Tohoku J. Exp. Med., 1999, **188**, 119-132

Effect of Mandibular Advancement Splint on Psycho-Intellectual Derangements in Patients with Sleep Apnea Syndrome

YASUTAKA NAMBU, YUKIO NAGASAKA, ETSUO FUJITA, SUGURU HAMADA[1] and MASAHIRO FUKUOKA

The Fourth Department of Internal Medicine, and [1]The Department of Stomatology, Kinki University School of Medicine, Osakasayama 589-8511

NAMBU, Y., NAGASAKA, Y., FUJITA, E., HAMADA, S. and FUKUOKA, M. *Effect of Mandibular Advancement Splint on Psycho-Intellectual Derangements in Patients with Sleep Apnea Syndrome.* Tohoku J. Exp. Med., 1999, **188** (2), 119-132 —— The mandibular advancement splint (MAS) was recently introduced for the management of sleep apnea syndrome (SAS), although its effects on psycho-intellectual functions have not been elucidated yet. We examined psycho-intellectual function before and after treatment with MAS in patients with SAS. Twenty patients with SAS underwent psycho-intellectual function testing before and after treatment with MAS for 3 to 4 weeks. The apnea index significantly decreased from 19.0±15.6 to 2.4±1.9. The state anxiety score significantly decreased from 44.6±12.1 to 33.7±11.1, the trait anxiety score significantly decreased from 46.2±13.4 to 37.6±13.8, and the depression scale score significantly decreased from 39.2±11.0 to 30.8±9.9 with MAS treatment. By the Cornell Medical Index and the Yatabe-Guilford test, the patients became less neurotic and less eccentric after treatment. By the Uchida-Kraepelin psychodiagnostic test, calculation ability significantly increased from 1247.4±402.1 to 1950.2±651.9. We conclude that MAS treatment reduces apneic episodes and improves psycho-intellectual derangements in patients with SAS. ——— sleep apnea syndrome; mandibular advancement splint; nocturnal desaturation; psycho-intellectual function

Daytime sleepiness and impaired function are major clinical features of sleep apnea syndrome (SAS) (Cheshire et al. 1992), and a deterioration of psycho-intellectual function has been shown in these patients (Findley et al. 1986, 1992; Lamphere et al. 1989; Whyte et al. 1989; Bedard et al. 1993; Engleman et al. 1994, 1997; Baumel et al. 1997). In SAS, sleep is disturbed by frequent apnea. This lesser quality of sleep and repeated hypoxemia during sleep may lead to daytime hypersomnia and possibly to impaired psycho-intellectual function during the daytime (Findley et al. 1986; Cheshire et al. 1992). Nasal continuous

Received February 3, 1999; revision accepted for publication May 16, 1999.

Address for reprints: Dr. Yasutaka Nambu, The Fourth Department of Internal Medicine, Kinki University School of Medicine, 377-2 Ohnohigashi, Osakasayama 589-8511, Japan.

positive airway pressure (NCPAP) has been the treatment of choice in most cases of obstructive sleep apnea when there were no specific causes of upper airway obstruction such as enlarged tonsils and adenoids (Kryger 1992). The NCPAP treatment has been shown to improve daytime function in patients with SAS (Engleman et al. 1994, 1997), although neuropsychological deficits may be persistent (Bédard et al. 1993).

Although NCPAP is a useful modality in the treatment of SAS, it requires a rather expensive device. The noise of the motor to generate positive pressure to the nasal mask and the tight mask around the patients' nose are other problems with NCPAP and may disturb sleep. Thus, acceptance and compliance are major problems associated with NCPAP therapy (Kribbs et al. 1993a, b; Reeves-Hoche et al. 1994; Engleman et al. 1996; Likar et al. 1997).

The mandibular advancement splint (MAS) holds the mandible forward and increases oropharyngeal and hypopharyngeal dimensions (O'Sullivan et al. 1995; Miyamaru et al. 1996). MAS was recently introduced in the management of SAS and is noninvasive and usually well tolerated (O'Sullivan et al. 1995; Miyamaru et al. 1996; Ferguson et al. 1997). However, the effect of MAS on psycho-intellectual function has not been elucidated yet. To clarify this, we assessed psycho-intellectual function in patients with SAS before and after treatment with MAS.

Patients and Methods

Study subjects

Twenty patients with SAS diagnosed by clinical history and portable apnea monitor (Apnomonitor, MAY-715, Chest, Tokyo) were assigned to use MAS (Tables 1 and 2). Duration of SAS was determined by the clinical history of the symptoms including daytime hypersomnia and/or disruption of breathing with snoring. Apneic episodes of more than 30 times/night or apnea index (AI: number of apneic episodes per hour) of more than five was diagnosed as sleep apnea. When the diagnosis was established, the patients were informed of the study protocol and agreed to participate.

