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A randomized prospective long-term study of two oral appliances for sleep apnoea treatment

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SUMMARY Various types of mandibular protrusive appliances have revealed different treatment success in mild-to-moderate obstructive sleep apnoea (OSA). The present study compared the long-term effect of two different appliances in the treatment of OSA. A total of 103 patients with OSA were randomized and treated with an IST® or Thornton Anterior Positioner (TAP™) appliance. They were followed-up after a short-term treatment period of 6 months and long-term treatment period of over 24 months. Sleep studies in the sleep laboratory were conducted with and without the appliances, and various questionnaires assessing subjective daytime sleepiness, sleep quality, quality of life and symptom scores were administered at each time interval. Quality of life, sleep quality, sleepiness, symptoms and sleep outcome showed significant improvement in the short-term evaluation with both appliances, but the TAP™ appliance revealed a significantly greater effect. After more than 2 years of treatment, sleep outcomes revealed an equal effect with both appliances. The subjective benefits achieved initially lessened significantly. This study illustrates that both the IST® and the TAP™ appliances are effective therapeutic devices for OSA after a period of over 24 months. Lack of compliance may be due to insufficient improvement in anticipated subjective symptoms and/or a recurrence of symptoms over time.

KEYWORDS mandibular advancement devices, obstructive sleep apnoea, oral appliances, sleep apnoea syndrome, sleep-disordered breathing

INTRODUCTION

The obstructive sleep apnoea (OSA) syndrome is treated by the nocturnal application of continuous positive airway pressure (CPAP). Although CPAP is the most efficacious treatment (Giles *et al*., 2006), limited acceptance as long-term treatment has been described (Barnes *et al*., 2004; Engleman *et al*., 1999; Ferguson *et al*., 1997; Redline *et al*., 1998). Custom-made mandibular advancement appliances (MAAs) reduce symptoms in OSA and subjective sleepiness, but less than CPAP (Barnes *et al*., 2002; Clark *et al*., 1996; Engleman *et al*., 1999; Ferguson *et al*., 1997; Randerath *et al*., 2002). Treatment recommendations for the use of MAA have been updated recently (Kushida *et al*., 2006; Lim *et al*., 2006).

Most studies have verified MAAs' effectiveness in short-term evaluations in different clinical endpoints and patients' perception. The long-term effect was evaluated in a retrospective case–control study over 5 years, and found to change relatively little (Marklund *et al*., 2001). However, a recent meta-analysis of OSA treatment modalities concluded that the long-term data on treatment outcomes to determine whether initial benefits in short-term clinical trials persist are inadequate (Lim *et al*., 2006).

Several MAAs of different constructional design and made of various dental materials are currently in clinical use (Hoffstein, 2007). The different MAA designs may influence therapeutic outcome, compliance and persistence of usage. Regarding the persistence of MAA usage, there is a lack of comparable studies evaluating the efficacy of different types of

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MAAs in long-term clinical trials. The rationale of this study was to compare two types of MAA that differ in their ability to open the mouth during sleep in the protrusive position and in the splint material regarding their subjective and objective short- and long-term treatment efficacy. Both appliances were chosen because previous short-term studies comparing both MAAs with CPAP by other groups had reported successful treatment results (Bloch *et al*., 2000; Pancer *et al*., 1999; Randerath *et al*., 2002).

MATERIALS AND METHODS

Study population and design

Patients were recruited between July 2001 and December 2003 through the sleep laboratory of the department of Respiratory Care at the University Hospital of Freiburg (Germany) for a randomized trial comparing the short- and long-term effects of two MAAs. One hundred and thirty-three patients aged more than 20 years diagnosed as having OSA [5 ≥ apnoea–hypopnoea index (AHI) ≤ 40 h^{-1}] based on a history including complaint of excessive daytime sleepiness, habitual snoring and nocturnal apnoeas observed by the patient's domestic partner, and one night polysomnography (PSG) (= T0) were assessed for eligibility. All patients were examined before hand by an otolaryngologist to rule out any structural obstruction. One hundred and three patients [17 females and 86 males; age: 55.5 ± 10.6 years, body mass index (BMI): 25.9 ± 2.9 kg m^{-2}] were enroled consecutively in the prospective study. Enroled patients were randomized according to a computer-generated randomization list. Fifty-one patients were allocated randomly to a modified Herbst appliance (IST®; Scheu Dental, Iserlohn, Germany), and 52 patients to the TAP™ (Airway Management, Inc., Dallas, TX, USA). The trial was approved by the University Hospital of Freiburg im Breisgau Ethics Committee.

Patients with primarily central apnoea, obstructive apnoeas and hypopnoeas associated mainly with rapid eye movement sleep on baseline PSG, significant chronic diseases, Cheyne–Stokes respiration, BMI > 40 kg m^{-2}, history of upper airway surgery or underlying psychopathology did not undergo eligibility assessment.

