

The Mandibular Advancement Device and Patient Selection in the Treatment of Obstructive Sleep Apnea

Chul Hee Lee, MD; Ji-Hun Mo, MD; Ik-Joon Choi, MD; Hyun Jong Lee, MD; Beom Seok Seo, MD; Dong-Young Kim, MD; Phil-Young Yun, DDS; In-Young Yoon, MD; Hye Won Lee, MD; Jeong-Whun Kim, MD, PhD

Objectives: To evaluate retrospectively the efficacy of the mandibular advancement device (MAD) in Korean patients with obstructive sleep apnea (OSA) in terms of severity and to evaluate prognostic factors deciding the success of MAD application.

Design: Retrospective analysis.

Setting: Academic tertiary referral center.

Patients: Of 142 patients who underwent MAD application for OSA management, 50 (46 men and 4 women; mean [SD] age, 50.2 [9.8] years) were included from March 2005 through August 2007.

Intervention: Full-overnight polysomnography was performed before and at least 3 months after intraoral MAD application in 50 patients. Questionnaires for sleep quality, Epworth sleepiness scale, and cephalometry were also studied.

Main Outcome Measures: Treatment results were evaluated and prognostic factors deciding success of MAD application were assessed.

Results: The mean (SD) apnea-hypopnea index (AHI) decreased significantly ($P < .001$) from 36.6 (18.9) to 12.3 (11.4). The success rate, defined by an AHI of lower than 20 and a 50% decrease in AHI, were 74% (37 of 50 patients). Even patients who were not categorized into the success group had a decreased AHI. The success rates of patients with mild, moderate, and severe OSA were 43% (3 of 7), 82% (22 of 27), and 75% (12 of 16), respectively, and a higher success rate in patients with severe OSA showed that MAD could be applied even in patients with severe OSA. The duration of apnea and hypopnea, percentage of patients with snoring, and the Pittsburgh Sleep Quality Index were improved significantly after treatment. Epworth sleepiness scale scores and lowest oxygen saturation did not change significantly. An analysis of prognostic factors did not reveal any significant difference between the success and nonsuccess groups.

Conclusions: The application of MAD significantly improved nocturnal respiratory function and sleep quality in patients with OSA, even in patients with severe OSA. In patients with OSA, MAD can be used as a good alternative treatment modality regardless of severity because it is noninvasive, easy to manufacture, and has good treatment results.

Arch Otolaryngol Head Neck Surg. 2009;135(5):439-444

Author Affiliations:
Departments of
Otorhinolaryngology
(Drs C. H. Lee, Mo, Choi,
H. J. Lee, Seo, D.-Y. Kim, and
J.-W. Kim), Oral Surgery
(Dr Yun), and Neuropsychiatry
(Drs Yoon and H. W. Lee),
Seoul National University
Bundang Hospital, Seoul
National University
College of Medicine,
Seongnam, Korea.

MANAGEMENT OF obstructive sleep apnea (OSA) can be divided into continuous positive airway pressure (CPAP) therapy, surgery, and oral appliances.^{1,2} Continuous positive airway pressure is considered the gold standard treatment modality in the treatment of OSA, and its effectiveness is well established. However, the limiting factor of CPAP therapy is compliance, and the reported long-term compliance ranges from 40% to 70%.³

Surgery is another treatment modality for OSA, and it has evolved from oropharyngeal surgery such as uvulopalatopharyngoplasty to staged multilevel surgery. Staged multilevel surgery is widely accepted these days, and the last surgical resort is maxillomandibular advancement,

which widens both retropalatal and retroglossal airway, with a success rate reported to be similar to that of CPAP.⁴ However, maxillomandibular advancement is an invasive procedure and is not well accepted in Asians whose jaws are relatively smaller than those of whites.

To overcome disadvantages of CPAP therapy and surgery, oral appliances such as the mandibular advancement device (MAD) have been used in the treatment of OSA for decades, especially in dental clinics. There are several advantages of MAD application over CPAP therapy, such as convenience, simpler procedure, smaller design, lower price, and portability. However, MAD application has usually been prescribed for patients with mild to moderate cases of OSA, and its effectiveness for patients with severe OSA has not been well established. For



Figure 1. A photograph of the mandibular advancement device used in this study. It is custom-made from a monobloc and individually fitted without an open bite.

severe OSA, CPAP treatment is considered the standard treatment modality.

