The Effect of Positional Dependency on Outcomes of Treatment With a Mandibular Advancement Device

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Objective: To evaluate retrospectively the efficacy of the mandibular advancement device (MAD) in patients with obstructive sleep apnea in terms of positional dependency.

Design: Retrospective analysis.

Setting: Academic tertiary referral center.

Patients: One hundred patients with obstructive sleep apnea treated with the MAD at the Department of Otorhinolaryngology sleep clinic were included from January 1, 2005, through December 31, 2010.

Interventions: All patients underwent nocturnal full-night polysomnography before and at least 3 months after intraoral MAD application.

Main Outcome Measures: Treatment results and prognostic factors deciding the success of MAD application.

Results: Of the 100 patients, 80 showed positional dependency and 20 showed nondependency. In the position-dependent obstructive sleep apnea group, the median (interquartile range) apnea-hypopnea index (AHI) decreased from 32.1 (24.4-41.9) to 8.6 (3.7-13.8) (P < .001); in the nondependent group, from 56.4 (26.2-71.5) to 15.7 (6.8-30.7) (P < .001). The success rate (AHI reduction ≥50% and AHI <10) was 57.5% and 30.0% in position-dependent and position-nondependent groups, respectively (P = .04).

Conclusion: Identifying patients with obstructive sleep apnea as position dependent or nondependent may have important therapeutic implications in predicting the outcome of MAD treatment.


A MANDIBULAR ADVANCEMENT device (MAD) is known as a conservative treatment for obstructive sleep apnea (OSA). The device was designed to increase the airway space during sleep by protruding the mandible forward. The device is simple, reversible, quiet, and cost-effective and may be indicated in patients who are unable to tolerate nasal continuous positive airway pressure (CPAP) therapy or in whom surgery carries high risks.1 Most of the previous studies assessing outcomes of MAD treatment focused on changes in the overall severity of OSA and did not investigate subgroups of patients with OSA, for example, patients with position-dependent vs position nondependent OSA. A few studies have considered the positional effect of OSA on the outcome of MAD treatment. The detrimental effect of the supine posture during sleep on the frequency and severity of apnea and hypopnea events is a well-known phenomenon.2 In a preliminary study including Koreans, about three-fourths of the patients with OSA had positional dependency (defined as a supine apnea-hypopnea index [AHI] of ≥2 times the lateral AHI). Therefore, positional dependency should be considered when the outcome of MAD treatment is analyzed or when the MAD is prescribed for the patients.

Treatment of OSA with the MAD has beneficial effects on a number of important clinical variables, including the polysomnographic (PSG) indices, subjective and objective measures of sleepiness, and quality of life.3-6 However, otorhinolaryngologists play a leading role in few studies. As a result, even if a large portion of OSA patients first visit otorhinolaryngologists, the physicians are not familiar with the effect of MAD treatment and the factors determining its outcome. In addition, little research about the MAD has included Asian patients, whose mandibular size is typically smaller than that in the white population. In our study, we assess the outcome of MAD treatment according to the positional dependency in Korean patients.
with OSA, and we present practical guidelines that can be used by otorhinolaryngologists.

**METHODS**

**PATIENTS**

The study population consisted of 100 patients with OSA diagnosed by means of attended full-night PSG and treated with the MAD at the Ear, Nose, and Throat sleep clinic of Seoul National University Bundang Hospital from January 1, 2005, through December 31, 2010. Initially, 276 patients underwent MAD application. We excluded 176 patients who did not undergo PSG with the MAD application mainly because of economic reasons. We ultimately included 100 patients who had undergone a full-night PSG with or without MAD application.

The diagnosis of OSA was made when the patients had an AHI greater than 5. Patients with dental or temporomandibular diseases were excluded. We obtained general information, including age, sex, body mass index (calculated as weight in kilograms divided by height in meters squared), current medications, and medical history. An Epworth Sleepiness Scale score for daytime sleepiness was acquired, and PSG data were retrospectively reviewed for all subjects. This study was approved by the institutional review board of Seoul National University Bundang Hospital.

