Oral appliance influence on jaw function in obstructive sleep apnea

Åke Tegelberg,[a,b] Eva Nohlert,[b] Thomas List,[a] and Göran Isacsson[b,c]
Malmö and Vasteras, Sweden

Introduction: Oral appliance (OA) therapy in obstructive sleep apnea (OSA) could be a risk factor for normal jaw function, given the prolonged effect of an OA in keeping the mandible in a protruded position away from a normal position. This study aimed to assess changes in symptoms and clinical findings related to jaw function after 1 year of treating OSA with an OA. **Methods:** In this follow-up clinical trial, 302 patients with OSA were assigned to treatment with either monobloc or bibloc OA. Baseline and 1-year follow-up assessment included using the Jaw Functional Limitation Scale, self-reported symptoms and signs related to jaw function. The clinical examination of jaw function included mandibular mobility, dental occlusion, and tenderness in the temporomandibular joints and masticatory muscles. Descriptive analyses of variables are presented for the per-protocol population. To evaluate differences between the baseline and the 1-year follow-up, paired Student *t* tests and the McNemar change test was used. **Results:** One-hundred and ninety-two patients completed the 1-year follow-up (male 73%, mean aged 55 ± 11 years). There was no change in the Jaw Functional Limitation Scale score at the follow-up (nonsignificant). The patients described no change in symptoms at the follow-up, except for improvements in morning headache ($P < 0.001$) and increased frequency of difficulties in opening the mouth or chewing on awakening ($P = 0.002$). Subjectively reported changes in dental occlusion during biting/chewing increased significantly at the follow-up ($P = 0.009$). **Conclusions:** No changes in measurements of jaw mobility, dental occlusion, or pain on palpation of the temporomandibular joints or masticatory muscles were seen at the follow-up. Thus, using an OA in treating OSA had limited influence on jaw functions and related symptoms. Moreover, the risk of developing pain and functional impairment in the masticatory system was infrequent, indicating that this treatment is safe and can be recommended. (Am J Orthod Dentofacial Orthop 2023;164:682-9)

Oral appliance (OA) therapy is recommended in treating obstructive sleep apnea (OSA), especially in mild-to-moderate forms, in which positive treatment outcomes have been reported by the American Academy of Sleep Medicine[1] as an alternative treatment option to the frequently used continued positive airway pressure, continuous positive airway pressure. The OA holds the lower jaw in a protruded position, thereby preventing the upper airway collapse at sleep and facilitating continuous respiration. However, this position might affect normal jaw functions such as mastication, jaw mobility and dental occlusion because of the forces applied by the OA to these structures.[2] The long-term use of an OA and the associated skeletal and dentoalveolar changes in tooth position over time[3-5] are well documented and seem to increase with time in use.[6,7] Short-term adverse effects are reported uncommon among typical OA patients,[8] but when it appears, complaints about the teeth, occlusal changes, and pain in temporomandibular joints and jaw muscles[9] are usually mild and transient.[10-13] The specific instrument Jaw Functional Limitation Scale (JFLS) was developed to receive a global assessment of jaw function.[14] The instrument was developed using item response theory and rash analysis, and the scale has satisfactory reliability and validity. The JFLS has 3-dimensions: mastication, jaw mobility, and emotional and verbal expression. There are 2 versions the 20-item JFLS and the shorter

[a]Department of Orofacial Pain and Jaw Function, Malmö University, Malmö, Sweden.
[b]Region Västmanland - Uppsala University, Centre for Clinical Research, Västmanland Hospital, Västerås, Sweden.
[c]Orofacial pain and jaw function Clinic, Department of Specialist Dental Care, Västmanland Hospital, Västerås, Sweden.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
This work was supported by the Uppsala-Örebro Regional Research and Västmanland County Councils. No one from the study sponsors participated in the study design, collection, interpretation, or analysis of the data, writing a report, or participating in the decision to submit the paper for publication.
Address correspondence to: Åke Tegelberg, Malmö University Faculty of Odontology, Department of Orofacial Pain and Jaw Function, Dental School, Malmö, Sweden; e-mail, ake.tegelberg@gmail.com.
Submitted, December 2022; revised and accepted, April 2023.
0889-5406

https://doi.org/10.1016/j.ajodo.2023.04.018

8-item JFLS. This study uses the short version. Subjective symptoms, clinical signs, and consequences in daily activities of jaw function, such as eating and chewing, have rarely been reported from a medium- or long-term perspective. Therefore, we aimed to evaluate changes in symptoms and clinical findings related to jaw function after 1 year of treatment of OSA using OAs.