Patients underwent a thorough dental examination before MAA treatment. The oral requirements with an MAA protrusive appliance were established in reference to Clark's recommendations (Clark, 1998). Patients were monitored clinically after a habituation period to become used to wearing the MAA. If the patients expressed dissatisfaction with the treatment benefits, the degree of protrusion was adjusted by 5–10% of the initial protrusion. Patients who complained of wearing discomfort had the fit of their appliance and dental retention checked. Control PSG was carried out once the patient had tolerated the MAA for at least 5 nights per week (= T1).

Efficacy was evaluated based on the patients' subjective satisfaction and PSG. When the MAA was adjusted due to a sleep evaluation result indicating an AHI above 5 h^{-1}, a second sleep recording was made. In those cases, the latter was then included in the final analysis. Titration process at T1 was performed in nine patients with the IST® and in six patients with the TAP™. All patients treated adequately at T1 were recalled after a treatment time of at least 2 years (= T2).

Sleep studies

A PSG with the device and one without were made after a habituation period and after at least 2 years from the start of treatment. One week before the PSG, we asked the patients to refrain from using the appliance. A detailed description of the standard PSG has been provided (Rose *et al*., 2004).

We modified the classification of treatment response used by other groups regarding mild-to-moderate OSA at baseline (Barnes *et al*., 2002; Mehta *et al*., 2001). Due to our inclusion criteria of mild-to-moderate OSA treatment, a complete treatment response with an MAA was defined when patients were satisfied with treatment and the AHI was less than five events per hour; a sufficient response was recorded when the AHI fell to less than 10 events per hour. A partial response was defined as a reduction of at least 50% in the AHI but not below 10 events per hour with an improvement in symptoms.

Clinical evaluation and questionnaires

A general medical history was taken and clinical examination performed on each patient. German versions of the Epworth Sleepiness Scale (ESS) (Bloch *et al*., 1999; Johns, 1991), the Pittsburgh Sleep Quality Index (PSQI) (Buysse *et al*., 1989), a 36-item Medical Outcome Study questionnaire (Ware and Kosinski, 2001) and modified sleep-symptom questionnaire described by Bloch *et al*. (2000) (Appendix I) were administered. Domestic partners estimated the MAA's effect on snoring frequency and loudness according to questions 4 and 5 of the sleep symptoms questionnaire. Questions 4 and 5 were ignored in patients with no partner. Reasons for non-compliance and side effects were evaluated in a structured interview.

Mandibular advancement appliances

Both types of MAA were manufactured by specially trained dental technicians. The splints of the IST® (Fig. 1a) were made of hard methylmethacrylate (Steady Resin S; Scheu Dental, Iserlohn, Germany). The dental splint provided full coverage of the upper and lower dental arches. A construction bite of each patient was taken by an orthodontist at 75% of maximum protrusion, corresponding to a protrusion of 5 ± 2 mm. The TAP™ (Fig. 1b) was made of a laminated, hard–soft polymer with inner soft polyurethane and external hard polycarbonate components (Durasoft®, thickness: 2.5 mm; Scheu-Dental). After insertion, patients were encouraged to wear the appliance for at least 2 months to become accustomed to it. If a patient was dissatisfied with the therapy, we increased the protrusion in 1–3 mm steps. Protrusion was

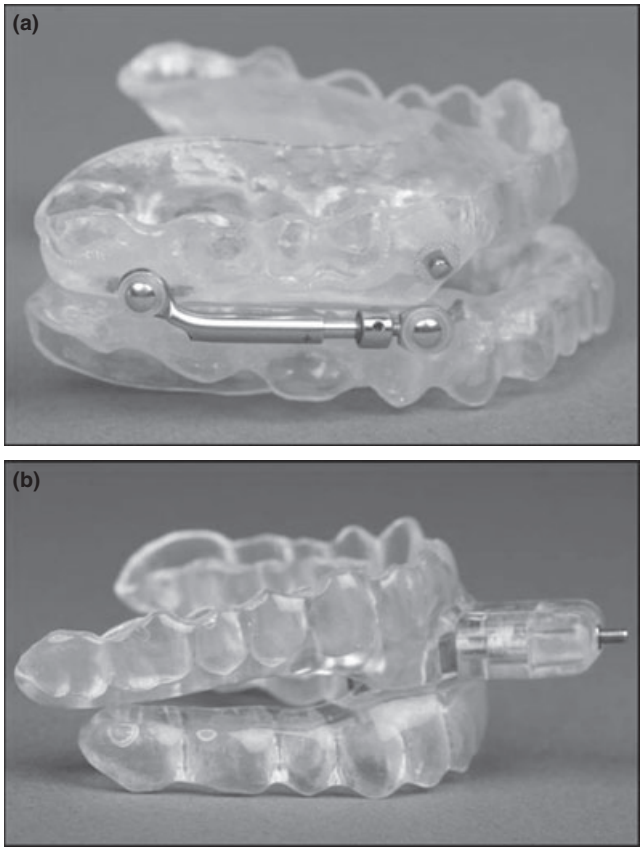

Figure 1. Each patient was fitted with an IST® (a) or a Thornton Anterior Positioner (TAP™) appliance (b). Both are two-splint appliances. The lateral telescopic rods of the IST® appliance allow limited mandibular opening, while the anterior position titration screw of the TAP™ allows only restricted mandibular movements. Both appliances require maximum dental retention.