MAS

Dental impressions were taken of both the maxillary and the mandibular arch in each patient. MAS was constructed of copolyester (Erkodur, Erkodent, Pfalzgrafenweiler, Germany) to be in contact with all teeth and adjacent gingiva from the mandibular impression (Fig. 1). The mandibular part was then protruded by 5 to 10 mm anterior to the maxillar part of MAS and was adhered with quick self-curing acrylic resin (Unifast Trad, GC Dental Products, Kasugai). The degree of protrusion was readjusted when necessary according to patient comfort and to its effectiveness on apneic episodes. The final advancement of the mandibular part was 6.6 ± 1.7 mm (mean $\pm$ S.D.). The vertical opening of the

Table 1. *Patient characteristics*

Subjects	Age (Years)	Sex	BMI	History of SAS (Years)
1	44	F	20.3	3
2	45	F	22.8	10
3	47	F	16.7	3
4	52	F	28.8	3
5	57	F	22.2	10
6	61	F	24.1	1
7	63	F	29.3	1
8	64	F	26.2	6
9	27	M	35.7	2
10	37	M	35.4	10
11	41	M	24.6	1
12	45	M	23.1	1
13	46	M	23.6	1
14	46	M	29.1	17
15	49	M	25.6	6
16	55	M	25.6	10
17	56	M	25.8	6
18	60	M	22.1	5
19	64	M	22.7	5
20	67	M	22.7	13
Mean $\pm$ s.d.	51.3 $\pm$ 10.4		25.3 $\pm$ 4.6	5.7 $\pm$ 4.6

BMI, body mass index ; SAS, sleep apnea syndrome.

device was set at around 10 mm and was also adjusted according to patient comfort. The final opening of MAS was 7.4 $\pm$ 2.1 mm. The side effects of MAS (jaw pain and dryness of throat etc.) were determined by questioning the patient.

Study design

The effects of MAS on SAS were assessed by examining the sleep respiration monitoring and psychological tests before and three to four weeks after continuing MAS treatment.

Sleep respiration monitoring

We recorded the duration and frequency of apnea with an Apnomonitor (Hida et al. 1993). With the Apnomonitor, nasal flow of breathing and tracheal breath sounds detected at the anterior neck were recorded along with an electrocardiogram (ECG). The frequency of apnea was counted when disruption of nasal flow along with disappearance of breath sound was observed for more than 10 seconds. The frequency of apnea and total and longest duration of apnea were

TABLE 2. *The effects of MAS (mandibular advancement splint) on apneic episodes and oxygen saturation (SpO_2)*

Subjects	Apnea index		Apneic episodes (times)		Lowest SpO_2 (%)		Mean SpO_2 (%)	
	No MAS	MAS	No MAS	MAS	No MAS	MAS	No MAS	MAS
1	21.3	3.7	197	34	93	91	97	97
2	40.4	3.4	370	27	64	79	94	98
3	3.5	0.4	32	0	81	88	96	97
4	37.4	4.9	351	47	35	43	86	95
5	6.2	1.3	47	11	84	88	96	96
6	13.1	2.5	110	23	80	77	95	95
7	5.8	0	58	0	78	86	91	92
8	8.2	2.5	77	24	87	81	96	94
9	43.5	5.5	387	46	34	75	79	93
10	19.0	2.4	145	24	53	48	88	94
11	5.3	0.4	47	1	65	81	92	96
12	12.5	4.4	125	40	63	64	96	96
13	20.1	0	174	0	75	82	93	96
14	53.6	5.4	405	46	79	90	90	95
15	16.6	4.2	154	39	73	68	94	94
16	6.1	1.4	60	17	77	86	95	95
17	12.7	0.5	115	4	75	86	95	96
18	3.6	0.1	32	1	87	87	97	97
19	42.3	1.2	344	9	80	76	96	96
20	9.6	2.9	85	26	89	89	96	96
Mean ± S.D.	19 ± 15.6	2.4 ± 1.9***	166.8 ± 130.6	21 ± 17.1***	72.6 ± 16.3	78.3 ± 13.3*	93.1 ± 4.5	95.4 ± 1.5*

$^{*}p<0.05$, $^{***}p<0.001$.