In addition, although otorhinolaryngologists have played a major role in the treatment of OSA, they may not have sufficient experiences with MAD application and are not aware that it could be a good adjunct to surgery. Furthermore, most of the articles about MAD application have been published in Western countries, and there have been few articles on Asian patients. Our objectives were to evaluate the results of MAD application in Korean patients with OSA retrospectively, especially in terms of severity, and to evaluate the prognostic factors affecting the results of MAD application for patients with OSA. We also wanted to give helpful information to otorhinolaryngologists on the concept of MAD application.

METHODS

PATIENTS

Initially, 142 patients had undergone MAD application from March 2005 through August 2007 at Seoul National University Bundang Hospital, Seongnam, Korea. Twenty-five patients who underwent previous surgery, 51 patients who did not undergo polysomnography (PSG) with MAD application mainly because of economic reasons, and 16 patients who were lost to follow-up were excluded from this study. Fifty patients had undergone a full-overnight PSG with or without MAD application, and they were included in this study. They were 46 male and 4 female patients who were diagnosed as having OSA with an apnea-hypopnea index (AHI) of greater than 5. Their ages ranged from 21 through 69 years, with a mean age of 50.2 years. This study was approved by the institutional review board of Seoul National University Bundang Hospital, Seongnam, Korea.

The Friedman staging system for tonsil size and tongue position was assessed. The nasal cavity was endoscopically examined to exclude patients with moderate to severe nasal sep-

Table 1. Definition of Treatment Results After MAD Application

AHI Reduction	With MAD Application	
	AHI <20	AHI ≥20
Negative, increased AHI	Failure	Failure
0%-20%	No response	No response
20%-50%	Response	Response
>50%	Success	Response

Abbreviations: AHI, apnea-hypopnea index; MAD, mandibular advancement device.

tal deviation. A lateral cephalometric radiograph was taken to measure the length of the soft palate and tongue base and width of the posterior upper airway space.

All the patients were referred to a dentist, and a custom-made MAD was fabricated for each patient (**Figure 1**). The MAD was designed as a monobloc that holds the mandible fixed at 60% of the maximum protrusion without an open bite. Patients had a second full-overnight PSG after 3 months with the custom-made MAD applied.

ASSESSMENT OF TREATMENT OUTCOMES

Treatment outcomes were assessed using questionnaires including the Epworth sleepiness scale and the Pittsburgh Sleep Quality Index (PSQI) and PSG data according to OSA severity, classified as mild (AHI <20), moderate (AHI ≥20 to <40), and severe (AHI ≥40).

The treatment responses were divided into 4 categories according to the change in AHI after MAD application: success, response, no response, and failure. Success was defined as a greater than 50% reduction in AHI and, with MAD application, an AHI of less than 20; response, a 20% to 50% reduction in AHI or a greater than 50% reduction in AHI and, with MAD application, an AHI of 20 or greater; no response, a less than 20% reduction in AHI; and failure, an increased AHI after MAD application (**Table 1**).

ANALYSIS OF PROGNOSTIC FACTORS

Patients were classified into a success group and a nonsuccess group. The nonsuccess group includes patients who showed response, no response, or failure after MAD application.

Age, tonsil size (0, 1, 2, 3, and 4), Friedman tongue position (grade 1, 2, 3, and 4), Friedman stage (1, 2, 3, and 4), body mass index (BMI), AHI, average oxygen saturation (percentage), lowest oxygen saturation (percentage), mean apnea duration (seconds), mean hypopnea duration (seconds), and supine position (percentage) during sleep were analyzed between success and nonsuccess groups to find out prognostic factors. Cephalometry was used for the analysis of prognostic factors in terms of anatomic characteristics of the upper airway between the 2 groups. Uvula length, length of tongue base from the posterior nasal spine, pharyngeal airway space (PAS) at the level of the tongue base (TB-PAS), and pharyngeal airway space at the level of the soft palate (SP-PAS) were measured and analyzed.

STATISTICAL ANALYSIS

Statistical analysis was performed, and all the continuous variables were given as mean (SD) values. The *t* test and paired *t* test were performed for the analysis of data. *P* < .05 was considered statistically significant.