reduced in steps of 1–3 mm up to a half-width of a bicuspid if discomfort such as tension in the temporomandibular joint region was reported. After these adjustments, the average protrusion was 5.5 ± 2.7 mm for both appliances, which represented 83% of maximum mandibular advancement. Before each sleep study with the appliance, an orthodontist assessed each patient's oral health and the appliance's fit. Inspection of the MAA at the dental evaluation before the nocturnal sleep studies revealed signs of regular use.

Statistical analysis

A minimum sample size was calculated based on 80% power and a two-sided 0.05 significance level. Sample size capable of detecting a change of five events per hour for AHI with the appliance was estimated using a mean ± SD baseline AHI value of 19.6 ± 12.8 events per hour obtained from a previous study (Rose *et al.*, 2004). We estimated the critical sample size to be 20 patients for the long-term analysis and performed an analysis according to the protocol. Data with normal distribution are summarized as means ± SD. Non-normal distributed data are summarized as medians and quartile ranges. For the short-term evaluation we used Wilcoxon's signed-rank test for paired observation and Fisher's exact test; Spearman's correlation and one-way analysis of variance (ANOVA) were calculated. Data obtained during different treatment intervals with different treatment devices were compared by means of repeated-measures ANOVA with Bonferroni correction using SAS version 6.12 software (SAS Institute, Inc., Cary, NC, USA). If the overall test was significant, Tukey's adjusted *post hoc* comparisons were used to assess the significance of each pairwise comparison. The modified sleep-symptom questionnaire at various time intervals was analysed using the Kruskal–Wallis test. Associations between treatment successes, age, gender, obesity, weight gain and AHI at the onset of treatment were estimated by odds ratios. $P < 0.05$ was considered as statistically significant for all analyses.

RESULTS

Subject characteristics are presented in Table 1. The flow of participants through each stage in this study is summarized in Fig. 2.

Short-term evaluation

Initial PSG follow-up data were performed after a median of 5.4 months with the IST® and 5.2 months with the TAP™. Patient self-assessment and domestic partners' assessment revealed significant differences between T0 and T1 with both appliances regarding subjective daytime sleepiness, overall quality of sleep, energy level and snoring. Domestic partners assisted in answering the questionnaire in 42 patients and 40 patients, respectively. Daytime performance improved significantly in the TAP™ appliance group only. Quality of life (SF-36), snoring frequency and snoring intensity improved significantly greater with the TAP™ than with the IST® at T1. At T1 both appliances improved respiratory parameters, snoring and sleep quality significantly. There was an increase in slow-wave sleep and a decrease in the arousal indices with both appliances. The other parameters were not influenced by appliance treatment. The effect was statistically more

Table 1 Patient characteristics at baseline

Characteristics	*IST® group (n = 51)*	*TAP™ group (n = 52)*
Age ± SD (years)	50.5 ± 10.9	50.4 ± 11.1
Body mass index (BMI) (kg m^{-2})	25.9 ± 2.9	26.0 ± 2.7
Females/males (*n*)	10/41	7/45
Apnoea–hypopnoea index (events per h)	32 ± 6	37 ± 8
Epworth Sleepiness Scale score	8 ± 2	10 ± 3

TAP™, Thornton Anterior Positioner.
Values are means ± SD.