METHODS

This analysis is based on a multicentre, randomized equivalence study on patients with verified OSA with 2 parallel groups treated with 1 type of bibloc or monobloc appliance over 1 year.[15] The treatment effects in improving respiratory impairments in terms of apnea-hypopnea index were equivalent to the used types of appliances.[15] A prestudy on jaw function symptoms and clinical findings disclosed no significant differences between the monobloc and bibloc cohorts. As efficacy and all reported symptoms and clinical findings in jaw function were nonsignificant (NS) between the 2 types of treatment modalities, the analyses of this study will hereafter include results of the 2 appliances altogether. The results of the prestudy are presented in an added Supplementary Material and Supplementary Tables I-IV.

The study protocol was performed in accordance with the ethical principles regarding human experimentation in the 1964 Declaration of Helsinki and good clinical practice. Oral and written informed consent was obtained from all patients before inclusion. The Uppsala Regional Ethical Review Board, Sweden, approved the study: 2014 (no. 2014/021). The trial registration code in ClinicalTrials.gov is NCT02148510.

This study comprised evaluations from baseline to the 1-year follow-up, including questionnaires, clinical variables, and polygraphic home recordings of sleep parameters earlier reported in Tegelberg et al.[15] All participants underwent 1-night at-home respiratory baseline polygraphy without any respiratory support. At the 1-year follow-up visit, polygraphy was repeated with the appliance in situ. Interpretation of the polygraph recordings was made by 2 experienced biomedical technicians at the Västmanland County Hospital Physiology Unit, who were blinded to the type of OA used. The methods have been presented in detail by Isacsson et al[9] and Tegelberg et al.[15] The full study protocol is available at http://www.medfarm.uu.se/ckfvasteras/forskning/studieprotokoll.

All participating dentists were certified or experienced in dental sleep medicine. Before the start of the study, 1 calibration and training event was performed. The patients visited the 3 participating dental specialist clinics on 5 scheduled occasions: (1) baseline visit, (2) initial visit when the appliance was fitted, (3) between check-up visit before the 8-week evaluation, (4) 8-week evaluation visit, and (5) final evaluation visit after 1 year of treatment with an OA. Monitoring and data management were performed by 2 independent persons (G.I.).

All patients had an established diagnosis of OSA and were referred to the study clinics by physicians requesting treatment. Patients were eligible if they had a minimum apnea-hypopnea index of 15 according to the referral, an oral status allowing retention of an OA and at least 1 molar in each jaw quadrant, and a mandibular maximum advancement capacity of $\geq$6 mm. They needed to provide informed consent, could understand, and communicate in Swedish, understood the instructions for applying the portable polygraphic equipment at home and were able to provide valid baseline polygraphy. Exclusion criteria were as follows: aged $<$18 years, body mass index $>$35 kg/m^2, jaw functional problems subjected to dental treatment over the past year, pain or locking of the jaw at the baseline evaluation, hypersensitivity to the materials used in the OA, actual OA treatment in the past month, or unable to follow the instructions of the study. In the Figure, a flowchart of the study is visualized.

The OAs providing mandibular advancement were the Narval bibloc appliance manufactured by ResMed (Kista, Sweden) and the other was monobloc appliance: a 1-piece heat-cured acrylic structure retained by clasps on the teeth, manufactured by Boxholm Tandteknik, Sweden and the Public Dental Service of Örebro, Sweden. A construction index was made for a predetermined position of 75% of the maximum mandibular protrusion capacity (at least 5 mm advancement). When commencing the OA treatment, the subject was encouraged to use the OA every night and during a full night's sleep.