Table 2. Friedman Staging System and Demographic Data of Patients According to the OSA Severity

Variable	OSA Severity ^a			P Value
	Mild	Moderate	Severe	
Friedman tonsil size, grade	1.7 (1.0)	1.3 (0.7)	1.2 (0.8)	.19
Friedman tongue position, grade	2.0 (0.7)	2.0 (0.9)	2.2 (0.8)	.73
Friedman stage	2.1 (0.8)	2.3 (0.3)	2.3 (0.6)	.77
Age, y	48.3 (12.0)	51.7 (11.1)	50.4 (11.2)	.73
BMI	24.2 (2.2)	25.4 (2.8)	27.1 (2.9)	.07

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); OSA, obstructive sleep apnea.
^aData are given as mean (SD) value.

Table 3. Polysomnographic Results After MAD in All Patients

Result	Without MAD Application (A) ^a	With MAD Application (B) ^a	Difference Between A and B ^a	95% CI Around the Difference	P Value
AHI	36.6 (18.9)	12.3 (11.4)	24.3 (16.7)	16.7 to 31.9	<.001
AI	20.8 (18.3)	4.0 (9.0)	16.8 (15.6)	11.5 to 22.1	<.001
HI	16.0 (8.9)	8.6 (6.7)	7.4 (9.9)	4.0 to 10.8	.004
Apnea duration, s	24.5 (7.3)	18.4 (7.1)	6.1 (6.8)	3.8 to 8.4	<.001
Hypopnea duration, s	23.7 (5.2)	25.7 (5.5)	-2.0 (5.4)	-3.7 to 0.3	.04
Average oxygen saturation, %	94.7 (2.1)	95.2 (4.8)	-0.5 (2.1)	-1.2 to 0.3	.09
Lowest oxygen saturation, %	81.2 (6.6)	83.4 (13.4)	-2.2 (17.2)	-8.0 to 3.6	.31
Snoring, %	41 (21)	27 (8)	14 (28)	4 to 23	.007
ESS, score	9.9 (4.9)	9.0 (5.0)	0.9 (4.1)	-0.5 to 2.3	.12
PSQI	7.6 (4.0)	6.3 (3.3)	1.3 (4.1)	-0.1 to 2.7	.04

Abbreviations: AHI, apnea-hypopnea index; AI, apnea index; CI, confidence interval; ESS, Epworth sleepiness scale; HI, hypopnea index; MAD, mandibular advancement device; PSQI, Pittsburgh Sleep Quality Index.

^aData are given as mean (SD) value.

RESULTS

There were 7, 27, and 16 patients with mild, moderate, and severe OSA, respectively. There were no significant differences in baseline characteristics such as age, BMI, tonsil size, Friedman tongue position, and Friedman stage among the 3 severity groups (**Table 2**). Patients did not complain of any serious complications except for 2 patients with mild temporomandibular joint pain, which improved spontaneously over time.

TREATMENT OUTCOMES OF MAD APPLICATION

With MAD application, AHI significantly improved from 36.6 (18.9) to 12.3 (11.4) (difference, 24.3 [16.7]; 95% confidence interval [CI], 16.7 to 31.9; $P < .001$). Thirty-seven patients (74%) were classified as success, 11 (22%) as response, and 2 (4%) as no response. The apnea and hypopnea indexes also significantly improved, and the mean duration of apnea and hypopnea significantly decreased (**Table 3**). Average oxygen saturation increased from 94.7% (2.1%) to 95.2% (4.8%), without reaching statistical significance. The percentage of patients with snoring decreased markedly from 41% (21%) to 27% (8%) (difference, 14% [28%]; 95% CI, 4% to 23%; $P = .007$). Epworth sleepiness scale score also decreased from 9.9 (4.9) to 9.0 (5.0), without reaching statistical significance (difference, 0.9 [4.1]; 95% CI, -0.5 to 2.3; $P = .12$), whereas the PSQI decreased significantly from

7.6 (4.0) to 6.3 (3.3) (difference, 1.3 [4.1]; 95% CI, -0.1 to 2.7; $P = .04$) (**Table 3**).