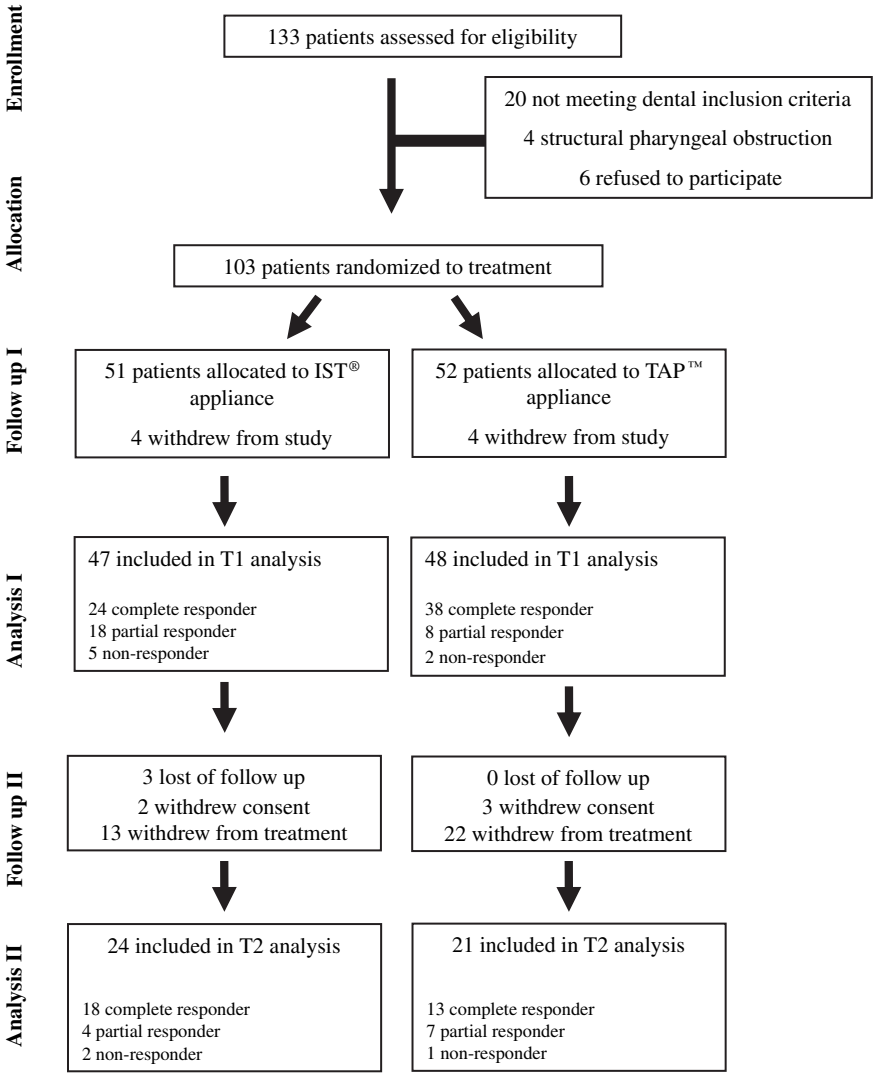

Figure 2. Flow of participants through each trial phase. TAP™, Thornton Anterior Positioner.

pronounced for the TAP™ than for the IST® for AHI, oxygen desaturation index and arousal index (Table 2).

Long-term evaluation

Twenty-six of the 42 patients (61.9%) recommended after T1 evaluation to use the IST® on a regular basis verified having used the appliance continuously for at least 5 nights per week. Between the T1 the T2 intervals, 13 patients withdrew from treatment due to a lack of perceived efficacy ($n = 7$), dental side effects ($n = 1$), discomfort ($n = 3$) and temporomandibular joint pain ($n = 2$). Two patients withdrew their consent to the follow-up investigation; however, they assured us that they were continuing to wear the appliance as recommended. Their reasons for not submitting to the control were that the patients were not willing to have their appliances removed for the washout period of 1 week prior to follow-up PSG and the fact that they were satisfied subjectively with the appliance treatment. After a median treatment time with the IST® appliance of 42.7 months, 24 (age: 54.0 ± 9.8 years, 19 males and five females) of the 51 patients included initially (47.1%) were followed-up at T2. Twenty-five of the 46 patients (51.1%) remaining in the TAP™ appliance cohort after T1 evaluation had discontinued regular MAA at the long-term follow-up visit. Two patients dropped out of the study due to temporomandibular joint discomfort, two patients discontinued treatment due to dental side effects and 18 patients reported a lack of treatment benefit. Three patients withdrew consent for the follow-up investigation. After a median time interval of 41.5 months at T2, 21 patients (age: 50.3 ± 11.6 years, 17 males and four females) were followed-up. We observed no significant differences in terms of patient characteristics between the compliant patients and those non-compliant regarding MAA treatment (age, sex, BMI, amount of teeth) and OSA severity (AHI, arousal index, ESS, PSQI, SF-36) in both groups.

The positive effect based on the patients' own evaluation of sleepiness using the MAA at T1 fell at T2 to the baseline level with both appliances. PSQI and SF-36 also dropped to baseline levels for the IST® but not for the TAP™. Domestic partners still described a marked improvement in snoring frequency and snoring loudness at T2; however, they also

Table 2 Short-term effects of the IST® and Thornton Anterior Positioner (TAP™) appliances on sleep and respiration variables