The questionnaires included items about pain and other symptoms as yes/no alternatives related to jaw function, changes in occlusal comfort, reported headaches and frequency, and awareness of bruxism the last month during the day or night. The JFLS-8, a validated instrument that contains 8 questions, was used. A summary score of the JFLS-8 items was used to assess global jaw function.[14,16]

The JFLS is a self-report instrument measuring jaw function limitations. The JFLS is a reliable and valid set of scales comprising 20 items. Each item indicates the limitation level during the past month with response options 0 (no limitation) and 10 (severe limitation). The patient can receive a total score of 0-200. Three conceptually distinct constructs are identified: (1) mastication, which comprises all movements related to preparing food for swallowing; (2) vertical jaw mobility, which

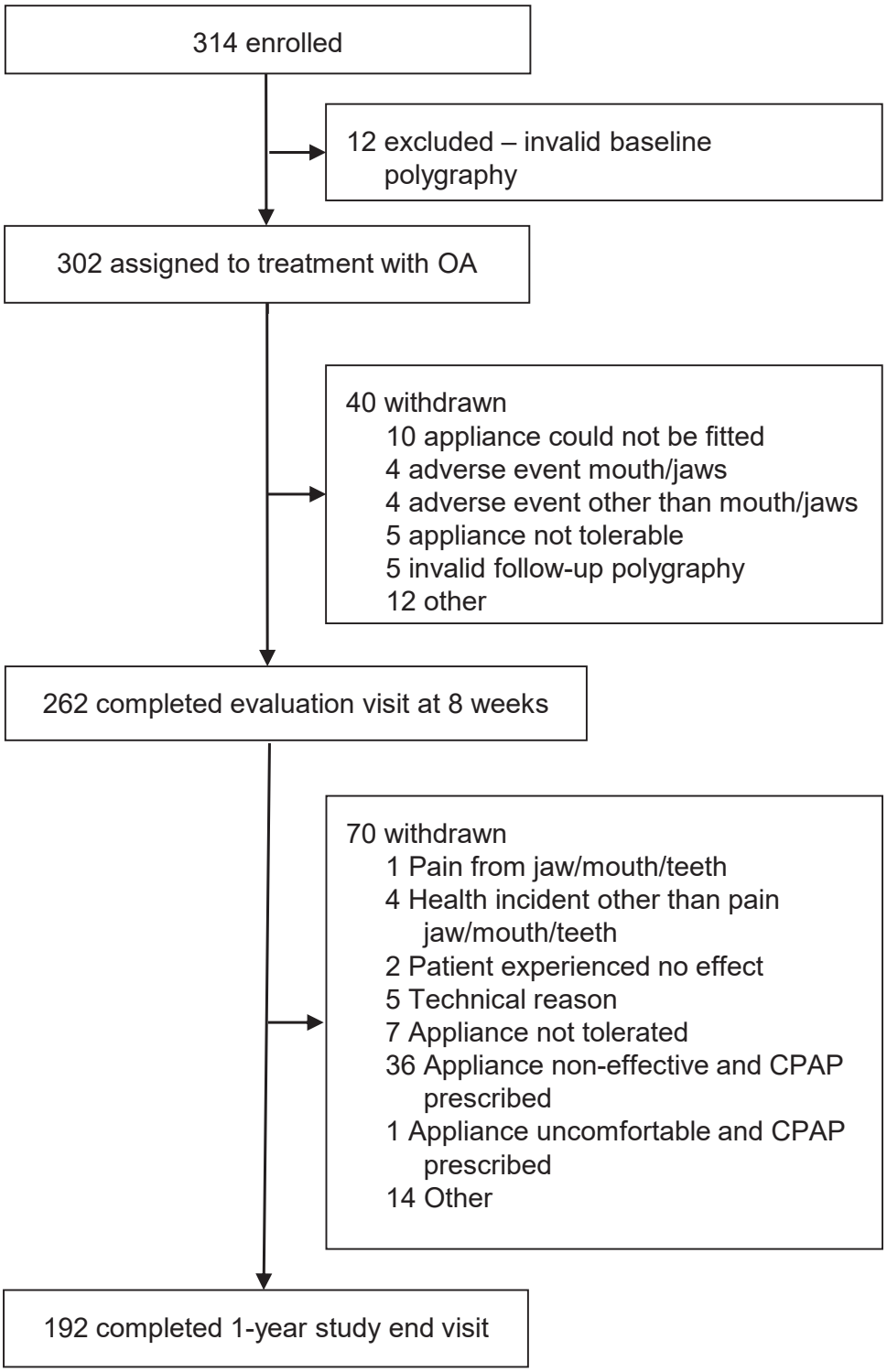

Fig. Study flowchart.

