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## Review

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# Dental Approach for Obstructive Sleep Apnea by Using Oral Appliance in Tokushima University Hospital: New Challenge of Clinical Treatment

Susumu ABE<sup>1)</sup>, Keisuke NISHIGAWA<sup>2)</sup>, Fumiaki KAWANO<sup>1)</sup>

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**Abstract :** Obstructive sleep apnea (OSA) is characterized by intermittent upper airway obstruction during sleep. It causes sleep fragmentation from brief arousal and affects social life by excessive daytime sleepiness. Moreover, OSA is considered a risk factor for cardiovascular complications and type 2 diabetes as associated features. The gold standard treatment for OSA is continuous positive airway pressure during sleep. However, if this treatment is frustrating to the patient or the apnea and hypopnea index is low or mild, alternative treatments for OSA must be found. One possible treatment is an oral appliance (OA) to improve the upper airway configuration. Dental clinicians have attempted to improve this respiratory condition caused by OSA by using OA, and at Tokushima University Hospital, OA therapy has been in use since 1993. Nishigawa et al. introduced a method to fabricate an OA and to investigate the effects of this therapy. In the present article, the method of OA fabrication was modified, and its effects were evaluated. Dental clinicians should have some knowledge about the mechanics of sleep and the management of sleep conditions so that they can cooperate closely with medical physicians. Thus, collaboration between the medical and dental fields can help patients attain healthy sleep.

### Introduction

Sleep apnea is one of the sleep-related breathing disorders. It is mainly divided into two types: obstructive sleep apnea (OSA) and central sleep apnea. OSA is characterized by intermittent upper airway obstruction experienced as complete or partial events during sleep and defined as the occurrence of five or more episodes per hour of sleep<sup>1)</sup>. Furthermore, OSA is estimated to affect 5%–15% of adults in the United States, of whom 24% are middle-aged men and 9% are women<sup>2)</sup>. In Japan, there are around two billion potential OSA patients. Because OSA interferes with refreshing sleep, sleepiness and fatigue during the daytime decrease the quality of life and

social function. Moreover, excessive sleepiness may cause traffic accidents<sup>3)</sup>. OSA is also associated with systemic illnesses such as systemic hypertension<sup>4)</sup> or type 2 diabetes<sup>5,6)</sup> and a pervasive sleep problem worldwide.

To examine a patient with a sleep complaint, medical physicians interview a patient to understand his/her sleep condition or systemic or respiratory condition and administer a sleep questionnaire (such as the Epworth Sleepiness Scale [ESS])<sup>7)</sup> and sleep test by using polysomnography (PSG) or portable respiratory recording device during sleep (PRRS) to determine an OSA diagnosis. The apnea and hypopnea index (AHI) during sleep is calculated for each patient. Medical

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<sup>1)</sup> Department of Comprehensive Dentistry, Tokushima University Graduate School

<sup>2)</sup> Department of Oral Health Sciences, Faculty of Health and Welfare, Tokushima Bunri University

physicians provide a treatment for OSA after considering the patient's systemic condition, sleepiness level, and AHI. The gold standard for the treatment of OSA is usually the continuous positive airway pressure (CPAP) therapy during sleep as respiratory management. However, the continuous usage of CPAP therapy is difficult and has low compliance because it has mainly nasal and pharyngeal side-effects<sup>8)</sup>, and the CPAP machine is relatively huge to carry and needs electrical power. Moreover, if the AHI during sleep needs to be 20 or less from PSG or 40 or less from PRRS, CPAP is not covered by the national health insurance in Japan<sup>9)</sup>; therefore, patients with mild to moderate AHI will not use CPAP therapy regardless of daytime sleepiness and physical fatigue. Thus, an oral appliance (OA) is an alternative treatment to OSA and can be fabricated by dental clinicians. OA is easy to carry (and therefore easy to travel with) because it is smaller than a CPAP machine and does not need electricity to run. Furthermore, OA therapy is covered by the national health insurance regardless of the AHI during sleep. However, it is less effective for mild-moderate OSA (AHI  $\leq$  20) than CPAP.

Dental clinicians can usually provide OSA patients with a mandibular advancement device (MAD) as one of OA and fabricate one to improve a respiratory problem. After wearing the MAD during sleep, the patient can be interviewed about the frequency of MAD usage and daytime sleepiness. If necessary, the dental clinician can ask the medical physician about the patient's respiratory condition, including apnea, hypopnea, and snoring while using PSG or PRRS. Thus, collaboration between the medical and dental fields can help the patient realize good quality sleep.