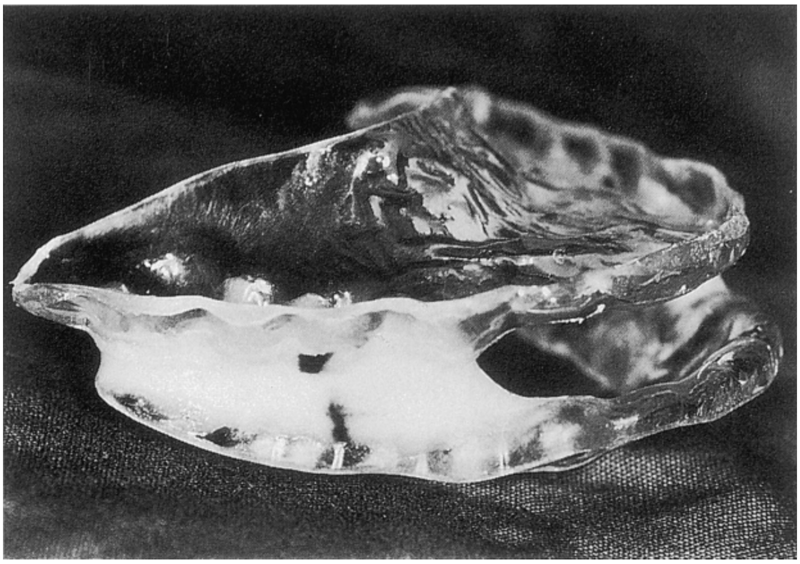

Fig. 1. Upper oblique view of mandibular advancement splint (MAS).
(length × width × height = average 5.5 × 7.0 × 2.0 cm in average)

recorded. We recorded oxygen saturation (pulse oxymetric monitor of arterial oxygen saturation: SpO_2) during sleep with a pulse oxymeter (Pulsox 5, MINOLTA, Osaka) with a finger-tip probe (Taguchi et al. 1994). The accuracy of SpO_2 is within ±5% of arterial oxygen saturation (SaO_2).

Psycho-intellectual tests

We assessed psycho-intellectual function by State Trait Anxiety Inventory (STAI, Sankyohboh, Kyoto) (Watanabe and Nakazato 1993), Self-rating Depression Scale (SDS, Sankyohboh) (Yamamoto 1993), Cornell Medical Index (CMI, Japanese version by Fukamachi, Sankyohboh) (Murakami 1993), and Yatabe-Guilford Test (Y-G test, Takei-Kiki Kogyo, Tokyo) (Katsumata 1985) and Uchida-Kraepelin psychodiagnostic test (Standard Form-I, Nihon Seishin-Gijyutsu Kenkyujo, Tokyo) (Takimoto 1985). STAI was used to assess state anxiety and trait anxiety which were expressed both in scores and grades. SDS was used to assess the degree of depression which was expressed both in scores and grades. We used CMI, to assess the tendency of neurosis, and Y-G test to assess social and psychological characteristics. CMI was also expressed both in scores and grades. The Uchida-Kraepelin test was used to assess ability and accuracy of calculation.

Statistical analysis

We compared the results of sleep monitoring between pre and post MAS treatment by paired t-test and psycho-intellectual functions by paired t-test and Wilcoxon signed-ranks test when the results were obtained numerically. We examined the correlation of the grade of SAS and the grade of psycho-intellectual function before the treatment of MAS by Pearson's correlation coefficient and

Spearman's correlation coefficient. We examined the correlation of the improvement of SAS and the improvement of psycho-intellectual function by the treatment of MAS by Pearson's correlation coefficient and Spearman's correlation coefficient.

Results

Effect of MAS on apneic episodes and blood gases

The total number of apneic episodes decreased from 166.8±130.6 to 21.0±17.1 episodes/night ($p<0.001$). AI decreased from 19.0±15.6 to 2.4±1.9 ($p<0.001$). In two of the twenty patients, apneic episodes disappeared (Table 2). Using MAS, the lowest SpO_2 during sleep time increased from 72.6±16.3 to 78.3±13.3% ($p<0.05$) and mean SpO_2 increased from 93.1±4.5 to 95.4±1.5% ($p<0.05$) (Table 2). In seven of the subjects, there was significant improvement of daytime PaO_2 after MAS treatment, although $PaCO_2$ did not differ significantly.

Effect of MAS on psycho-intellectual functions

By using MAS, the STAI-I (state anxiety) score decreased from 44.6±12.1 to 33.7±11.1 ($p<0.001$) and the STAI-II (trait anxiety) score from 46.2±13.4 to 37.6±13.8 ($p<0.001$) (Table 3). In twelve of nineteen examined patients, the STAI-I score exceeded the upper normal limits before treatment and became normal after MAS treatment in eight. In nine patients, the STAI-II score exceeded the upper normal limits before the treatment. Improvement by at least one grade of the anxiety score was observed in 5 of them. The SDS score decreased from 39.2±11.0 to 30.8±9.9 ($p<0.001$) (Table 3). In nine of nineteen examined patients, the SDS score exceeded 40 allowing a classification of depression. Among them, four were mild and the other 5 patients had moderate depression. After MAS treatment, the depression score was improved by at least one grade in all of the nine patients (Fig. 2). By CMI, five of the nineteen examined patients became less neurotic after using MAS. Before MAS treatment, only four of nineteen examined patients were within the normal range. After MAS treatment, at least one grade of improvement was noted in seven patients. After MAS treatment, the grade of CMI was improved ($p<0.01$) (Wilcoxon singed rank test).