includes all movements associated with opening the jaw; and (3) verbal and emotional expression. The JFLS-8 score measures a fourth construct, global functional jaw limitation. Each scale can be administered independently. This study used the global jaw limitation scale, which includes 8 of the 20 items: Chew tough food,

chew chicken, eat soft food, open wide enough to drink from a cup, swallow, yawn, talk, and smile. A score ranging from 0 to 80 for each individual was received.

The clinical status was examined at baseline and the 1-year follow-up and included pain on digital palpation of the temporomandibular joints (TMJs), temporalis, and masseter muscles. Occurrences of estimated impaired condylar translation and pain in the TMJ during movements were noted as yes/no alternatives. Mandibular mobility (ie, maximum protrusion and maximal opening [including overbite and overjet]) was measured millimeters with a ruler. The patient was asked to bite in the intercuspal position with a mild force, and the occlusal contacts were recorded using an occlusal foil. Normal occlusal support was registered if the molar teeth firmly grip the foil. Any mandibular shift in a lateral direction in the movement from intercuspidal to maximal protrusion position was recorded. Any slide from the central relation of the mandible to the central occlusion of the mandible was observed.

No specified primary measure was chosen in this analysis, but of interest and exploration were the total JFLS-8 index and the multiple outcomes based on reported symptoms and clinical parameters focusing on jaw function when comparing the differences between before and after 1 year of treatment.

Statistical analysis

Descriptive analyses of variables are presented for the per-protocol population. Continuous variables are presented as mean and standard deviation or median with interquartile range and categorical variables as number and percentage. Paired Student *t* tests were used to evaluate differences between baseline and the 1-year follow-up for the means of continuous variables, and the McNemar change test was used for categorical variables. Statistical analyses were performed using SPSS software (version 26; IBM, Armonk, NY). Statistical significance was assumed at $P < 0.05$.

RESULTS

Of the 313 enrolled patients, 192 completed the 1-year follow-up. Patient demographics and baseline characteristics of the per-protocol population are presented in Table 1. The mean duration of the follow-up visit was 12.5 ± 1.5 months. The patient's self-reported compliance was measured as the mean number of nights using the appliance the past week before the 1-year follow-up was 6 ± 1 nights. The mean proportion of sleep time when using the appliance per night during the week before the follow-up was 88% ± 21%.

Table I. Patient demographics and baseline characteristics of the per-protocol populations

Demographics and characteristics	*n = 192*
Male gender	141 (73)
Age (y)	55 (11)
Weight (kg)	86 (13)
BMI	28 (3)
Respiratory variables	
AI (events/h)	12 ± 10
Longest apnea incident (s)	43 ± 20[†]
AHI (events/h)	24 ± 13
ODI (events/h)	23 ± 13
Lowest SpO_2, %	82 ± 5
Average SpO_2, %	93 ± 2
SpO_2 time < 90%; % of sleep time	8 ± 15
Estimated sleep efficiency (%)	90 ± 12
OSA severity, categorized by AHI	
Mild (AHI <15)	54 (28)
Moderate (AHI 15-29)	81 (42)
Severe (AHI ≥30)	57 (30)

Note. Data are shown as n (%) or mean ± standard deviation.
BMI, body mass index; *AI*, apnea index; *AHI*, apnea-hypopnea index; *ODI*, oxygen desaturation index; *SpO_2*, oxygen desaturation level.
[†]n = 190.

The mean of overall jaw functional limitations measured with the JFLS-8 scale (0-80 points) was 3.5 ± 7.7 at baseline and 2.7 ± 6.4 (NS) at follow-up.

The patients described the following symptoms at waking after a night's sleep at baseline and the follow-up: discomfort or tiredness in jaw muscles (NS); experience of headache in the morning reduced in frequency ($P < 0.001$); and difficulties in opening the mouth or chewing on awaking after a night's sleep in the morning increased at the 1-year follow-up ($P = 0.002$). The reported pain symptoms (once a week or more) related to jaw function are shown in Table II. Pain in the temple, face, or jaws and locking and TMJ sounds showed no significant difference. However, mouth opening and chewing pain significantly increased from 8% to 20%.