TREATMENT OUTCOMES ACCORDING TO OSA SEVERITY

Treatment results were analyzed according to OSA severity (**Table 4** and **Table 5**). Success rates for patients with mild and moderate OSA were 43% (3 of 7 patients) and 82% (22 of 27 patients, respectively). Even in severe cases, a 75% success rate (12 of 16 patients) was obtained. In patients with mild OSA, AHI and AI were significantly improved, whereas AHI, AI, HI, snoring, and PSQI were improved in patients with moderate OSA (**Table 5** and **Figure 2**). Average and lowest oxygen saturation increased significantly in patients with severe OSA (**Table 5**).

ANALYSIS OF PROGNOSTIC FACTORS

Patients were classified into success and nonsuccess groups, and prognostic factors were assessed between the 2 outcomes (**Table 6**). Both demographic data (age and BMI) and PSG data (AHI, AI, apnea duration, hypopnea duration, average oxygen saturation, and lowest oxygen saturation) did not show any significant differences between the 2 groups. There were no significant differences between the 2 groups for Friedman tonsil size, Friedman tongue position, and Friedman stage. Furthermore,

Table 4. Cross-tabulation of Treatment Results According to OSA Severity

OSA Severity	Treatment Failure, No.	Patients, No. (%)			Total
		No Response	Response	Success	
Mild	0	1 (14)	3 (43)	3 (43)	7 (100)
Moderate	0	1 (4)	4 (15)	22 (81)	27 (100)
Severe	0	0 (0)	4 (25)	12 (75)	16 (100)
Total	0	2 (4)	11 (22)	37 (74)	50 (100)

Abbreviation: OSA, obstructive sleep apnea.

Table 5. Treatment Results After MAD Application According to OSA Severity

OSA Severity	Without MAD Application (A) ^a	With MAD Application (B) ^a	Difference Between A and B ^a	95% CI Around the Difference	P Value
Mild (n=7)					
AHI	15.7 (2.4)	10.1 (3.7)	5.6 (3.1)	3.3 to 7.9	.005
AI	5.7 (3.0)	1.7 (1.4)	4.0 (2.4)	2.2 to 5.8	.009
HI	10.0 (4.9)	8.3 (4.2)	1.7 (4.4)	-1.6 to 5.0	.42
Apnea duration, s	25.2 (7.9)	19.6 (7.0)	5.6 (5.7)	1.4 to 9.8	.12
Hypopnea duration, s	23.0 (5.9)	27.0 (6.5)	4.0 (6.3)	-0.7 to 8.7	.08
Average oxygen saturation, %	95.6 (1.7)	95.7 (1.5)	0.1 (0.8)	-0.5 to 0.7	.25
Lowest oxygen saturation, %	85.0 (3.2)	86.6 (5.7)	1.6 (5.3)	-2.3 to 5.5	.44
Snoring, %	42 (26)	18 (23)	24 (16)	11 to 35	.07
Supine position, %	48 (27)	46 (18)	2 (19)	-13 to 16	.67
ESS	10.0 (4.5)	8.9 (6.1)	1.1 (4.8)	-2.5 to 4.7	>.99
PSQI	7.2 (3.9)	5.4 (2.1)	1.8 (2.7)	-0.2 to 3.8	.35
Moderate (n=27)					
AHI	29.7 (5.7)	9.2 (6.7)	20.5 (7.6)	17.6 to 23.4	<.001
AI	15.0 (8.8)	2.3 (3.12)	12.7 (7.5)	9.9 to 15.5	<.001
HI	15.3 (6.2)	6.9 (4.7)	8.4 (8.2)	5.3 to 11.5	<.001
Apnea duration, s	24.8 (9.3)	18.1 (6.1)	6.7 (7.1)	4.0 to 9.4	<.001
Hypopnea duration, s	24.2 (4.3)	25.5 (5.3)	-1.3 (4.6)	-3.0 to 0.4	.27
Average oxygen saturation, %	94.8 (2.1)	95.0 (1.7)	-0.2 (0.7)	-0.5 to 0.1	.65
Lowest oxygen saturation, %	81.2 (6.2)	82.3 (7.8)	-1.2 (18.9)	-8.3 to 5.9	.77
Snoring, %	44 (26)	28 (23)	16 (33)	3 to 28	.04
Supine position, %	68 (26)	57 (27)	11 (15)	5 to 16	.08
ESS	10.0 (8.8)	8.2 (4.1)	1.8 (4.3)	0.2 to 3.4	.04
PSQI	8.0 (4.2)	6.1 (5.7)	1.9 (3.9)	0.4 to 3.4	.02
Severe (n=16)					
AHI	61.1 (18.5)	19.6 (17.0)	41.5 (19.9)	31.7 to 51.3	<.001
AI	41.9 (21.6)	8.7 (15.2)	33.2 (18.3)	24.2 to 42.2	<.001
HI	19.1 (12.3)	10.9 (6.6)	8.2 (16.2)	0.3 to 16.1	.10
Apnea duration, s	23.3 (6.0)	17.6 (5.3)	5.7 (7.2)	2.2 to 9.2	.02
Hypopnea duration, s	23.3 (6.3)	24.8 (5.7)	-1.5 (6.2)	-4.5 to 1.5	.43
Average oxygen saturation, %	94.0 (1.0)	95.3 (3.3)	-1.3 (3.1)	-2.8 to 0.2	.02
Lowest oxygen saturation, %	79.6 (5.4)	83.9 (8.0)	-4.3 (5.7)	-7.1 to -1.5	.02
Snoring, %	34 (20)	29 (30)	5 (33)	-11 to 21	.56
Supine position, %	64 (36)	66 (30)	-2 (27)	-11 to 16	.76
ESS	9.7 (4.4)	9.8 (5.6)	-0.1 (2.7)	-1.4 to 1.2	.92
PSQI	8.6 (4.8)	6.4 (6.8)	2.2 (4.6)	-0.1 to 4.5	.22