By Y-G test, only three of nineteen examined patients were classified as average before MAS treatment. After MAS treatment, six patients were classified as average (Table 4). Before MAS treatment, six patients were classified as calm and only three were classified as calm after MAS treatment. After MAS treatment, they became less eccentric or more calm. By Uchida-Kraepelin test, ability of calculation increased from 1247.4±402.1 to 1950.2±651.9 after MAS treatment ($p<0.001$). The rate of miscalculation before and after MAS treatment was 1.6±1.7% and 0.8±0.8%, respectively ($p<0.05$) (Table 5).

The improvement of AI correlated with that of STAI-I ($r=0.557$, $p<0.05$),

TABLE 3. *The effects of MAS (mandibular advancement splint) on the State Trait Anxiety Inventory (STAI) and the Self-rating Depression Scale (SDS) in patients with SAS (sleep apnea syndrome)*

Subjects	STAI-1				STAI-2				Degree of depression and score	
	No MAS	(Grade[a])	MAS	(Grade[a])	No MAS	(Grade[a])	MAS	(Grade[a])	No MAS	MAS
1	50	(IV)	30	(II)	39	(III)	25	(II)	45	25
2	45	(IV)	30	(II)	40	(III)	25	(II)	50	25
3	66	(V)	60	(V)	74	(V)	70	(V)	55	49
4	57	(V)	30	(II)	57	(V)	37	(III)	53	38
5	45	(IV)	40	(III)	37	(III)	33	(II)	34	30
6	33	(III)	22	(II)	27	(II)	30	(II)	27	23
7	40	(III)	30	(II)	45	(IV)	40	(III)	35	27
8	34	(III)	30	(II)	39	(III)	35	(III)	43	39
9	28	(II)	20	(I)	29	(II)	25	(II)	25	20
10	44	(IV)	38	(III)	53	(V)	38	(III)	33	20
11	25	(II)	24	(II)	58	(V)	55	(V)	32	31
12	67	(V)	50	(V)	70	(V)	65	(V)	51	47
13	61	(V)	41	(IV)	65	(V)	45	(IV)	57	49
14	30	(II)	20	(I)	34	(III)	20	(I)	27	20
15	41	(IV)	36	(III)	37	(III)	30	(II)	34	30
16	39	(III)	35	(III)	39	(IV)	45	(IV)	30	28
17	44	(IV)	34	(III)	45	(IV)	34	(III)	49	39
18	NT		NT		NT		NT		NT	NT
19	46	(IV)	20	(I)	38	(III)	22	(I)	41	25
20	52	(V)	50	(V)	42	(III)	40	(III)	23	20
Mean ± S.D.	44.6 ± 12.1		33.7 ± 11.1***		46.2 ± 13.4		37.6 ± 13.8***		39.7 ± 11.0	30.8 ± 9.9***

NT, not tested. [a] Grade determined by Spielberger's classification.
*** $p < 0.001$.

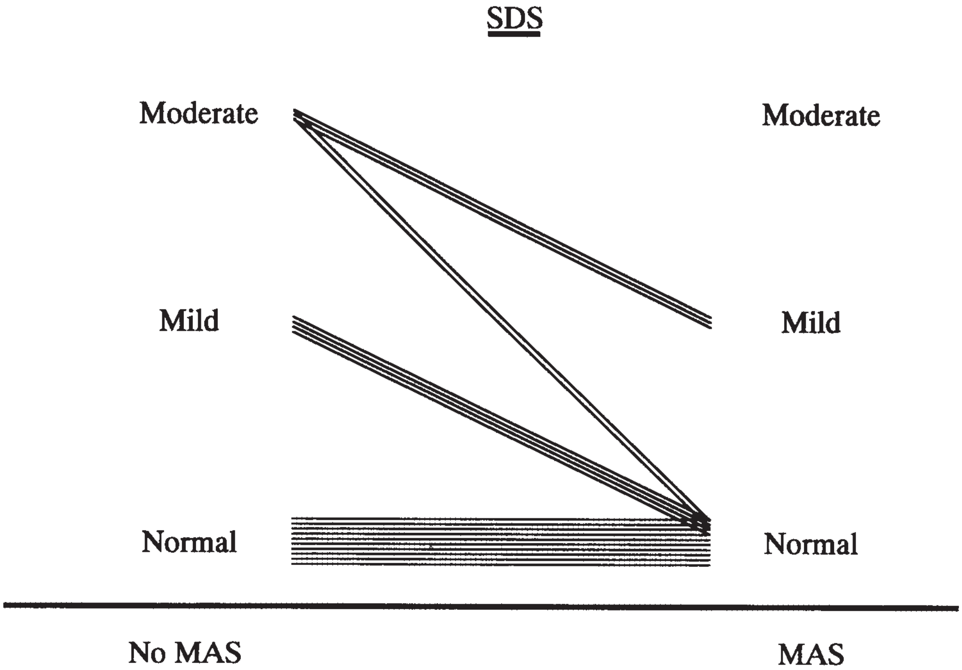

Fig. 2. Effects of mandibular advancement splint (MAS) on depression in patients with sleep apnea syndrome (SAS). The grade of depression is expressed as a grade of the SDS (Self-rating Depression Scale). All of the patients who had mild or moderate depression became less depressive or normal with MAS treatment.