Reported awareness of bruxism during night-time was 28% at baseline and 30% at the 1-year follow-up (NS) and was lower for daytime bruxism (baseline, 19%; 1-year follow-up, 20%; NS).

Subjectively reported uncomfortable dental occlusion during biting/chewing was reported among 9% of patients at baseline and 18% at the follow-up ($P = 0.009$). However, the clinical examination of the occlusion could not confirm any significant change over time (Table III). Tooth wear (score 1-4) was registered at baseline in >90% of the patients according to the tooth wear index established by Carlsson et al,[17] but only 2% had the most severe score of 4.

Table II. Reported symptoms and pain related to jaw functions at waking after a night's sleep in using an OA at baseline and at the 1-year follow-up in the per-protocol population

Pain/discomfort: Yes, once a week or more often	*Baseline (n = 192)*	*1-y follow-up (n = 192)*	P *value**
Pain in the temple, face, TMJ or jaws	42 (22)†	50 (26)	0.401
Pain on mouth opening or chewing	16 (8)	38 (20)	0.002
Locking or closed lock of the jaw	14 (7)	18 (9)	0.541
Clicking or crepitus in the TMJ during chewing or mouth opening	42 (22)	42 (24)‡	0.710

Note. Values are presented as n (%).
*Differences between baseline and the 1-year follow-up were tested using the McNemar change test; †n = 191; ‡n = 175.

Table III. Jaw mobility, relationships, and occlusion support in users of OAs at baseline and the 1-year follow-up in the per-protocol population

Variables	*Baseline*† *(n = 192)*	*1-y follow-up*† *(n = 192)*	P *value*
Maximal mouth opening (mm)	51.7 ± 6.5	51.4 ± 6.4	0.402
Maximum protrusive capacity (mm)	8.7 ± 1.8	9.0 ± 1.9	0.009†
Overbite (mm)	3.2 ± 2.1	2.8 ± 2.1	<0.001†
Overjet (mm)	3.1 ± 1.6	2.8 ± 1.5	<0.001†
Normal occlusion support (right side)	176 (92)	171 (89)	0.486‡
Normal occlusion support (left side)	176 (92)	168 (87)	0.230‡
Detectable sliding, CR to CO	37 (20)§	12 (6)¶	<0.001‡
Mandibular deviation on maximal protrusive motion	78 (41)¶	58 (30)	0.007‡

Note. Data are shown as mean ± standard deviation or n (%).
CR, central relation of the mandible; *CO*, central occlusion of the mandible.
†Differences between baseline and 1-year follow-up were tested by paired *t* test; ‡Differences between baseline and 1-year follow-up were tested by McNemar change test; §n = 188; ¶n = 191.

Table IV. Presence of tenderness on palpation in TMJs and masticatory muscles in users of OAs at baseline and the 1-year follow-up in the per-protocol population

Variables	*Baseline (n = 192)*	*1-y follow-up (n = 192)*	P *value**
TMJs			
Palpatory tenderness (right side)	12 (6)	12 (6)	1.000
Palpatory tenderness (left side)	14 (7)	14 (7)	1.000
Reduced translatory mobility (right side)	4 (2)	2 (1)	0.688
Reduced translatory mobility (left side)	8 (4)	2 (1)†	0.070
TMJ sounds (right side)	32 (17)	42 (22)	0.089
TMJ sounds (left side)	46 (24)	35 (18)	0.082
Pain on jaw motion (right side)	3 (2)	1 (1)	0.625
Pain on jaw motion (left side)	5 (3)	3 (2)‡	0.727
Masticatory muscles			
Palpatory tenderness in temporalis/masseter muscles (right side)	21 (11)	16 (8)	0.424
Palpatory tenderness in temporalis/masseter muscles (left side)	28 (15)	26 (13)	0.871
Pain on jaw motion (right side)	7 (4)	1 (1)	0.031
Pain on jaw motion (left side)	7 (4)	2 (1)	0.125

Note. Values are presented as n (%).
*Differences between baseline and the 1-year follow-up results were evaluated using the McNemar change test; †n = 191; ‡n = 190.