Nishigawa et al. introduced the MAD fabrication method and showed the results of MAD usage and treatment effect by using self-report questionnaires from their patients in Tokushima University Hospital<sup>10)</sup>. However, the amount of mandibular advancement could not be determined at chairside with the patient; the mandibular position of MAD was based on the dental clinician's experience in the dental laboratory. Furthermore, the need for patients to be educated about the sleep environment and to collaborate with the medical physician for sleep management became evident in some cases of OSA.

The aim of this article is mainly to introduce the present modified treatment method and flow in Tokushima University Hospital, and the need for management of the sleep conditions is described after cooperating closely with the medical physician.

### **Oral appliance (mandibular advancement device) therapy**

Because MAD therapy for OSA and the general outline of

the shape were described in detail in a previous article<sup>10,11)</sup>, a summary of MAD therapy flow is introduced in this section. In particular, the fabrication method of a MAD is modified in contrast with the previous report. First, the amount of mandibular advancement (protractive mandibular position) was determined at chairside with the patient. Second, the simple appliance (bite plane) on each dental arch was used in order to determine the protractive mandibular position in patient's oral cavity.

#### **1. Examination of stomatognathic system**

After obtaining the information about AHI or sleep condition from medical physicians, dental clinicians must interview patients to understand their sleep quality and examine their oral condition, including the number of missing teeth, tooth mobility, dental decay, occlusal relationship, and prosthodontic appliances in detail. Furthermore, the temporomandibular joint must be checked by determining mandibular movement and a panoramic radiograph. If patients have dental disease such as dental decay, periodontal disease, or temporomandibular disease, dental clinicians should suggest the most compelling dental treatment to them. Because the MAD is secured to the teeth, periodontal disease can induce undesirable mobility because of missing teeth or tooth. A summary and conceivable side-effects of MAD are explained to the patients before taking an impression.

#### **2. Preparation for MAD**

The individual tray for each patient is prepared by creating a brief dental cast. A final impressions for maxillary and mandibular dentitions are taken using a silicon rubber material. Moreover, a brief maxillomandibular registration is taken by a silicon bite material. The maxillary and mandibular cast models are set on the articulator in the dental laboratory. Maxillary and mandibular bite plates are prepared to determine a suitable protractive mandibular position and made by a thermoplastic resin plate of a hard type, which is 1 mm thick and fixed on the articulator (Figure 1). There are some critical regulations when dental clinicians select the type of MAD; it should be either a monobloc type or a two-piece type, considering the patient's oral and sleep condition. We usually select the two-piece type in Tokushima University Hospital in the case of a dentulous jaw. If the two-piece type with Herbst appliance is selected, the vertical dimension increases to secure space. On the other hand, a monobloc appliance for MAD therapy is adopted in cases of anodontia or lack of many teeth<sup>10)</sup>.

First, conformation of each bite plate needs to be fixed on the jaw (Figure 2). Next, the overjet is measured using a

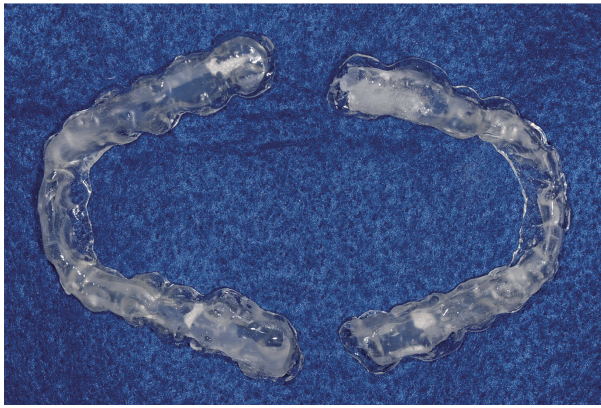


Fig. 1 The thermoplastic hard resin plate with a thickness of 1 mm is provided.



Fig. 2 The dental clinician checks whether the resin bite plate is rigidly placed on each jaw.