		IST® appliance			*TAP™ appliance*	
Variables		*Without the appliance*	*With the appliance*		*Without the appliance*	*With the appliance*
Epworth Sleepiness Scale score	47	7.5 (6.0–16)	6.5 (4–12)**	48	10.0 (7–15)	4.5 (4–8)**
Pittsburgh Sleep Quality Index	47	8 (3–16)	5 (3–9)**	48	8.5 (3–16)	4 (3–8)**
SF-36 means score	47	69.4 (60.3–79.4)	73.2 (70.3–81.9)**	48	73.5 (62.2–80)	80 (75.3–84.2)** †
Interference with daily tasks	47	3.0 (2.5–4.0)	2.0 (1.0–3.5)	48	2.5 (1.5–3.5)	1.5 (1.0–2.5)
Performance ability	47	3.2 (2.0–4.5)	2.0 (2.0–3.5)	48	3.0 (2.0–4.0)	2.0 (1.0–2.0)**
Energy level	47	3.0 (2.5–4.5)	2.0 (2.0–3.0)**	48	3.0 (2.5–5.0)	2.0 (2.0–3.0)**
Snoring frequency	42	4.0 (3.0–4.0)	2.0 (1.0–3.5)**	40	3.5 (3.5–4.0)	1.5 (1.0–3.0)** †
Snoring intensity	42	3.5 (3.0–4.0)	2.0 (1.0–3.0)**	40	3.5 (3.0–4.0)	1.0 (1.0–3.0)** †
Apnoea–Hypoapnoea Index, events per hour	47	23 (7.4–32)	8.7* (0.4–16)	48	21 (7–40)	5.3*† (0–21)
Lowest SaO_2	46	82 (76–89)	85.5 (87–90)	48	82 (82–93)	86* (78–91)
Oxygen Desaturation Index, desaturation per hour	46	16 (4–22)	8.0* (1–12)	48	14 (2–16)	4*† (0.8–19)
Total sleep time, min	46	415 (290–490)	402 (270–512)	48	419 (275–492)	390 (301–498)
Sleep efficiency, %	46	89 (30–98)	82 (48–96)	48	81 (41–98)	89 (41–98)
REM stage, % sleep time	46	14 (0.1–41)	13 (0.4–6)	48	19 (0.0–40)	14 (0.4–36)
Stage 1, % sleep time	46	27 (11–49)	22 (8–31)	48	24 (12–42)	18 (9–51)
Stage 2 sleep time	46	47 (21–78)	43 (19–69)	48	51 (20–86)	48 (12–79)
Stage 3 and 4, % sleep time	46	5.7 (0.0–16)	8.1* (0.3–18)	48	6.9 (0.0–21)	8* (0.0–26)
Arousal Index, events per hour	46	24 (10–29)	9* (3–18)	48	18 (9–24)	6* (3–8)
Supine body position, % sleep time	45	48 (4–70)	45 (8–78)	48	43 (6.2–69)	41 (6–81)

REM: rapid eye movement; TAP, Thornton Anterior Positioner.
*$P < 0.05$; **$P < 0.001$ compared without the appliance, †$P < 0.05$ IST® appliance versus TAP™ appliance. IST® appliance: $n = 47$; TAP™ appliances: $n = 48$.
Values are means ± SD, medians (quartiles ranges).

reported a reduction in effectiveness from T1 to T2. Both appliances revealed the same effect on AHI, oxygen desaturation index and arousal index at T2. There were no differences regarding sleep position during the different registrations (Table 3). Table 4 summarizes the results in categories from the intention-to-treat perspective.

DISCUSSION

The present study provides the first prospective, randomized long-term comparison between two different types of custom-made MAA in treating OSA. Both appliances differ in how they open the mouth during sleep, in the position of the protrusion units and in the splint material. Our short-term evaluation results demonstrate that the TAP™ has a higher success rate than the IST®. In the long-term evaluation, the respiratory variables associated with both appliances remained stable in those still using the MAA. Despite the stable response in terms of respiratory parameters, the patients' own appraisals of treatment became less positive over time when compared with the results achieved initially. After more than 2 years of MAA treatment, the percentage of patients who persisted in participating in regular MAA treatment with either appliance was approximately 62% with the IST® and 46% with the TAP™, respectively, when a positive treatment effect had been confirmed with the appliance; 43.1% and 38.5% of the patients we intended to treat at T0 were treated and provided at least a sufficient or partial response, respectively.

Our short-term findings resembled the treatment response reported in other studies of similar MAA design in terms of the percentage of AHI reduction from baseline (Bloch *et al*., 1999; Randerath *et al*., 2002; Rose *et al*., 2004). This study confirmed those initial effects; in the short-term PSG control, the AHI fell to 62% with IST® and to 74% with the TAP™. Applying our cut-off points, only 51% of the patients with the IST® and 79.2% with the TAP™ demonstrated complete treatment success, revealing the TAP™ appliance's initial advantage.

The difference we observed in the short-term evaluation between the two appliances is due most probably to the particular type of appliances used in this study. While the TAP™ held the mandible firmly in a protrusive position during the entire sleep, the Herbst telescopes of the IST® allowed the mouth to open during sleep. The telescopes directed the mandible into a more backward position, resulting in a reduced pharyngeal airway diameter as an adverse effect.