The clinical measurements of jaw mobility, jaw relationships, and dental occlusion at baseline and at the 1-year follow-up are shown in Table III. A significant increase in maximal protrusive capacity was detected, as a significant decrease of overbite and overjet, as also a detectable slide from centric relation to centric occlusion and mandibular deviation at the protrusion. Pain scores on palpation in the TMJ and masticatory muscles did not change significantly, except for jaw pain on motion in the masticatory muscles of the right side (Table IV).

DISCUSSION

The main results of this secondary analysis originating from the original randomized controlled trial[15]

showed that OA treatment of OSA had a limited affection on jaw function.

Oral function is an important aspect of a patient's health. As a part of oral function, jaw functions can be affected following the use of OAs, which protrude the mandible in an abnormal position during sleep. Although an OA is intermittent, it can lead to adverse consequences. Our study focused on assessing the functional status of the masticatory system with the JFLS-8 global functional limitation scale. The JFLS -8 is a valid and reliable instrument, provides an overall assessment of the functional limitation and has less respondent burden for the patient. Our study found low average values of reduced jaw function at the baseline registration, consistent with other studies in which healthy subjects participated.[16,18] Significantly higher values of reduced jaw function have been noted in patients with temporomandibular disorder pain, primary Sjögren syndrome, severe malocclusions and burning mouth syndrome.[16] At the follow-up, the average JFLS-8 value was unchanged, which indicates that even if there were changes in the bite, it has no consequence for the everyday masticatory function.

The amount of mandibular advancement is an important factor in the effectiveness of OA therapy, as shown in several studies.[19,20] In a meta-analysis, Bartolucci et al[4] found no evidence that a protrusion of more than 50% of the maximum advancement of the lower jaw has any benefit for mild and moderate conditions. Therefore, it has been recommended to "titrate" the minimum degree of mandibular advancement to determine the subjectively optimal effect.[21] The amount of mandibular advancement is important in treating severe OSA, in which a greater advancement produces better outcomes.[11] Our patients were subjected to an advancement of 75% of the individual maximum protrusion capacity, which might be deemed excessive because the incidence of side effects is reported to be larger at increasing degrees of protrusion.[22] However, that was not observed in 2 earlier studies with monobloc therapy,[11,23] nor when monobloc appliances were compared with a bibloc design.[15] Adverse events following the use of OAs in the treatment of OSA have been documented, but they are mild and usually well tolerated by most patients.[15]

The symptoms and consequences of OA use are mostly mild, as documented in a systematic review and meta-analysis.[24] That was confirmed in this study, as no differences of clinical relevance were observed between baseline and the follow-up, although statistical significance was found for some specific variables, such as difficulties in jaw mobility and function in the morning after waking after a night's sleep. However, these findings were not influencing the overall JFLS score.

There was an obvious reduction in headache frequency in this study, as also found in previous studies,[11,12,23,25] probably caused by a reduction in the arterial carbon dioxide with lower apnea-hypopnoea episodes during sleep.

In the clinical measurements of jaw function, movement ranges were stable with only minor changes, which confirms results from previous studies[26,27] indicating that the jaw function has enough recovery time during the day. A small reduction in overbite and overjet was observed in our study. This aligns with previous reports in which these changes increase over time.[7,12,28]

Palpatory tenderness to the TMJs and masticatory muscles indicates pain or dysfunction in jaw function. This occurred infrequently and did not change in any used treatment options or over the treatment period. This result is consistent with the meta-analysis by Alessandri-Bonetti et al.[24]

Compliance with treatment with an OA is the basis for efficacy and knowledge about patients' experiences and affection of the jaw function in using such a device. In this study, the patients reported their use of OA to a great extent, with self-reported rates of about 90% sleep time. Extrapolating to our study, we can assume that the compliance to treatment was probably good, but of course, the lack of an objective compliance measure is a limitation of this study.