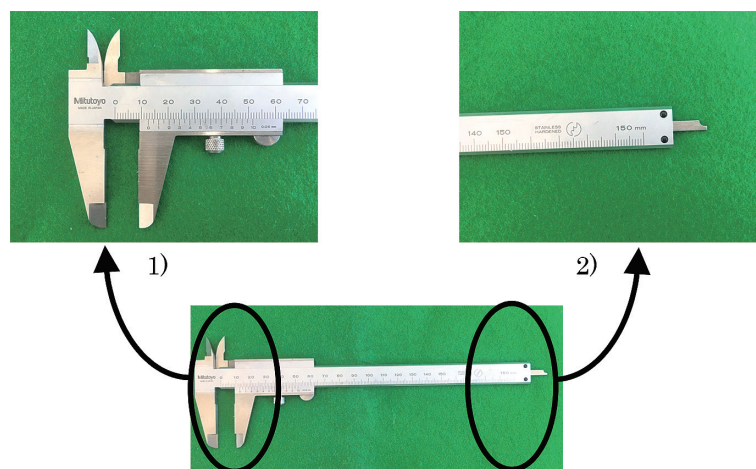


Fig. 3 A pair of calipers is used for the measurement of overjet at the centric position or mandibular advancement position.  
1) The measured value; 2) The depth gauge to measure overjet

pair of calipers (530-101 N15, Mitutoyo Co., Japan, Figure 3), and the midline is determined when the patient bites the centric position (Figure 4-1). Moreover, the mandibular bite plate is easily fixed because it needs to move to the maximum mandibular advancement position (Figure 4-2). A point to be aware of regarding the maxillomandibular registration is the lateral dislocation of the right and left midline of the mandible when it moves to a frontal excursion. The mandibular advancement position is usually considered when the lower arch appliance keeps the maximum position, which is between 50% and 75% of the maximum protrusion<sup>12, 13</sup>. Then, a suitable amount of mandibular advancement needs the maximum position to maintain within a permissible range for the patient. Amount of mouth opening is less than 5 mm in incisal tooth<sup>10</sup>. The mandibular position is decided, and the maxillary and mandibular bite plates are attached firmly by a photo-curable resin (Figure 5-1 and 5-2). The mandibular

advancement position in this series is recommended to be established by tilting the dental chair to a supine position similar to the patient's sleeping position.

### 3. Fabrication of OA (MAD)

The MAD is a Herbst appliance, which is constructed of hard acrylic resin connected with bilateral telescopic tubes (Figure 6). This two-piece OA is provided for most of the patients with OSA in Tokushima University Hospital. This MAD is quite advantageous because of its bilateral telescopic tubes. If the OSA condition is not improved or the patient has jaw pain or fatigue in the morning, the bilateral telescopic tubes can easily change the mandibular advancement position<sup>10</sup>. However, because the joint structure is close to the bilateral corner of the mouth, it can be uncomfortable to a patient when his/her mouth is closed (Figure 7).

The presence of temporomandibular pain when the MAD

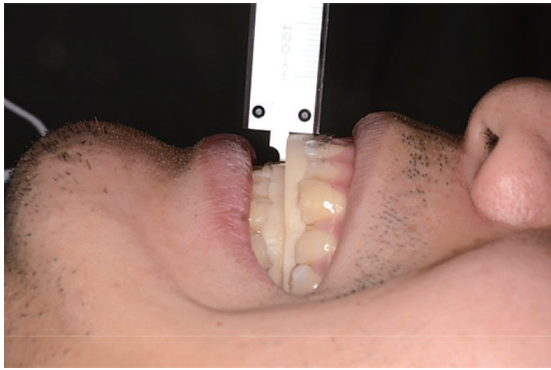


Figure 4-1

Fig. 4-1 Amount of overjet is measured at the centric position with the resin bite plate by using a depth gauge.



Figure 4-2

Fig. 4-2 The amount of mandibular advancement is measured and is the same as the measurement of the centric position.



Figure 5-1

Fig. 5-1 The patient holds at a suitable mandibular advancement position. The photo-curable resin is poured between maxillary and mandibular bite plates.



Figure 5-2

Fig. 5-2 The dental photopolymerization device is immediately used to fix both bite plates without removing them.

is inserted requires an adjustment of the MAD. Moreover, the patient must be educated about the handling methods of the MAD and the minor side-effects, which are jaw fatigue, occlusal discomfort, and xerostomia in the morning. Dental clinicians must make a subsequent appointment to evaluate the patient's condition.