Abbreviations: AHI, apnea-hypopnea index; AI, apnea index; CI, confidence interval; ESS, Epworth sleepiness scale; HI, hypopnea index; MAD, mandibular advancement device; OSA, obstructive sleep apnea; PSQI, Pittsburgh Sleep Quality Index.

^aData are given as mean (SD) value.

pretreatment cephalometric data (length of uvula, length of tongue base, TB-PAS, and SP-PAS) did not show any significant difference between the 2 groups.

COMMENT

The application of MAD has been considered an established treatment option for snoring and mild OSA. A guideline published by American Academy of Sleep

Medicine in 1995 stated that MAD was indicated as first-line therapy for mild OSA and as second-line therapy for moderate to severe OSA.⁵ In the present study, we evaluated the success rate of MAD application according to OSA severity, and the success rate (based on an AHI <20 and a ≥50% reduction in AHI), even when including patients with severe OSA, was 74%. A recent article on the effectiveness of oral appliances in the treatment of severe OSA also showed that the suc-

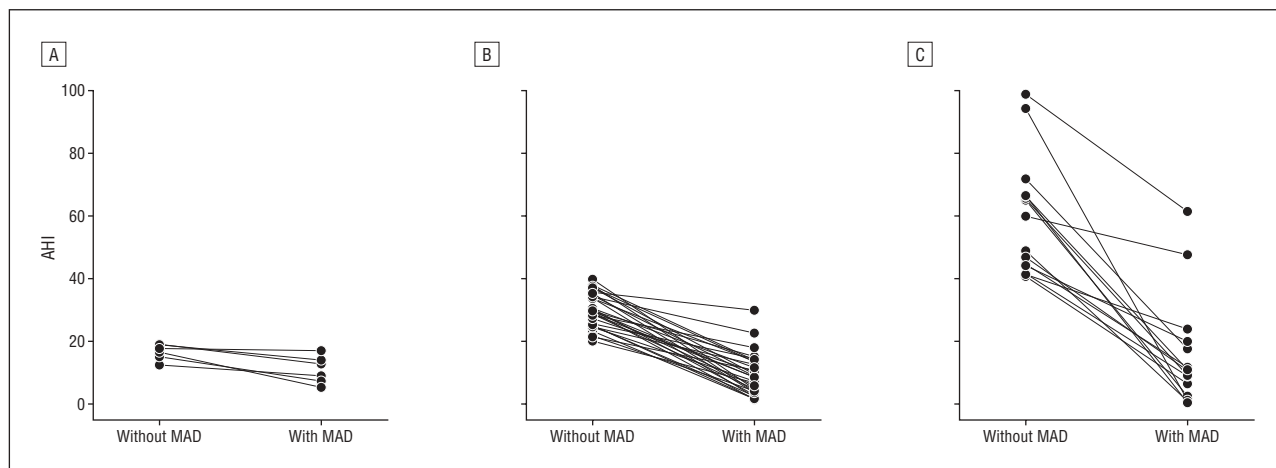


Figure 2. Change of apnea-hypopnea index (AHI) before and after mandibular advancement device (MAD) application according to severity of obstructive sleep apnea (OSA) (A, mild; B, moderate; and C, severe). A marked decrease in AHI was observed in all patients with OSA regardless of severity.

cess rate (based on an AHI <0) was 52%, showing similar results with our study.⁶ Other articles also showed a good efficacy of MAD application even for patients with severe OSA.^{7,8}

The reason that CPAP therapy has been preferred in patients with severe OSA is that CPAP therapy is more effective, relieves symptoms and apnea completely, and can be prescribed without patient selection. Two published studies have evaluated overnight titration of MAD application to determine the therapeutic efficacy and position, making it possible to be used in patients with severe OSA without delay.^{9,10} However, since MAD application had a more than 70% success rate without titration in our study, it may be controversial whether titration is required before MAD application. Interestingly, several randomized crossover studies comparing CPAP therapy vs MAD application showed that MAD application was preferred by patients even though CPAP therapy was more effective in reducing AHI, suggesting that MAD was more convenient than CPAP.¹¹⁻¹⁴