The strengths of this study are that the study was performed at 3 different specialist clinics, comprised a large number of patients and had a rather long follow-up period. Another strength is independent monitoring and data management. However, the limitations are that the data analyses are not based on primary statistical hypothesis testing or the dropout rates. The most common reason for the dropouts (33%) was an ineffective appliance and was referred to continuous positive airway pressure treatment. Related adverse events to the mouth and jaw occurred in $<1\%$, and in 11%, the patients could not tolerate using an OA.[15] Another limitation is using only yes/no response alternatives in some questionnaires, which decreased the ability to detect any nuances in the answers.

CONCLUSIONS

The use of an OA in treating OSA was in this follow-up with limited influence on jaw functions and related symptoms. Moreover, the risk of developing pain and function impairment in the TMJ complex appears to be limited among users of OAs over 1 year,

which indicates that the treatment is safe and can be recommended.

ACKNOWLEDGMENTS

The authors thank the patients who participated in this study. The authors also thank the participating dental specialists: Anna Avdelius, Clara Fodor, Eva Ortlieb, Mohamad Schumann, Magnus Sturebrand, Livia Trepp and Eva Wiman-Eriksson for their clinical work.

AUTHOR CREDIT STATEMENT

Åke Tegelberg contributed to conceptualization, methodology, formal analysis, data curation, original draft preparation, manuscript review and editing, visualization, and supervision; Eva Nohlert contributed to formal analysis, data curation, manuscript review and editing, visualization, supervision, and project administration; Thomas List contributed to investigation, data curation, manuscript review and editing, and supervision; Göran Isacsson contributed to conceptualization, methodology, formal analysis, investigation, data curation, original draft preparation, manuscript review and editing, supervision, and project administration.

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ajodo.2023.04.018.