#### 4. Evaluation of OSA

A questionnaire is provided to evaluate the OSA by using the Japanese ESS and original questionnaire items. The dental clinician asks the patient detailed questions about his/her oral or sleep conditions on the basis of the questionnaire. Moreover, we must check his/her oral cavity, the amount of mouth opening, overjet and overbite, jaw movement, and temporomandibular joint condition by using the diagnostic criteria of the temporomandibular joint and adaptation of the MAD. Lateral skull radiographs are used for cephalometric analysis to confirm the role of opening the pharynx in

comparison to no MAD<sup>14,15</sup>. Moreover, a pulse oximetry device during sleep is prepared as an objective evaluation of OSA<sup>16,17</sup>. The patient measures the oxygen saturation and heart rate for four consecutive nights, alternately without and with the MAD<sup>18</sup>. If these data and subjective evaluation are not satisfactory, the mandibular advancement position is reconsidered or a treatment method by changing the position of the sleeping body is developed. The dental clinician should make appointments to ask about the sleep or daytime condition and assess the patient's stomatognathic system every two or three months. After the frequency of MAD usage increases or the OSA improves, the patient is reintroduced to the medical physician, and a sleep test with the MAD is performed using PSG or PRRS to compare to the previous data<sup>10</sup>. These data should be shared between the medical and dental fields.



Fig. 6 MAD with bilateral telescopic tubes, a Herbst type made from hard acrylic resin.

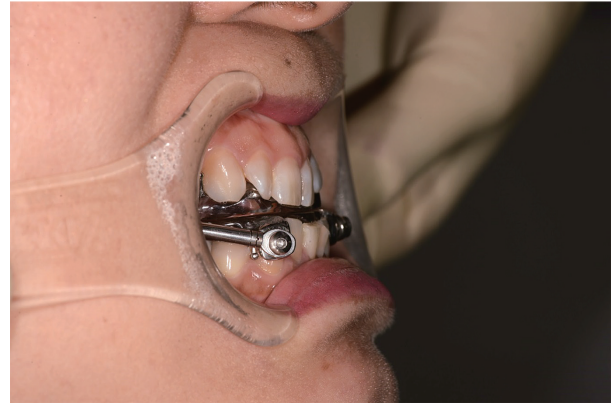


Fig. 7 Because the bilateral joint structure is close to each corner of the mouth, it is uncomfortable to a patient when his/her mouth is closed; it is difficult to close the lips.

Table 1 Demographic data and information of MAD for each patient.

Patient	Gender	Age	Period	Type of MAD	Usage	Effective
1	Female	47.8	2.8	Herbst	0	3
2	Male	67.6	2.1	Mono	1	4
3	Female	74.4	1.7	Mono	1	2
4	Female	79.5	2.2	Herbst	1	1
5	Male	59.8	1.5	Herbst	0	2

Usage (frequency of MAD usage): 0, every night; 1, five or six days in a week

Effective (subjective effectiveness of OSA): 1, somewhat effective; 2, effective; 3, very effective; 4, does not know whether it is effective

### Progress report of the new trial

#### 1. Investigation object

A new fabrication method and evaluation were started in 2015, and 17 patients (13 male, four female) underwent treatment of OSA by using a MAD. Some research parameters were investigated such as frequency of MAD usage; subjective effectiveness of the MAD therapy; cephalometric analysis; and AHI (apnea and hypopnea index), apnea index (AI), and hypopnea index (HI) from PSG or PRRS compared to a night without the MAD. Five of the patients had an examination after becoming accustomed to the MAD for more than one year in this evaluation; their results for evaluation or items of MAD usage were fully satisfactory. This research was approved by the Ethical Committee of Tokushima University Hospital (no. 2544).

#### 2. Results of investigation

Five patients (two males and three females) were introduced from the cardiovascular medicine department in the hospital. They used an OA for about  $2.0 \pm 0.4$  years on average.

The MAD treatment period of these patients was ranged from 1.5 years to 2.8 years. Three patients used a twin-block MAD such as the Herbst type, and two patients used the monobloc type of OA (Table 1).

Two patients used the MAD every night; however, three patients did not use the MAD one or two days in a week. One patient felt subjectively good relief from OSA symptoms, which were sleepiness, laziness, and snoring before using the MAD. However, one patient did not know whether the MAD was enough to affect his OSA symptoms (Table 1).

