSA part 1: Towards a clinical classification system for position-dependent obstructive sleep apnoea. *Sleep Breath*. 2015;19(2):473–480.
17. Oksenberg A, Silverberg DS, Arons E, Radwan H. Positional vs nonpositional obstructive sleep apnea patients: anthropomorphic, nocturnal polysomnographic, and multiple sleep latency test data. *Chest*. 1997;112(3):629–639.
18. Richard W, Kox D, den Herder C, Laman M, van Tinteren H, de Vries N. The role of sleep position in obstructive sleep apnea syndrome. *Eur Arch Otorhinolaryngol*. 2006;263(10):946–950.
19. Mador MJ, Kufel TJ, Magalang UJ, Rajesh SK, Watwe V, Grant BJ. Prevalence of positional sleep apnea in patients undergoing polysomnography. *Chest*. 2005;128(4):2130–2137.
20. Itasaka Y, Miyazaki S, Ishikawa K, Togawa K. The influence of sleep position and obesity on sleep apnea. *Psychiatry Clin Neurosci*. 2000;54(3):340–341.
21. Lee CH, Shin HW, Han DH, et al. The implication of sleep position in the evaluation of surgical outcomes in obstructive sleep apnea. *Otolaryngol Head Neck Surg*. 2009;140(4):531–535.
22. Kastoer C, Benoist LBL, Dieltjens M, et al. Comparison of upper airway collapse patterns and its clinical significance: drug-induced sleep endoscopy in patients without obstructive sleep apnea, positional and non-positional obstructive sleep apnea. *Sleep Breath*. 2018;22(4):939–948.
23. van Maanen J, Witte B, de Vries N. Theoretical approach towards increasing effectiveness of palatal surgery in obstructive sleep apnea: role for concomitant positional therapy? *Sleep Breath*. 2014;18(2):341–349.
24. van Maanen JP, Ravesloot MJ, Witte BI, Grijseels M, de Vries N. Exploration of the relationship between sleep position and isolated tongue base or multilevel surgery in obstructive sleep apnea. *Eur Arch Otorhinolaryngol*. 2012;269(9):2129–2136.

Downloaded from jcsm.aasm.org by 49.145.234.186 on March 14, 2022. For personal use only. No other uses without permission.
Copyright 2022 American Academy of Sleep Medicine. All rights reserved.

25. de Raaff CAL, Gorter-Stam MAW, de Vries N, et al. Perioperative management of obstructive sleep apnea in bariatric surgery: a consensus guideline. *Surg Obes Relat Dis*. 2017;13(7):1095–1109.
26. Benoist LB, Verhagen M, Torensma B, van Maanen JP, de Vries N. Positional therapy in patients with residual positional obstructive sleep apnea after upper airway surgery. *Sleep Breath*. 2017;21(2):279–288.
27. Ravesloot MJL, White D, Heinzer R, Oksenberg A, Pépin JL. Efficacy of the new generation of devices for positional therapy for patients with positional obstructive sleep apnea: a systematic review of the literature and meta-analysis. *J Clin Sleep Med*. 2017;13(6):813–824.
28. Shie DY, Tsou YA, Tai CJ, Tsai MH. Impact of obesity on uvulopalatopharyngoplasty success in patients with severe obstructive sleep apnea: a retrospective single-center study in Taiwan. *Acta Otolaryngol*. 2013;133(3):261–269.
29. Liu SA, Li HY, Tsai WC, Chang KM. Associated factors to predict outcomes of uvulopharyngopalatoplasty plus genioglossal advancement for obstructive sleep apnea. *Laryngoscope*. 2005;115(11):2046–2050.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication May 12, 2019
Submitted in final revised form September 1, 2019
Accepted for publication September 4, 2019

Address correspondence to: Patty E. Vonk, MD, Department of Otorhinolaryngology - Head and Neck Surgery, OLVG, Jan Tooropstraat 164, 1061 AE Amsterdam, The Netherlands, Tel: +31 20 510 88 94; Email: p.e.vonk@olvg.nl

DISCLOSURE STATEMENT

All authors declare that they have seen and approved the final manuscript. Work for this study was performed at the Department of Otorhinolaryngology - Head and Neck Surgery, OLVG, Amsterdam, the Netherlands. Nico de Vries is a member of the Medical Advisory Board of NightBalance. He is also an investigator of Inspire and Jazz Pharmaceutics, consultant of Philips, Olympus and the AE Mann Foundation. The other authors report no conflicts of interest.

Downloaded from jcsm.aasm.org by 49.145.234.186 on March 14, 2022. For personal use only. No other uses without permission.
Copyright 2022 American Academy of Sleep Medicine. All rights reserved.