Most of the studies of MAD were performed in Western countries, and studies in Asian countries are rare.¹⁵ Because Asians have different craniofacial characteristics and have more severe OSA compared with whites when matched for age, sex, and BMI,^{16,17} we assumed that treatment outcome of MAD application might be different. However, our results are almost the same as those from previous studies.^{7,15,18,19}

We also evaluated predictors of treatment outcome using multiple variables including demographic and anatomic variables. Several known predictors related to treatment outcome have been previously published. Clinical variables such as younger age,^{13,20,21} lower BMI,^{21,22} positional sleep apnea,^{22,23} and increased amount of MAD protrusion have been shown to be related to better outcome. Smaller soft palate and tongue, shorter soft palate length, and increased retropharyngeal airway space were known to be related to better outcome. However, our study has revealed no predictors of treatment outcome. All the demographic and cephalometric variables were not different between success and nonsuccess group, while a study using precephalometry and postcephalometry

Table 6. Prognostic Factors of the Success Group vs the Nonsuccess Group

Factor	Success Group ^a (n=37)	Nonsuccess Group ^a (n=13)	P Value
Age, y	49.7 (11.1)	51.1 (11.7)	.69
BMI	25.5 (2.5)	26.9 (2.6)	.24
AHI	37.6 (28.4)	34.6 (17.4)	.66
AI	20.2 (25.6)	23.3 (15.5)	.08
Apnea duration, s	23.8 (5.4)	25.7 (6.5)	.45
Hypopnea duration, s	24.7 (6.0)	27.5 (7.8)	.24
Average oxygen saturation, %	94.8 (2.2)	94.3 (1.1)	.30
Lowest oxygen saturation, %	81.8 (6.9)	80.2 (6.2)	.49
Friedman tonsil size, grade	1.3 (0.9)	1.4 (0.6)	.62
Friedman tongue position, grade	1.9 (0.8)	2.2 (0.9)	.46
Friedman stage	2.2 (0.5)	2.3 (0.7)	.44
Length of uvula, cm	4.3 (0.4)	4.3 (0.6)	.08
Length of tongue base, cm	7.9 (0.7)	8.4 (0.3)	.29
Uvula/TB	0.5 (0.2)	0.5 (0.2)	.24
TB-PAS, cm	1.2 (0.3)	1.1 (0.4)	.33
SP-PAS, cm	0.9 (0.3)	0.9 (0.2)	.49

Abbreviations: AHI, apnea-hypopnea index; AI, apnea index; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); SP-PAS, posterior pharyngeal airway space at the level of the soft palate; TB-PAS, pharyngeal airway space at the level of tongue base; Uvula/TB, length of uvula/length of tongue base.