STAI-II ($r=0.627$, $p<0.01$), SDS ($r=0.553$, $p<0.05$), CMI ($rs=0.710$, $p<0.01$) and ability of calculation by Uchida-Kraepelin psychodiagnostic test ($r=0.862$, $p<0.001$) (Fig. 3). We assumed that those psycho-intellectual improvement induced by MAS treatment are not placebo effects, because those who failed to respond to MAS initially, i.e., due to insufficient advancement of the mandible, did not show any improvement of psycho-intellectual functions. The improvement of SpO_2 correlated with psycho-intellectual function, CMI was significantly correlated ($rs=0.56$, $p<0.05$).

Discussion

In SAS, the inferior quality of sleep and possibly severe hypoxemia during sleep result in impaired psycho-intellectual functioning during the daytime (Findley et al. 1986, 1992; Lamphere et al. 1989; Whyte et al. 1989; Cheshire et al. 1992; Bédard et al. 1993; Engleman et al. 1994, 1997; Baumel et al. 1997). Findley et al. (1986) reported that patients with sleep apnea with associated hypoxemia have cognitive impairment severer than those with sleep apnea without hypoxemia. Cheshier et al. (1992) reported that the frequency of breathing irregularities and the extent of both sleep disruption and nocturnal hypoxemia were important in determining daytime function in patients with SAS. In the present study, the improvement of the degree of apnea or nocturnal hypoxemia resulted in improved psycho-intellectual functioning after MAS treatment as has

TABLE 4. *The effects of MAS (mandibular advancement splint) on the neurotic tendency on the Japanese version of Cornell Medical Index (CMI) and type of Yatabe-Guilford Test in patients with SAS (sleep apnea syndrome)*

Subjects	Cornell medical index				Yatabe-Guilford test (type of character)	
	No MAS	(Grade[a])	MAS	(Grade[a])	No MAS	MAS
1	Almost neurotic	(III)	Almost normal	(II)	Calm	Average
2	Almost neurotic	(III)	Almost notmal	(II)	Director	Director
3	Neurotic	(IV)	Neurotic	(IV)	Eccentric	Non classifiable
4	Neurotic	(IV)	Neurotic	(IV)	Eccentric	Non classifiable
5	Almost neurotic	(III)	Almost neurotic	(III)	Calm	Average
6	Normal	(I)	Normal	(I)	Average	Average
7	Normal	(I)	Normal	(I)	Average	Average
8	Almost normal	(II)	Almost normal	(II)	Average	Average
9	Normal	(I)	Normal	(I)	Director	Non classifiable
10	Almost neurotic	(III)	Almost normal	(II)	Director	Director
11	Almost neurotic	(III)	Almost notmal	(II)	Blast	Non classifiable
12	Neurotic	(IV)	Neurotic	(IV)	Eccentric	Eccentric
13	Neurotic	(IV)	Neurotic	(IV)	Eccentric	Average
14	Almost normal	(II)	Normal	(I)	Non classifiable	Non classifiable
15	Almost normal	(II)	Normal	(I)	Calm	Calm
16	Almost notmal	(II)	Almost normal	(II)	Calm	Calm
17	Almost neurotic	(III)	Almost normal	(II)	Calm	Calm
18	NT		NT		NT	NT
19	Almost neurotic	(III)	Almost neurotic	(III)	Average-director	Director
20	Normal	(I)	Normal	(I)	Calm	Average-calm

NT, not tested. [a]Grade determined by Fukamachi's classification.

TABLE 5. *The effects of MAS (mandibular advancement splint) on the calculation ability by the Uchida-Kraepelin test*

Subjects	Total calculation		Error (%)	
	No MAS	MAS	No MAS	MAS
1	729	1204	5.9	1.2
2	1920	2890	1.0	0.7
3	1665	1700	0.4	0.3
4	582	1530	2.7	2.6
5	1326	1420	0.9	0.6
6	1374	1595	0.4	0.3
7	1387	1600	1.1	0.6
8	728	950	3.2	1.1
9	1170	2820	0.5	0.5
10	1800	2776	0.1	0
11	1117	1306	1.3	0.2
12	1050	1300	1.9	0.4
13	850	2350	0.9	1.1
14	986	2860	5.7	0.8
15	1085	1428	2.8	2.8
16	1680	1950	0.1	0
17	1250	2650	0.3	0.3
18	1955	2099	0.4	0.4
19	930	2830	1.3	0.9
20	1363	1745	0.5	0.5
Mean ± S.D.	1247.4 ± 402.1	1950.2 ± 651.9***	1.6 ± 1.7	0.8 ± 0.8*

$^*p<0.05$, $^{***}p<0.001$.