**ATTENDED FULL-NIGHT PSG**

Attended full-night PSG was conducted in all the patients using a commercially available recording system (N7000; Embla Recording Systems) and standard electrodes and sensors, with the supervision of an experienced technician. Electroencephalography electrodes were applied at C3-M2, C4-M1, O1-M2, and O2-M1, and 2 electro-oculography electrodes were applied at the sides of both eyes to record horizontal and vertical eye movements. Submental electromyography electrodes were applied at the submental muscle, and leg movements during sleep were recorded via electromyography electrodes from both anterior tibialis muscles. Strain gauges were used for recording chest and abdominal respiratory movements, and nasal pressure cannulas were used to record airflow. Arterial oxygen saturation was measured using pulse oximeters applied on index fingers. Based on the criteria of Rechtschaffen and Kales,7 scoring was performed every 30-second epoch as recorded on PSG. Apnea was defined as the complete cessation of airflow for at least 10 seconds. Hypopnea was defined as a substantial reduction in airflow (≥50%) for at least 10 seconds or a moderate reduction in airflow for at least 10 seconds associated with electroencephalographic arousals or oxygen desaturation (≥4%). The AHI was defined as the total number of apneas and hypopneas per hour of sleep. The severity of OSA was defined according to the criteria of the American Academy of Sleep Medicine Task Force8 (mild, AHI > 5 to <15; moderate, 15 to 30; and severe, >30).

**MANDIBULAR ADVANCEMENT DEVICE**

The MAD was made as previously described.9 In brief, all the patients were referred to a dentist, and a custom-made MAD was fabricated for each patient. The MAD was designed as a single piece (monobloc) that holds the mandible fixed at 60% of the maximum protrusion without an open bite. All the patients were regularly followed up to evaluate any dental or temporomandibular joint problems and to adjust the advancement length. Patients had a follow-up attended full-night PSG about 3 months later with the MAD in place. A successful treatment was defined in the following 2 ways: (1) reduction of AHI by 50% or more and an AHI less than 20 and (2) reduction of AHI by 50% or more and an AHI less than 10.

**POSITIONAL DEPENDENCY**

Sleeping position was analyzed by a position sensor on the chest and confirmed by direct observation of a technician using a low-light camera. The proportion of supine or lateral sleep position was measured as the percentage of time the subject was sleeping in a supine or lateral position. The AHI of supine or lateral sleep position was also recorded. All the subjects were divided into 2 groups as having position-dependent or position-nondependent OSA following the criteria of Cartwright.10 Positional dependency in OSA was defined when the supine AHI was at least 2 times greater than the lateral AHI. We also defined the positional dependency index (PDI) as the lateral AHI divided by the supine AHI to show the degree of positional dependency. In other words, if the PDI is less than 0.5, patients are described as having positional dependency; if greater than 0.5, patients do not have positional dependency.

**STATISTICAL ANALYSIS**

Descriptive statistics were first calculated. Data are presented as mean (SD) or median (interquartile range) unless otherwise stated. We used the Mann-Whitney test or Wilcoxon signed rank test to compare the demographic and PSG data. A Fisher exact test was performed to evaluate the effect of positional dependency on the outcome of MAD treatment, and AHI adjustment was accomplished using the Mantel-Haenszel test. All statistical analysis was performed using a commercially available statistical software package (Sigmastat for Windows SPSS, version 12.0; SPSS, Inc). P < .05 was regarded as statistically significant.

The average age of the patients was 51.5 (10.6) years, and 87 male and 13 female patients were included in our study. Of the 100 patients, 1 had mild, 42 had moderate, and 57 had severe OSA. The mean body mass index was 25.9 (2.9) and the mean AHI was 38.7 (19.4).