^aData are given as mean (SD) value.

showed that responders had an increase in hypopharyngeal sagittal cross-sectional area after wearing the appliance.²⁰

Dentists have reported most of the studies of MAD application. Otorhinolaryngologists may have not been active in the use of oral appliances owing to insufficient knowledge of MAD and low confidence in their efficiency. However, in our experience it has many advantages and could be a good adjunct treatment option in patients with OSA with poor surgical outcome. Therefore, more interest in MAD application by otorhinolaryngologist, is necessary for its development.

The limitation of our study in evaluating prognostic factors is the study size. A study with 630 patients showed

some prognostic factors such as female sex, mild sleep apnea, and supine-dependent sleep apnea.²³ Clearly, a more large-scale study would be required in evaluating treatment outcome and prognostic factors.

There might be a possibility of selection bias. Those who had not been satisfied with MAD might not have undergone PSG with MAD application, suggesting the possibility of an observed success rate higher than what would be the actual success rate. However, most of the reasons for not undertaking PSG with MAD application were economical, implying that the selection bias could be negligible. Another limitation of cephalometric data in predicting treatment outcome is that cephalometry cannot represent the dynamic physiologic state of sleep, and therefore studies with dynamic airway evaluation would be required in the future.

In conclusion, MAD is a simple, noninvasive, easy-to-manufacture, and easy-to-use device and showed good treatment outcome in nocturnal respiratory function and sleep quality in Korean patients with OSA. Even in patients with severe OSA, MAD application showed a good success rate. Hence, MAD application can be used as a good alternative option in patients with OSA, without patient selection, and could be used in patients with severe OSA.

Submitted for Publication: July 22, 2008; final revision received November 4, 2008; accepted November 16, 2008.

Corresponding Author: Jeong-Whun Kim, MD, PhD, Department of Otorhinolaryngology, Seoul National University Bundang Hospital, Seoul National University College of Medicine, 300 Gumi-dong Bundang-gu, Seongnam 464-707, Korea (kimemail@snu.ac.kr).

Author Contributions: Dr Mo had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Drs C. H. Lee and Mo contributed equally to this article. *Study concept and design:* C. H. Lee, Mo, Yoon, J.-W. Kim. *Acquisition of data:* C. H. Lee, Mo, Choi, H. J. Lee, Seo, D.-Y. Kim, Yun, H. W. Lee, and J.-W. Kim. *Analysis and interpretation of data:* Mo, Choi, H. J. Lee, Seo, D.-Y. Kim, J.-W. Kim. *Drafting of the manuscript:* Mo, Seo, J.-W. Kim. *Critical revision of the manuscript for important intellectual content:* C. H. Lee, Mo, Choi, H. J. Lee, D.-Y. Kim, Yun, Yoon, H. W. Lee, and J.-W. Kim. *Statistical analysis:* C. H. Lee, Mo, Choi, H. J. Lee, Seo, and J.-W. Kim. *Obtained funding:* C. H. Lee. *Administrative, technical, and material support:* C. H. Lee, Mo, Seo, Yun, H. W. Lee, and J.-W. Kim. *Study supervision:* D.-Y. Kim, Yoon, and J.-W. Kim.

Financial Disclosure: None reported.