Mechanical devices such as MAAs necessitated lifelong treatment; the patient's ability to tolerate a MAA was necessary. We did not evaluate patient compliance because there was currently no commercially available compliance monitor. We relied upon feedback from our patients for the data on adequate appliance usage. The high number of dropouts after a treatment period of more than 2 years for both appliances was disappointing in this study. We had anticipated that long-term patient tolerability would be higher, because in nearly all comparable studies between CPAP and

Table 3 Long-term effects of the IST® and Thornton Anterior Positioner (TAP™) appliances on sleep and respiration variables

	IST® appliance				*TAP™ appliance*			
	T1		*T2*		*T1*		*T2*	
Variables	*Without the appliance*	*With the appliance*	*Without the appliance*	*With the appliance*	*Without the appliance*	*With the appliance*	*Without the appliance*	*With the appliance*
Epworth Sleepiness Scale score	7.8 ± 4.2	6.9 ± 5.3*		7.3 ± 3.9	9.5 ± 5.6*	4.5 ± 5.1		8.4 ± 4.9
Pittsburgh Sleep Quality Index	5.9 ± 2.5	4.2 ± 2.4†		5.5 ± 2.9	5.6 ± 2.7	4.9 ± 2.8*		4.8 ± 2.6*
SF-36 means score	71.4 ± 18.2	74.8 ± 16.2*		73.2 ± 12.6	74.1 ± 15.0	79 ± 16.6*		80.6 ± 22.9*
Interference with daily tasks	3 (2.5–4)	2 (1–3.5)		3 (2–4.0)	2.5 (1.5–3.5)	1.5 (1–2.5)		2.5 (2–3.5)
Performance ability	3.5 (2–4.5)	2 (2–3.5)*		3 (2–4.5)	3 (2–4)	2 (1–2)*		2.5 (2–4)
Energy level	3 (2.5–4.5)	2 (2–3)*		3 (2–4.5)	3 (2.5–5)	2 (2–3)*		3 (2–4)
Snoring frequency	4 (3–4)	2 (1–3.5)*		2 (0–3) †	3.5 (3.5–4)	1.5 (0–3)*		2 (0–3)†
Snoring intensity	2.5 (2–4)	1.5 (1–3)*		2 (0–3) †	3 (2–4)	1 (1–3)*		2 (1–3)†
Apnoea–hypopnoea index, events per hour	21.5 ± 13.5	11.1 ± 11.8*	18.4 ± 8.9	4.6 ± 5.8*†	21.5 ± 16.9	6.7 ± 9.1*‡	19.8 ± 12.7	5.4 ± 5.1*†
Lowest SaO_2	82.2 ± 7.9	85.5 ± 4.0*	83.5 ± 7.1	84.5 ± 4.6	84.3 ± 5.4	87.6 ± 3.9*	84.9 ± 7.1	87.2 ± 2.3*
oxygen desaturation index, desaturation per hour	16.9 ± 13.4	8.0 ± 10.9*	19.2 ± 12.4	3.4 ± 4.9*	17.2 ± 13.4	7.8 ± 11.5*	15.7 ± 14.4	4.3 ± 5.5*
Total sleep time, min	400 ± 30	402 ± 20	410 ± 24	398 ± 30	401 ± 19	396 ± 20	382 ± 8	395 ± 5
Sleep efficiency, %	86 ± 5	89 ± 2	88 ± 5	90 ± 6	85 ± 3	88 ± 5	87 ± 6	88 ± 7
REM stage, % sleep time	14 ± 5	13 ± 6.7	17 ± 7.5	16 ± 4.2	17 ± 2.5	14 ± 4.3	18 ± 8.1	21 ± 7.1
Stage 1, % sleep time	27 ± 12	22 ± 8.2	26 ± 6	18 ± 6	21 ± 14	22 ± 11	25 ± 12	19 ± 4
Stage 2 sleep time	47 ± 11	43 ± 14	51 ± 16	49 ± 12.4	50 ± 14.7	48 ± 17.1	51 ± 12	50 ± 18.3
Stage 3 and 4, % sleep time	5.7 ± 5.4	8 ± 5.2*	7.1 ± 6.3	8.4 ± 5.3	7 ± 4.6	8 ± 5.3	6.9 ± 5.7	7.8 ± 5.1
Arousal index, events per hour	22 ± 19	9.3 ± 14*	20.3 ± 15	6.5 ± 5.1*†	18 ± 10.2	6.1 ± 7.5*‡	17 ± 8.3	6.2 ± 4.3*
Supine body position, % sleep time	39 ± 8.5	41 ± 8.7	42 ± 7.1	42 ± 6.4	44 ± 5.3	45 ± 6.7	47 ± 7.5	41 ± 7.4

REM, rapid eye movement; T1 = short-term evaluation, T2 = follow-up evaluation.
*Significant with the device compared without it; †significant comparison between T1 and T2; ‡significant comparison between IST® appliance and TAP™ appliance, IST®: $n = 24$, TAP™: $n = 21$.
Values are means ± SD, medians (quartiles ranges).