REFERENCES

1. Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. The report of an American Academy of Sleep Medicine task force. Sleep 1999;22:667-89.
2. Dieltjens M, Vanderveken O. Oral appliances in obstructive sleep apnea. Healthcare (Basel) 2019;7.
3. Doff MH, Finnema KJ, Hoekema A, Wijkstra PJ, de Bont LG, Stegenga B. Long-term oral appliance therapy in obstructive sleep apnea syndrome: a controlled study on dental side effects. Clin Oral Investig 2013;17:475-82.
4. Bartolucci ML, Bortolotti F, Raffaelli E, D'Antò V, Michelotti A, Alessandri Bonetti G. The effectiveness of different mandibular advancement amounts in OSA patients: a systematic review and meta-regression analysis. Sleep Breath 2016;20:911-9.
5. Araie T, Okuno K, Ono Minagi H, Sakai T. Dental and skeletal changes associated with long-term oral appliance use for obstructive sleep apnea: a systematic review and meta-analysis. Sleep Med Rev 2018;41:161-72.
6. Tsolakis IA, Palomo JM, Matthaios S, Tsolakis AI. Dental and skeletal side effects of oral appliances used for the treatment of obstructive sleep apnea and snoring in adult patients-a systematic review and meta-analysis. J Pers Med 2022;12.
7. Fransson AMC, Benavente-Lundahl C, Isacsson G. A prospective 10-year cephalometric follow-up study of patients with obstructive sleep apnea and snoring who used a mandibular protruding device. Am J Orthod Dentofacial Orthop 2020;157:91-7.
8. Sheats RD. Management of side effects of oral appliance therapy for sleep-disordered breathing: summary of American Academy of Dental Sleep Medicine recommendations. J Clin Sleep Med 2020;16:835.
9. Isacsson G, Nohlert E, Fransson AMC, Bornefalk-Hermansson A, Wiman Eriksson E, Ortlieb E, et al. Use of bibloc and monobloc oral appliances in obstructive sleep apnoea: a multicentre, randomized, blinded, parallel-group equivalence trial. Eur J Orthod 2019;41:80-8.
10. Tegelberg A, Wilhelmsson B, Walker-Engström ML, Ringqvist M, Andersson L, Krekmanov L, et al. Effects and adverse events of a dental appliance for treatment of obstructive sleep apnoea. Swed Dent J 1999;23:117-26.
11. Walker-Engström ML, Ringqvist I, Vestling O, Wilhelmsson B, Tegelberg A. A prospective randomized study comparing two different degrees of mandibular advancement with a dental appliance in treatment of severe obstructive sleep apnea. Sleep Breath 2003;7:119-30.
12. Doff MH, Veldhuis SK, Hoekema A, Slater JJ, Wijkstra PJ, de Bont LG, et al. Long-term oral appliance therapy in obstructive sleep apnea syndrome: a controlled study on temporomandibular side effects. Clin Oral Investig 2012;16:689-97.
13. Doff MH, Jansma J, Schepers RH, Hoekema A. Maxillomandibular advancement surgery as alternative to continuous positive airway pressure in morbidly severe obstructive sleep apnea: a case report. Cranio 2013;31:246-51.
14. Ohrbach R, Granger C, List T, Dworkin S. Preliminary development and validation of the Jaw Functional Limitation Scale. Community Dent Oral Epidemiol 2008;36:228-36.
15. Tegelberg Å, Nohlert E, Bornefalk-Hermansson A, Fransson A, Isacsson G. Respiratory outcomes after a 1-year treatment of obstructive sleep apnoea with bibloc versus monobloc oral appliances: a multicentre, randomized equivalence trial. Acta Odontol Scand 2020;78:401-8.
16. Ohrbach R, Larsson P, List T. The Jaw Functional Limitation Scale: development, reliability, and validity of 8-item and 20-item versions. J Orofac Pain 2008;22:219-30.
17. Carlsson GE, Johansson A, Lundqvist S. Occlusal wear. A follow-up study of 18 subjects with extensively worn dentitions. Acta Odontol Scand 1985;43:83-90.
18. Oghli I, List T, John MT, Häggman-Henrikson B, Larsson P. Prevalence and normative values for jaw functional limitations in the general population in Sweden. Oral Dis 2019;25:580-7.
19. Vecchierini MF, Léger D, Laaban JP, Putterman G, Figueredo M, Levy J, et al. Efficacy and compliance of mandibular repositioning device in obstructive sleep apnea syndrome under a patient-driven protocol of care. Sleep Med 2008;9:762-9.
20. Kato J, Isono S, Tanaka A, Watanabe T, Araki D, Tanzawa H, et al. Dose-dependent effects of mandibular advancement on pharyngeal mechanics and nocturnal oxygenation in patients with sleep-disordered breathing. Chest 2000;117:1065-72.
21. Ramar K, Dort LC, Katz SG, Lettieri CJ, Harrod CG, Thomas SM, et al. Clinical practice guideline for the treatment of obstructive sleep apnea and snoring with oral appliance therapy: an update for 2015. J Clin Sleep Med 2015;11:773-827.
22. Aarab G, Lobbezoo F, Hamburger HL, Naeije M. Effects of an oral appliance with different mandibular protrusion positions at a constant vertical dimension on obstructive sleep apnea. Clin Oral Investig 2010;14:339-45.
23. Tegelberg A, Walker-Engström ML, Vestling O, Wilhelmsson B. Two different degrees of mandibular advancement with a dental appliance in treatment of patients with mild to moderate obstructive sleep apnea. Acta Odontol Scand 2003;61:356-62.

24. Alessandri-Bonetti A, Bortolotti F, Moreno-Hay I, Michelotti A, Cordaro M, Alessandri-Bonetti G, et al. Effects of mandibular advancement device for obstructive sleep apnea on temporomandibular disorders: a systematic review and meta-analysis. Sleep Med Rev 2019;48:101211.
25. Fransson AM, Tegelberg A, Johansson A, Wenneberg B. Influence on the masticatory system in treatment of obstructive sleep apnea and snoring with a mandibular protruding device: a 2-year follow-up. Am J Orthod Dentofacial Orthop 2004;126:687-93.
26. Zhou J, Li DH, Zhu PF, Yi CY, Chang L, Zhang Y, et al. Effect of mandibular advancement device on the stomatognathic system in patients with mild-to-moderate obstructive sleep apnoea-hypopnoea syndrome. J Oral Rehabil 2020;47:889-901.
27. Patel S, Rinchuse D, Zullo T, Wadhwa R. Long-term dental and skeletal effects of mandibular advancement devices in adults with obstructive sleep apnoea: a systematic review. International orthodontics / College europeen d'orthodontie 2019;17:3-11.
28. Hoffstein V. Review of oral appliances for treatment of sleep-disordered breathing. Sleep Breath 2007;11:1-22.