A subjective sleepiness test was performed using ESS after MAD therapy for comparison to that before OSA treatment. The average ESS score decreased from 7.4 to 5.8 (Figure 8), and four patients reduced their sleepiness score. Two of four patients reduced sleepiness from the range of strong to light sleepiness. One of them showed reduced sleepiness from the range of light sleepiness to the range of no sleepiness. One of five patients showed increased sleepiness score; however, his sleepiness score included the range of no sleepiness both before and after MAD therapy (Figure 8). The patients

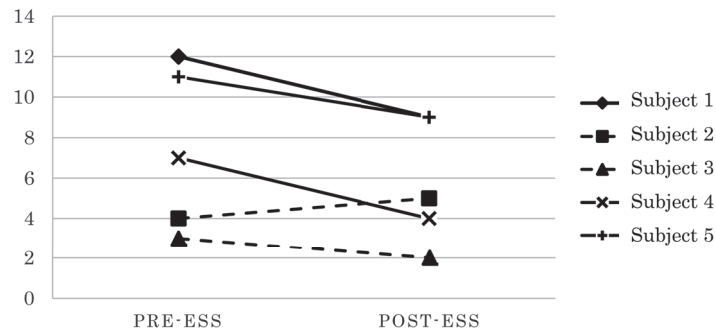


Fig. 8 Subjective sleepiness tests were performed using ESS before MAD therapy (Pre-ESS) and after MAD therapy (Post-ESS).

Full-line, two-piece MAD (Herbst). Dash line, monobloc MAD

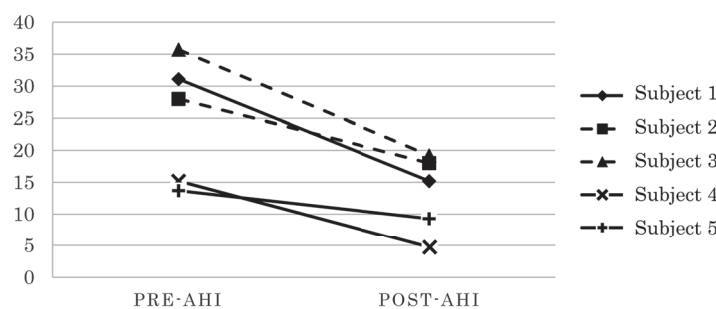


Fig. 9-1 AHI was calculated from PSG or PRRS as objective evaluation before MAD therapy (Pre-AHI) and after MAD therapy (Post-AHI).

Full-line, two-piece MAD (Herbst). Dash line, monobloc MAD

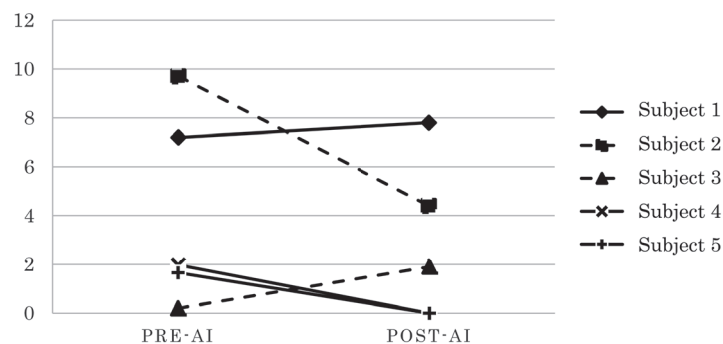


Fig. 9-2 AI was calculated from PSG or PRRS as objective evaluation before MAD therapy (Pre-AI) and after MAD therapy (Post-AI).

Full-line, two-piece MAD (Herbst). Dash line, monobloc MAD

received a post-treatment examination using PSG or PRRS, after they became accustomed to MAD therapy during sleep. An average AHI was 24.72 before MAD therapy, whereas AHI after MAD therapy decreased to 13.28 (Figure 9-1). For AI, one patient with a monobloc MAD reduced sleepiness from 9.7 to 4.4. However, there was no significant change in the AI between before and after MAD therapy for other patients (Figure 9-2). The change in HI showed the same trend as that

of the AHI (Figure 9-3). The cephalometric measurements were performed without and with MAD. Thus, the difference in craniofacial bony structure or soft-tissue variables between the presence and absence of MAD was validated. These patients did not have abnormal values for craniofacial bony structure or soft-tissue variables. However, the minimum pharyngeal distance (PAS (Minimum)) was relatively small, and insertion of the MAD increased it. Moreover, mandibular