**DEMOGRAPHIC AND PSG DIFFERENCES ACCORDING TO POSITIONAL DEPENDENCY**

Of the total number of patients, 80 showed positional dependency and 20 showed nondependency. The median PDI in the position-dependent group was 0.17 (0.01-0.28) and that in the position-nondependent group was 0.77 (0.66-0.93) (P < .001). The position-dependent group included 1 patient with mild, 35 with moderate, and 44 with severe OSA, whereas the position-nondependent group included 7 with moderate and 13 with severe OSA. The median AHI was 32.1 (24.4-41.9) and 56.4 (26.2-71.5) in the position-dependent and position-nondependent groups, respectively (P = .045). The median supine AHI was 50.7 (34.1-65.9) in the position-dependent group and 58.2 (26.9-76.4) in the position-nondependent group, and there was no significant difference between the 2 groups (P = .83). The median lateral AHIs were 8.8 (0.7-15.0) and 43.5 (23.9-60.1) in position-dependent and position-nondependent groups, respectively (P < .001). The demographic and PSG data of the subjects are summarized in Table 1.
The median AHI decreased from 33.6 (24.7-49.2) to 9.6 (4.0-14.6) after MAD application in all patients (P < .001). In the position-dependent OSA group, the median AHI decreased from 32.1 (24.4-41.9) to 8.6 (3.7-13.8) (P < .001), and it decreased from 56.4 (26.2-71.5) to 15.7 (6.8-30.7) in the position-nondependent group (P < .001) (Figure, A). The median supine AHI decreased from 50.7 (34.1-65.9) to 10.8 (3.7-21.6) in the position-nondependent group (P < .001) (Figure, B). The median lateral AHI decreased from 8.8 (0.7-15.0) to 1.8 (0-5.1) in the position-dependent group (P < .001) (Figure, C). The successful rate was 57.5% and 30.0% in position-dependent and position-nondependent groups, respectively (P = .04), when the success was defined as reduction of AHI by 50% or more and an AHI less than 10. When the effect of AHI severity was controlled by the Mantel-Haenszel technique, the difference between the 2 groups was more significant (P = .03).

TREATMENT OUTCOMES ACCORDING TO SEVERITY AND POSITION

When we compared the success rate (AHI reduction ≥50% and AHI < 10) among patients with severe OSA, the success rate showed a tendency of difference between patients with position-dependent (52.3%) and position-nondependent (23.1%) severe OSA (P = .11). There was no significant difference in the success rate between the position-dependent (65.7%) and position-nondependent (42.9%) groups among patients with moderate OSA (P = .40) (Table 2).

The position-specific success rate was compared between the position-dependent and position-nondependent groups. The success rate in the supine position (supine AHI reduction ≥50% and supine AHI < 10) was 48.8% and 25.0% in the position-dependent and position-nondependent groups, respectively (P = .08). The success rate in the lateral position (lateral AHI reduction ≥50% and lateral AHI < 10) was 71.3% and 40.0% in the position-dependent and position-nondependent groups, respectively (P = .02).

CHANGE OF POSITIONAL DEPENDENCY AFTER MAD APPLICATION

The PDI was 0.31 and changed to 0.45 after MAD application (P = .76). In the position-dependent group, the PDI changed from 0.17 to 0.11 (P = .63). Among the 80 patients in the position-dependent group, 15 (19%) were changed to the position-nondependent group after MAD application. In the position-nondependent group, the PDI changed from 0.77 to 0.71 (P = .98). Of 20 patients, 10 (50%) changed to the position-dependent group after MAD application.

The treatment of OSA includes several modalities, such as airway surgery, application of the MAD, use of a tongue retainer, CPAP, weight reduction, and position therapy. Among these modalities, CPAP has been considered the most effective treatment. However, a critical limitation of CPAP is poor patient adherence to therapy. One study reported that only 46% of CPAP-treated patients continued therapy for at least 4 hours on at least 70% of all nights. As another treatment option, various upper airway surgeries have some limitations, such as postoperative pain and bleeding and no consistent success owing to the various obstructive levels and mechanisms. In this situation, the use of the MAD is now gradually increasing because it is easy, reversible, quiet, and conservative and has quite a good outcome. Nevertheless, MAD treatment has shown some limitations, such as its discomfort, temporomandibular joint pain, malocclusion, and imperfect improvement in some patients. When it comes to treatment adherence, 17 months after the start of treatment, 82% of the patients were still using the MAD almost every night. Its mechanism of action is to maintain the upper airway not only by increasing retropalatal and retrolingual spaces but also by reducing pharyngeal collapsibility.

Therapy with the MAD has been recommended, considered, and most commonly prescribed for patients with mild to moderate, but not severe, OSA. However, a previous study showed that the rate of successful outcomes in patients with severe OSA was almost comparable to that in patients with moderate OSA. The present study showed that patients with position-dependent OSA who have an AHI indicative of severe OSA also can achieve efficacious outcomes with MAD therapy. In this study, the success rate of MAD treatment in patients with position-dependent severe OSA was 52.3%.