Table 4 Long-term treatment response of the IST® and Thornton Anterior Positioner (TAP™) appliances

	IST® group (n = 51)	*TAP™ group (n = 52)*
Complete response	18 (35.3%)	13 (25%)
Sufficient or partial response	4 (7.8%)	7 (13.5%)
Compliance failure	13 (25.5%)	22 (42.3%)
Treatment failure	7 (13.7%)	3 (5.8%)
Withdrew consent/lost to follow-up	9 (17.6%)	7 (13.5%)

Values are number of patients (*n*) and percentage.

MAAs, patients expressed greater acceptance of MAAs when both were effective (Clark *et al*., 1996; Ferguson *et al*., 1997; Randerath *et al*., 2002). Only one cross-over study postulated less preference for MAAs than CPAP in patients with moderate OSA, and greater preference in patients with mild OSA (Barnes *et al*., 2004). In long-term evaluations, the patients' perceptions of benefits, side effects and discomfort were relevant parameters. We included mainly patients with mild-to-moderate sleep apnoea showing mild daytime symptoms; thus the subjective decrease in symptom relief with this treatment approach might not be as significant in certain patients. Domestic partners' satisfaction with a cessation or at least reduction in snoring also contributed to compliance (de Almeida *et al*., 2005). Our patients reported less daytime sleepiness, reduced snoring and improved quality of sleep using the appliance for a short interval, underlining this treatment's therapeutic efficacy. Sleep quality and quality of life as measured by PSQI and SF-36 decreased with the IST® but not with the TAP™ during 2 years of therapy. The reduction in subjective perceptions did not affect the objective respiratory parameters, thus confirming the results of Marklund *et al*. (2001). Although the TAP™ was more effective in treating OSA, its long-term patient acceptance was less than that of the IST®. Only patients unable or unwilling to tolerate CPAP were examined in this study. One could speculate that patients who failed to tolerate CPAP may be less likely to tolerate other treatments. This should be considered when extrapolating our findings to OSA patients in general.

There are currently many different MAAs available. To varying extents, all of them advance the mandible and open the bite. The MAAs used in previous studies differed in mandibular position, inclusion criteria and other parameters, which made it difficult to compare results. Consequently, there is still no published consensus as to what is the most efficient MAA. It is currently impossible to recommend a specific type of MAA when considering long-term results. Focusing upon short-term results, the IST® seem to be inferior to the TAP™ and OSA-monobloc devices (Bloch *et al*., 2000). However, these initial treatment effects should not be over-rated when considering long-term assessments of response. Our comparison of both types of MAA over the long term resulted in an approximately equal overall response. Despite the positive effect of both MAAs regarding respiratory parameters in the long-term evaluation, the worsening of subjective appraisals and snoring over the long term may be associated with reduced tolerability of MAA treatment.

Our study confirms that both MAAs improved sleep-disordered breathing and symptoms and that both are valid therapeutic options for selected patients with OSA provided that the patient tolerates MAA wear on a regular basis. Regular controls of the treatment efficacy and patient tolerability are recommended. As long as the mandible is advanced continuously during sleep with an appliance and during the treatment period, appliance characteristics that enhance comfort during wear and the greater durability of its material should be prioritized.

DECLARATIONS OF INTEREST

None of the authors has any conflict of interest in terms of personal or financial stake in the subject matter.

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REFERENCES

de Almeida, F. R., Lowe, A. A., Tsuiki, S. *et al*. Long term compliance and side effects of oral appliances used for the treatment of snoring and obstructive sleep apnoea syndrome. *J. Clin. Sleep Med*., 2005, 1: 143–152.

Barnes, M., Houston, D., Worsnop, C. J. *et al*. A randomized controlled trial of continuous positive airway pressure in mild obstructive sleep apnoea. *Am. J. Respir. Crit. Care Med*., 2002, 165: 773–780.

Barnes, M., McEvoy, R. D., Banks, S. *et al*. Efficacy of positive airway pressure and oral appliance in mild to moderate obstructive sleep apnoea. *Am. J. Respir. Crit. Care Med*., 2004, 170: 656–664.

Bloch, K. E., Schoch, O. D., Zhang, J. N. and Russi, E. W. German version of the Epworth Sleepiness Scale. *Respiration*, 1999, 66: 440–447.

Bloch, K. E., Iseli, A., Zhang, J. N. *et al*. A randomized, controlled crossover trial of two oral appliances for sleep apnoea treatment. *Am. J. Respir. Crit. Care Med*., 2000, 162: 246–251.

Buysse, D. J., Reynolds, C. F., III, Monk, T. H., Berman, S. R. and Kupfer, D. J. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*., 1989, 28: 193–213.