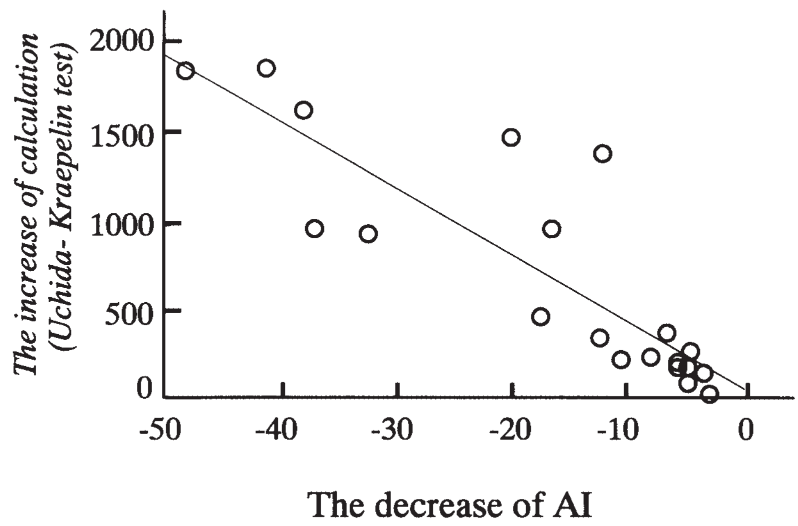

Fig. 3. The correlation of the changes of calculation ability and the apnea index (AI). The increase of calculation strongly correlated with the improvement of AI. The increase of calculation ability = 66.5 + 38.1 × the decrease of AI ($r = -0.862$, $p<0.001$, $r^2 = 0.743$).

been reported (Bédard et al. 1993; Engleman et al. 1994, 1997). In SAS, sleep is disturbed by frequent apnea, although the correlation of degree of apnea or nocturnal hypoxemia with psycho-intellectual function was not apparent.

It has been reported that after CPAP, patients became more alert (Lamphere et al. 1989) and also experienced improvement in symptoms and personal relationships with their bed partners (Kiely and McNicholas 1997). NCPAP is a useful modality in the treatment of SAS. However, it has problems with patient compliance (Kribbs et al. 1993a; Likar et al. 1997). Kribbs et al. (1993a) reported that average use of CPAP was 66% of the days, with only 46% of their patients using NCPAP regularly. They also reported that the most frequently cited problems with NCPAP were "inconvenience" (54%) and "stuffy nose" (46%). However, the complaint that the mask caused "claustrophobia" was the only problem identified significantly more often by patients who used NCPAP less regularly. Seven of 13 of our patients tried to use NCPAP. However they refused to use it continually because of stuffy nose and inconvenience (six cases) and cost (one case). NCPAP machine is rather expensive and was not covered by health insurance in Japan until recently.

MAS has recently been introduced for the treatment of SAS. MAS is noninvasive and was shown to be well tolerated and effective in the treatment of snoring and obstructive sleep apnea (O'Sullivan et al. 1995; Miyamaru et al. 1996). MAS holds the mandible forward and increases oropharyngeal and hypopharyngeal dimensions. Ferguson et al. (1997) compared the efficacy, side effects, patient compliance and patient preference between adjustable MAS and NCPAP in a prospective crossover study in patients with mild to moderate obstructive sleep apnea. They reported better compliance with MAS than NCPAP (5 vs. 30% compliance failure) and patient satisfaction was higher while being treated with MAS, although treatment success (reduction of AI <10/hour and relief of symptoms) was higher with NCPAP treatment. Although we did not use an adjustable MAS, we individually adjusted and remade the MAS until they became clinically useful and well tolerable for the patients.

In our preliminary study, we compared the effect of NCPAP or MAS in seven patients with SAS (Nagasaka et al. 1997). The apneic episodes decreased from 143 to 4/night ($p<0.1$) with NCPAP and to 15/night with MAS ($p<0.1$). This reduction of apneic events was more prominent with NCPAP than with MAS ($p<0.1$). The lowest transcutaneous oxygen saturation (SpO_2) increased from 69 to 88% with NCPAP ($p<0.02$) and to 82% with MAS ($p<0.05$). Side effects of MAS include mild jaw pain, excessive salivation, dryness of mouth, bruxism and headache (Miyamaru et al. 1996; Ferguson et al. 1997). In the present study, all the patients were treated with MAS without hazardous complications except for mild jaw pain and dryness in the mouth in some.