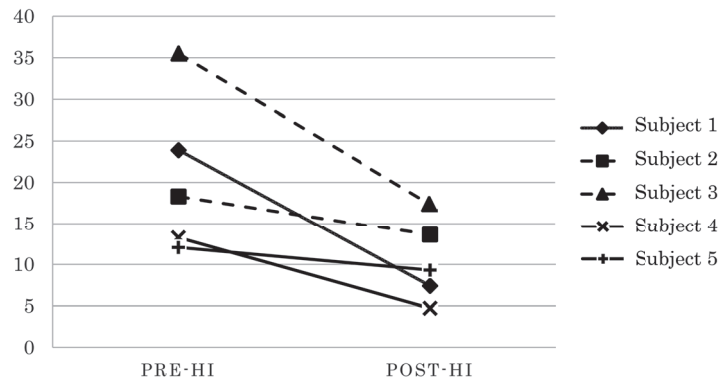


Fig. 9-3 HI was calculated from PSG or PRRS as objective evaluation before MAD therapy (Pre-HI) and after MAD therapy (Post-HI).

Full-line, two-piece MAD (Herbst). Dash line, monobloc MAD

Table 2 Basic craniofacial bony structure and soft-tissue variables, and hyoid bone positions and pharyngeal dimensions of the cephalometry in OSA patients.

Parameters	Average	Without OA	With OA
MPZ-H (mm)	14.00 ± 6.40	14.88 ± 3.61	9.18 ± 3.19
PNS-V (mm)	73.50 ± 5.80	69.36 ± 3.83	69.9 ± 4.43
PNS-P (mm)	39.00 ± 4.80	40.30 ± 3.25	38.62 ± 3.49
MPT (mm)	11.30 ± 2.20	10.02 ± 0.84	11.06 ± 1.95
SNB (°)	78.80 ± 3.40	78.38 ± 3.54	80.04 ± 3.34
S-N (mm)	73.50 ± 3.40	70.28 ± 2.60	70.28 ± 2.60
ANS-PNS (mm)	54.50 ± 4.40	54.32 ± 1.62	53.96 ± 1.57
Me-Go (mm)	77.00 ± 5.50	74.18 ± 5.83	74.76 ± 6.51
PNS-AA (mm)	40.00 ± 4.60	36.24 ± 4.34	36.64 ± 4.25
AW (PNS-Ba) (mm)	26.90 ± 4.50	29.74 ± 4.12	29.15 ± 3.22
PAS (Minimum) (mm)	11.00 ± 4.40	7.86 ± 3.61	10.66 ± 3.91
PAS (ML) (mm)	15.70 ± 5.20	12.36 ± 3.30	15.46 ± 2.65

MP, mandibular plane, a plane constructed from Me through Go; H, most antero-superior point of the hyoid; MP-H, the linear distance along a perpendicular plane from H to MP; PNS, posterior nasal spine, most posterior point of the nasal spine; V, most antero-inferior point of the epiglottic fold; P, lowest point of the soft palate; MPT, the greatest thickness of the soft palate; S, sella, midpoint of the fossa hypophysealis; N, nasion, anterior point at the frontonasal suture; B, deepest anterior point in the concavity of the anterior mandible; SNB, the angle between S-N and N-B; ANS, anterior nasal spine, most anterior point of the nasal spine; Me, menton, most inferior point of the bone chin; Go, gonion, a mid-plane point at the gonial angle located by bisecting the posterior and inferior borders of the mandible; AA, anterior atlas; Ba, basion, most postero-inferior point on the clivus; AW (PNS-Ba), the airway width along PNS-Ba; PAS (Minimum), the narrowest part of airway between PNS and P; PAS (ML), the narrow part of airway on MP level

protrusion increased the angle between sella-nasion (S-N) and nasion-deepest anterior point in the concavity of the anterior mandible (N-B) and reduced the linear distance along the

perpendicular plane from the most anterosuperior point of the hyoid because of mandibular rotation (Table 2).

### Conclusion

OSA is usually recognized as an effect of age. The population of potential OSA patients was approximately 2 billion in Japan in 1996. In an aging society, OSA patients will continue to increase. Furthermore, OSA affects systemic illness and induces excessive daytime sleepiness. Unfortunately, dental clinicians cannot diagnose OSA and fabricate an OA without diagnosis from medical physicians. Dental clinicians need to cooperate with medical physicians or professionals and retain accurate knowledge about patients' sleep and OSA, because a diverse range of OSA has become apparent in recent years. This article showed a modified method for the amount of mandibular protrusion and the evaluation between pre-OA and post-OA treatment by using an ESS questionnaire, AHI from PSG or portable respiratory recording device, and cephalometric measurements. For the future, a better method to decide the mandibular protractive position for MAD will be investigated through postoperative evaluation for OSA patients.

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