Clark, G. T. Mandibular advancement devices and sleep disordered breathing. *Sleep Med. Rev*., 1998, 2: 163–174.

Clark, G. T., Blumenfeld, I., Yoffe, N., Peled, E. and Lavie, P. A crossover study comparing the efficacy of continuous positive airway pressure with anterior mandibular positioning devices on patients with obstructive sleep apnoea. *Chest*, 1996, 109: 1477–1483.

Engleman, H. M., Kingshott, R. N., Wraith, P. K., Mackay, T. W., Deary, I. J. and Douglas, N. J. Randomized placebo-controlled crossover trial of continuous positive airway pressure for mild sleep apnoea/hypopnoea syndrome. *Am. J. Respir. Crit. Care Med*., 1999, 159: 461–467.

Ferguson, K. A., Ono, T., Lowe, A. A., al-Majed, S., Love, L. L. and Fleetham, J. A. A short-term controlled trial of an adjustable oral

appliance for the treatment of mild to moderate obstructive sleep apnoea. *Thorax*, 1997, 52: 362–368.
Giles, T. L., Lasserson, T. J., Smith, B. H., White, J., Wright, J. and Cates, C. J. Continuous positive airways pressure for obstructive sleep apnoea in adults. *Cochrane Database Syst. Rev.*, 2006, 3: CD001106.
Hoffstein, V. Review of oral appliances for treatment of sleep-disordered breathing. *Sleep Breath*, 2007, 11: 1–22.
Johns, M. W. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep*, 1991, 14: 540–545.
Kushida, C. A., Morgenthaler, T. I., Littner, M. R. *et al.* Practice parameters for the treatment of snoring and obstructive sleep apnoea with oral appliances: an update for 2005. *Sleep*, 2006, 29: 240–243.
Lim, J., Lasserson, T. J., Fleetham, J. and Wright, J. Oral appliances for obstructive sleep apnoea. *Cochrane Database Syst. Rev.*, 2006: CD004435.
Marklund, M., Sahlin, C., Stenlund, H., Persson, M. and Franklin, K. A. Mandibular advancement device in patients with obstructive sleep apnoea: long-term effects on apnoea and sleep. *Chest*, 2001, 120: 162–169.
Mehta, A., Qian, J., Petocz, P., Darendeliler, M. A. and Cistulli, P. A. A randomized, controlled study of a mandibular advancement splint for obstructive sleep apnoea. *Am. J. Respir. Crit. Care Med.*, 2001, 163: 1457–1461.
Pancer, J., Al-Faifi, S., Al-Faifi, M. and Hoffstein, V. Evaluation of variable mandibular advancement appliance for treatment of snoring and sleep apnoea. *Chest*, 1999, 116: 1511–1518.
Randerath, W. J., Heise, M., Hinz, R. and Ruehle, K. H. An individually adjustable oral appliance vs continuous positive airway pressure in mild-to-moderate obstructive sleep apnoea syndrome. *Chest*, 2002, 122: 569–575.
Redline, S., Adams, N., Strauss, M. E., Roebuck, T., Winters, M. and Rosenberg, C. Improvement of mild sleep-disordered breathing with CPAP compared with conservative therapy. *Am. J. Respir. Crit. Care Med.*, 1998, 157: 858–865.
Rose, E. C., Germann, M., Sorichter, S. and Jonas, I. E. Case control study in the treatment of obstructive sleep-disordered breathing with an intraoral protrusive appliance. *J. Orofac. Orthop.*, 2004, 65: 489–500.
Ware, J. E. and Kosinski, M. Interpreting SF-36 summary health measures: a response. *Qual. Life Res.*, 2001, 10: 405–413. Discussion 415–420.

APPENDIX I. SLEEP SYMPTOMS QUESTIONNAIRE

1. Interference with daily tasks: 'During the last week, to what extent has sleepiness interfered with your life?' Likert scale: (1) no interference; (6) totally (Bloch *et al.*, 2000).
2. Performance ability: 'During the last week, how would you rate your ability to perform tasks at home and at work?' Likert scale: (1) best: alert, concentrate well; (6) worst: feel 'foggy', tired.
3. Energy level: 'During the last week, how would you rate your level of energy?' Likert scale: (1) fresh as a daisy, (6) tired to death.
4. Snoring intensity: Over the last week, your snoring has been: (0) I have never snored; (1) only slightly louder than heavy breathing; (2) about as loud as mumbling or talking; (3) louder than talking; (4) extremely loud—can be heard through a closed door; (5) I don't know.
5. Snoring frequency: 'Over the last week, how many nights have you snored or have you been told that you snore?' (0) Never: (1) rarely; less than once weekly; (2) sometimes (once or twice weekly); (3) frequently (three or four times weekly); (4) almost always (five to seven times weekly); (5) I don't know.