In the present study, we used STAI, SDS, CMI, Y-G and Uchida-Kraepelin tests to clarify the derangements of psycho-intellectual function in SAS and the effect of MAS treatment on these derangements. As daytime psycho-intellectual functions have multiple facets, evaluation of these functions should include a combination of multiple psycho-intellectual tests. In this study, we studied the effect of MAS on psycho-intellectual function by the use of a "test battery" (Okadoh 1985). The use of a test battery, i.e., combination of at least a few psychological tests has been postulated to be desirable in the evaluation of psycho-intellectual function.

STAI has been used to evaluate state anxiety and trait anxiety. State anxiety is a rather transient sense of anxiety which responds to the environmental state of an individual. Trait anxiety is rather stable and reflects the character and potential of anxiety of an individual in response to changes in the environment. Although state and trait anxiety reflects different aspects of anxiety, they often shift concordantly. The severity of apnea did not correlate with the degree of anxiety before or after treatment. However, the patients became less anxious after being treated with MAS (Table 3). SDS is a self-rating depression scale by questionnaire to evaluate the degree of depressive feeling. By SDS, depressive mood, diurnal variation, and fatigability are scored into 4 grades by frequency, i.e., never or rare, sometimes, many times and almost always. There was a marked improvement in depression with the MAS treatment (Table 3). CMI was used to evaluate the neurotic tendency. By CMI, it was clarified that patients with SAS tended to be neurotic before the treatment, i.e., eleven of nineteen examined cases were neurotic or almost neurotic before the treatment. The effect of MAS treatment on CMI was significant and 13 patients were classified as normal or almost normal after MAS treatment.

The type of character of the patients was assessed by the Y-G test. It was disclosed that patients with SAS were usually classified other than average before the treatment. Only three patients were classified as average before the treatment. The type of character did not appear to correlate with the severity of apnea. The character of the patients became less eccentric or not too calm after using MAS (Table 4). This implies that the character of the patient may be affected by SAS and will become less prominent by MAS treatment. By Uchida-Kraepelin test, the ability of counting was improved and the accuracy of calculation was improved as the rate of miscalculation decreased after the MAS treatment (Table 5).

The combination of these psycho-intellectual tests revealed that derangement of psycho-intellectual function is not rare among patients with SAS and it was clarified that these psycho-intellectual derangements can be improved by decreasing apneic and hypoxemic episodes with MAS.

We conclude that MAS was not only effective in improving apneic episodes in patients with SAS, but also improved the psycho-intellectual impairment commonly seen in these patients.

Acknowledgments

The authors are grateful to Dr. Eiichiro Miyamaru of the Department of Stomatology of Kinki University School of Medicine for his kind treatment and making MAS for these patients.