REFERENCES

- Gay P, Weaver T, Loube D, Iber C; Positive Airway Pressure Task Force; Standards of Practice Committee; American Academy of Sleep Medicine. Evaluation of positive airway pressure treatment for sleep related breathing disorders in adults. *Sleep*. 2006;29(3):381-401.
- Ivanhoe JR, Attanasio R. Sleep disorders and oral devices. *Dent Clin North Am*. 2001;45(4):733-758.
- Johnson MK, Carter R, Nicol A, Paton R, Banham SW. Long-term continuous positive airway pressure (CPAP) outcomes from a sleep service using limited sleep studies and daycase CPAP titration in the management of obstructive sleep apnoea/hypopnoea syndrome. *Chron Respir Dis*. 2004;1(2):83-88.
- Riley RW, Powell NB, Guilleminault C. Maxillofacial surgery and nasal CPAP: a comparison of treatment for obstructive sleep apnea syndrome. *Chest*. 1990;98(6):1421-1425.
- American Sleep Disorders Association. Practice parameters for the treatment of snoring and obstructive sleep apnea with oral appliances. *Sleep*. 1995;18(6):511-513.
- Walker-Engström ML, Ringqvist I, Vestling O, Wilhelmsson B, Tegelberg A. A prospective randomized study comparing two different degrees of mandibular advancement with a dental appliance in treatment of severe obstructive sleep apnea. *Sleep Breath*. 2003;7(3):119-130.
- Cohen R. Obstructive sleep apnea: oral appliance therapy and severity of condition. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 1998;85(4):388-392.
- Mehta A, Qian J, Petocz P, Darendeliler MA, Cistulli PA. A randomized, controlled study of a mandibular advancement splint for obstructive sleep apnea. *Am J Respir Crit Care Med*. 2001;163(6):1457-1461.
- Pételle B, Vincent G, Gagnadoux F, Rakotonanahary D, Meyer B, Fleury B. One-night mandibular advancement titration for obstructive sleep apnea syndrome: a pilot study. *Am J Respir Crit Care Med*. 2002;165(8):1150-1153.
- Raphaelson MA, Alpher EJ, Bakker KW, Perlstrom JR. Oral appliance therapy for obstructive sleep apnea syndrome: progressive mandibular advancement during polysomnography. *Cranio*. 1998;16(1):44-50.
- Ferguson KA, Ono T, Lowe AA, Keenan SP, Fleetham JA. A randomized crossover study of an oral appliance vs nasal-continuous positive airway pressure in the treatment of mild-moderate obstructive sleep apnea. *Chest*. 1996;109(5):1269-1275.
- Ferguson KA, Ono T, Lowe AA, al-Majed S, Love LL, Fleetham JA. A short-term controlled trial of an adjustable oral appliance for the treatment of mild to moderate obstructive sleep apnoea. *Thorax*. 1997;52(4):362-368.
- Randerath WJ, Heise M, Hinz R, Ruehle KH. An individually adjustable oral appliance vs continuous positive airway pressure in mild-to-moderate obstructive sleep apnea syndrome. *Chest*. 2002;122(2):569-575.
- Engleman HM, McDonald JP, Graham D, et al. Randomized crossover trial of two treatments for sleep apnea/hypopnea syndrome: continuous positive airway pressure and mandibular repositioning splint. *Am J Respir Crit Care Med*. 2002;166(6):855-859.
- Yoshida K. Effects of a mandibular advancement device for the treatment of sleep apnea syndrome and snoring on respiratory function and sleep quality. *Cranio*. 2000;18(2):98-105.
- Li KK, Kushida C, Powell NB, Riley RW, Guilleminault C. Obstructive sleep apnea syndrome: a comparison between Far-East Asian and white men. *Laryngoscope*. 2000;110(10, pt 1):1689-1693.
- Ong KC, Clerk AA. Comparison of the severity of sleep-disordered breathing in Asian and Caucasian patients seen at a sleep disorders center. *Respir Med*. 1998;92(6):843-848.
- Millman RP, Rosenberg CL, Carlisle CC, Kramer NR, Kahn DM, Bonitati AE. The efficacy of oral appliances in the treatment of persistent sleep apnea after uvulopalatopharyngoplasty. *Chest*. 1998;113(4):992-996.
- Pancer J, Al-Faifi S, Al-Faifi M, Hoffstein V. Evaluation of variable mandibular advancement appliance for treatment of snoring and sleep apnea. *Chest*. 1999;116(6):1511-1518.
- Liu Y, Park YC, Lowe AA, Fleetham JA. Supine cephalometric analyses of an adjustable oral appliance used in the treatment of obstructive sleep apnea. *Sleep Breath*. 2000;4(2):59-66.
- Liu Y, Lowe AA, Fleetham JA, Park YC. Cephalometric and physiologic predictors of the efficacy of an adjustable oral appliance for treating obstructive sleep apnea. *Am J Orthod Dentofacial Orthop*. 2001;120(6):639-647.
- Cartwright RD. Predicting response to the tongue retaining device for sleep apnea syndrome. *Arch Otolaryngol*. 1985;111(6):385-388.
- Marklund M, Stenlund H, Franklin KA. Mandibular advancement devices in 630 men and women with obstructive sleep apnea and snoring: tolerability and predictors of treatment success. *Chest*. 2004;125(4):1270-1278.