Some studies have also suggested that the effectiveness of MAD therapy may be influenced by sleep posi-
Figure. Apnea-hypopnea index (AHI; defined as the total number of apneas and hypopneas per hour of sleep) with or without a mandibular advancement device (MAD) in position-dependent and -nondependent groups with obstructive sleep apnea (OSA). A, The overall median (interquartile range) AHI decreased from 32.1 (24.4-41.9) to 8.6 (3.7-13.8) (P<.001) in the position-dependent group and from 56.4 (26.2-71.5) to 15.7 (6.8-30.7) in the position-nondependent group (P<.001). B, The supine-specific AHI decreased from 50.7 (34.1-65.9) to 10.8 (3.7-21.6) in the position-dependent group (P<.001) and from 58.2 (26.9-76.4) to 16.4 (9.3-32.7) in the position-nondependent group (P<.001). C, The lateral-specific AHI decreased from 8.8 (0.7-15.0) to 1.8 (0-5.1) in the position-dependent group (P<.001), and it decreased from 43.5 (23.9-60.1) to 11.1 (5.2-24.9) in the position-nondependent group (P<.001). Black lines indicate medians; boxes, interquartile ranges; and limit lines, 5th and 95th percentiles.

Table 2. Success Rate of MAD Application According to Positional Dependency and Severity of AHI

<table>
<thead>
<tr>
<th>Position Dependency by AHI</th>
<th>Overall AHI</th>
<th>Position Dependent OSA (n=80)</th>
<th>Position Nondependent OSA (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=80</td>
<td>n=57</td>
<td>n=23</td>
</tr>
<tr>
<td>Mild (AHI &gt; 5 to &lt; 15)</td>
<td>0</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>Moderate (AHI 15 to 30)</td>
<td>71.4</td>
<td>52.3</td>
<td>53.8</td>
</tr>
<tr>
<td>Severe (AHI &gt; 30)</td>
<td>84.1</td>
<td>84.1</td>
<td>58.2</td>
</tr>
</tbody>
</table>

Abbreviations: AHI, apnea-hypopnea index (calculated as total number of apneas and hypopneas per hour of sleep); MAD, mandibular advancement device; NA, not applicable; OSA, obstructive sleep apnea.

Prevalence of position-dependent OSA varies from 9% to 20% according to the patient number and method of evaluating apnea. Cartwright first mentioned position-dependent OSA and reported that it accounted for 58.3% of patients with OSA. In our study, 80 of the 100 patients had position-dependent OSA.

This study evaluated the usefulness of MAD therapy in position-dependent and position-nondependent patients with OSA. We found that patients with position-dependent OSA had substantially better treatment outcomes than did patients with position-nondependent OSA. When treatment success was defined as an AHI less than 20 with MAD application, the MAD success rate was 77.5% in position-dependent and 60.0% in position-nondependent OSA. However, the difference was not statistically significant. On the other hand, when success was defined as more complete reduction of obstructive events to an AHI less than 10, the therapeutic outcome was much better in position-dependent (57.5%) than in position-nondependent (30.0%) patients. Because the MAD is also a device that, like a CPAP mask, should be put on every night, adherence cannot be perfect. Therefore, MAD application may not be enough as a treatment, especially for position-nondependent patients.

The present study has some limitations. For example, only a small number of position-nondependent patients were included. This imbalance may affect statistical interpretation of success rates between the 2 positional-dependency groups. In the future, investigations that include more position-nondependent patients are required. The previous studies also had some limitations in that they only reported the success rate of MAD treatment in position-dependent and position-nondependent groups. In our study, we tried to compare the success rate according to the severity of OSA. The success rate was likely to be different between the 2 groups in the patients with severe OSA, whereas there was no significant difference in patients with mild or moderate OSA. We also compared the position-specific success rate between position-dependent and po-
Our study has shown that the therapeutic effect of MAD application was quite encouraging; therefore, the MAD should be considered one of the therapeutic options as a single treatment modality or an adjunctive modality to airway surgery or CPAP treatment. However, the extent of improvement should also be predicted before MAD application by clinicians. Our study showed that positional dependency and disease severity were significantly helpful for the prediction of treatment outcome. Position-nondependent severe OSA in particular may not be an indication for MAD treatment. Further studies for predictors are needed to estimate more precisely the treatment results. In addition, the criteria for success with the MAD should be clarified in terms of future disease morbidity or mortality.

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