References

1) Baumel, M.J., Maislin, G. & Pack, A.I. (1997) Population and occupational screening for obstructive sleep apnea: Are we there yet? *Am. J. Respir. Crit. Care Med.*, **155**, 9-14.
2) Bédard, M.A., Montplaisir, J., Malo, J., Richer, F. & Rouleau, I. (1993) Persistent neuropsychological deficits and vigilance impairment in sleep apnea syndrome after treatment with continuous positive airway pressure (CPAP). *J. Clin. Exp. Neuropsychol.*, **15**, 330-341.
3) Cheshire, K., Engleman, H., Deary, I., Shapiro, C. & Douglas, N.J. (1992) Factors impairing daytime performance in patients with sleep apnea/hypopnea syndrome. *Arch. Intern. Med.*, **152**, 538-541.
4) Engleman, H.M., Martin, S.E., Deary, I.J. & Douglas, N.J. (1994) Effect of continuous positive airway pressure treatment on daytime function in sleep apnoea/hypopnoea syndrome. *Lancet*, **343**, 572-575.
5) Engleman, H.M., Asgari-Jirhandeh, N., McLeod, A.L., Ramsay, C.F., Deary, I.J. & Douglas, N.J. (1996) Self-reported use of CPAP and benefits of CPAP therapy. *Chest*, **109**, 1470-1476.
6) Engleman, H.M., Martin, S.E., Deary, I.J. & Douglas, N.J. (1997) Effect of CPAP therapy on daytime function in patients with mild sleep apnoea/hypopnoea syndrome. *Thorax*, **52**, 114-119.
7) Ferguson, K.A., Ono, T., Lowe, A.A., Al-Majed, S., Love, L.L. & Fleetham, J.A. (1997) A short term controlled trial of an adjustable oral appliance for the treatment of mild to moderate obstructive sleep apnea. *Thorax*, **52**, 362-368.
8) Findley, L.J., Barth, J.T., Powers, D.C., Wilhoit, S.C., Boyd, D.G. & Suratt, P.M. (1986) Cognitive impairment in patients with obstructive sleep apnea and associated hypoxemia. *Chest*, **90**, 686-690.
9) Findley, L.J., Levinson, M.P. & Bonnie, R. (1992) Driving performance and automobile accidents in patients with sleep apnea. *Clin. Chest Med.*, **13**, 427-435.
10) Hida, W., Shindoh, C., Miki ,H., Kikuchi, Y., Okabe, S., Taguchi, O., Takishima, T. & Shirato, K. (1993) Prevalence of sleep apnea among Japanese industrial workers determined by a portable sleep monitoring system. *Respiration*, **60**, 332-337.
11) Katsumata, T. (1985) Yatabe-Guilford Test. *Human Mind*, **3**, 64-70. (in Japanese)
12) Kiely, J.L. & McNicholas, W.T. (1997) Bed partners' assessment of nasal continuous positive airway pressure therapy in obstructive sleep apnea. *Chest*, **111**, 1261-1265.
13) Kribbs, N.B., Pack, A.I., Kline, L.R., Smith, P.L., Schwartz, A.R., Schubert, N.M., Redline, S., Henry, J.N., Getsy, J.E. & Dinges, D.F. (1993a) Objective measurement of patterns of nasal CPAP use by patients with obstructive sleep apnea. *Am. Rev. Respir. Dis.*, **147**, 887-895.
14) Kribbs, N.B., Pack, A.I., Kline, L.R., Getsy, J.E., Schuett, J.S., Henry, J.N., Maislin, G. & Dinges, D.F. (1993b) Effects of one night without nasal CPAP treatment on sleep and sleepiness in patients with obstructive sleep apnea. *Am. Rev. Respir. Dis.*, **147**, 1162-1168.
15) Kryger, M.H. (1992) Management of obstructive sleep apnea. *Clin. Chest Med.*, **13**, 481-492.
16) Lamphere, J., Roehrs, T., Wittig, R., Zorick, F., Conway, W.A. & Roth, T. (1989)

Recovery of alertness after CPAP in apnea. *Chest*, **96**, 1364–1367.
17) Likar, L.L., Panciera, T.M., Erickson, A.D. & Rounds, S. (1997) Group education session and compliance with nasal CPAP therapy. *Chest*, **111**, 1273–1277.
18) Miyamaru, E., Hamada, S., Kurimoto, T., Sugihara, M., Watatani, K. & Matsuya, T. (1996) Efficacy of mandibular advancement splints in sleep apnea syndrome (SAS) *Jpn. J. Oral. Maxillofac. Surg.*, **42**, 944–946.
19) Murakami, M. (1993) Evaluation of treatment response by CMI. *Shinshin-Iryo*, **5**, 1364–1370. (in Japanese)
20) Nagasaka, Y., Nambu, Y., Fujita, E., Hazu, R., Yoshida, M., Ikeshita, K. & Fukuoka, M. (1997) Comparison of the effect of nasal CPAP and mandibular advancement splint (MAS) in patients with obstructive sleep apnea (OSA). *Eur. Respir. J.*, **10**, 188.
21) Okadoh, T. (1985) Psychological tests: Their significance and limitation. *Human Mind*, **3**, 34–40. (in Japanese)
22) O'Sullivan, R.A., Hillman, D.R., Mateljan, R., Pantin, C. & Finucane, K.E. (1995) Mandibular advancement splint: An appliance to treat snoring and obstructive sleep apnea. *Am. J. Respir. Crit. Care Med.*, **151**, 194–198.
23) Reeves-Hoche, M.K., Meck, R. & Zwillich, C.W. (1994) Nasal CPAP: An objective evaluation of patient compliance. *Am. J. Respir. Crit. Care Med.*, **149**, 149–154.
24) Taguchi, O., Hida, W., Kikuchi, Y., Miki, H., Iijima, H., Homma, M., Tamura, G. & Shirato, K. (1994) Bronchial asthma and desaturation-assessment by pulse oxymetry. *Jpn. J. Thoracic Dis.*, **32**, S115–S120. (in Japanese)
25) Takimoto, T. (1985) Uchida-Kraepelin Psychodiagnostic Test. *Human Mind*, **3**, 110–117. (in Japanese)
26) Watanabe, T. & Nakazato, K. (1993) Evaluation of treatment response by STAI. *Shinshin-Iryo*, **5**, 1358–1363. (in Japanese)
27) Whyte, K.F., Allen, M.B., Jefferey, A.A., Gould, G.A. & Douglas, N.J. (1989) Clinical features of the sleep apnoea/hypopnoea syndrome *Quart. J. Med.*, **72**, 659–666.
28) Yamamoto, H. (1993) Evaluation of treatment response by SDS. *Shinshin-Iryo*, **5**, 1346–1351. (in Japanese)