ACTA ODONTOLOGICA SCANDINAVICA
2020, VOL. 78, NO. 6, 401–408
https://doi.org/10.1080/00016357.2020.1730436

ORIGINAL ARTICLE

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# Respiratory outcomes after a 1-year treatment of obstructive sleep apnoea with bibloc versus monobloc oral appliances: a multicentre, randomized equivalence trial

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**ABSTRACT**

**Objective:** The benefit of bibloc over monobloc appliances in treating obstructive sleep apnoea (OSA) has not been evaluated in randomized trials. We hypothesized that these types of appliances would be equally effective.

**Material and methods:** In this multicentre, randomized equivalence trial, patients with OSA received one type of bibloc or one type of monobloc treatment. At baseline, a 1-night polygraphy study was done, and this was repeated after 1 year. The outcome was any change in the apnoea–hypopnoea index (AHI) and the limits of equivalence between the two devices were set at ±5 AHI units.

**Results:** Of 302 patients, 146 were randomly assigned to bibloc and 156 to monobloc appliances. In 88 and 104 patients, respectively, there were significant reductions in the AHI ($p < .001$) with a mean change of −16.7 (95% CI −19.4 to −14.1) in the bibloc and −11.8 (−14.9 to −8.7) in the monobloc groups. The proportions of responders defined as having an AHI <10 were 68% and 65% for the bibloc and monobloc groups, respectively. Treatment-related adverse events were mild, transient and the dropouts were more frequent in the bibloc group.

**Conclusions:** Both types of treatments positively and significantly reduced respiratory disturbances, but at the 1-year follow-up, they were not significantly different in treating OSA, with a numerically greater reduction of the AHI value with the bibloc appliance. However, the higher proportion of treatment-related adverse events and higher proportion of dropouts among bibloc users should be balanced against the advantage of a greater reduction in the AHI.

**ARTICLE HISTORY**
Received 24 September 2019
Revised 22 January 2020
Accepted 6 February 2020

**KEYWORDS**
Breathing; obstructive sleep apnoea; randomized controlled trial; follow-up study; mandibular advancement

## Introduction

The importance of treating obstructive sleep apnoea (OSA) has been demonstrated to prevent or reduce comorbidities such as cardiovascular diseases, motor vehicle accidents and all-cause mortality [1]. Oral appliances are now a frequent treatment modality for patients with OSA, recommended by the American College of Physicians as a therapy especially in mild to moderate cases of OSA, or those experiencing adverse effects when undergoing treatment with continuous positive airway pressure (CPAP) devices [2].

There are two main types of oral appliances for use in treating OSA: bibloc and monobloc. The bibloc appliance, often called adjustable, has separate constructions for the upper and lower jaws and is equipped with connectors or guides that advance the mandible [3]. The monobloc appliance, often called fixed, is a one-piece acrylic device retained on the teeth that keeps the jaws in a fixed closed mandibular advanced position [4]. Lettieri et al. [5] reported significant advantages in reducing the apnoea–hypopnoea index (AHI) with adjustable compared with fixed appliances. Practice guideline for the treatment of OSA with oral appliance therapy [6] suggests that the dentist should use a custom-made, titratable appliance in preference to non-custom-made oral devices. However, the authors of this guideline also stated that the quality of evidence for this was low. In a retrospective study on 55 bibloc- and 110 monobloc-treated patients who were evaluated polygraphically after 5–6 months, Isacsson et al. [7] found similar efficacy and frequency of adverse events between the two devices. In addition, in a later short-term randomized controlled study with follow-up polygraphy after 8-weeks, bibloc appliances were shown to be as equally effective as monobloc ones [8]. In a systematic review, Sivaramakrishnan and Sridharan [9] found that titratable appliances did not show significant advantages compared with nontitratable ones. The authors concluded that high-quality randomized controlled trials comparing titratable and fixed appliances needed to be carried out to obtain conclusive evidence.

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Using the background data from Isacsson et al. [7] in this randomized controlled trial, we tested the hypothesis that bibloc mandibular advancement appliances would be as equally effective as monobloc appliances in modifying respiratory variables when treating patients with OSA over a 1-year period. Therefore, the aim of the study was to compare one type of bibloc appliance with one type of monobloc oral appliance in terms of their effect on the AHI.

## Material and methods

### Study design

This was a multicentre, randomized equivalence study on patients with verified OSA in two parallel groups – one treated with a bibloc appliance and one with a monobloc appliance – with a follow-up after 1 year. The patients visited the clinic at five scheduled occasions: (1) baseline visit; (2) start of treatment visit when the appliance was fitted; (3) a check-up visit after 2 weeks; (4) an evaluation visit after 8 weeks; and (5) an evaluation visit after 1 year of treatment.

At baseline, each subject provided written informed consent before participation, and completed a set of questionnaires. In addition, impressions of the jaws and a mandibular advancement index for construction of the appliance were taken and a 1-night polygraphy study (NOX-T3, ResMed, Kista, Sweden) was done.

This study was a continuation of a short-term evaluation by Isacsson et al. [8] performed in accordance with the principles of the 1964 Declaration of Helsinki and good clinical practice. Informed consent was obtained from all patients prior to inclusion. The Uppsala Regional Ethical Review Board, Sweden approved the study 2014 (#2014/021). The trial registration in ClinicalTrials.gov is NCT02148510.

### Polygraphic recordings

All participants underwent a 1-night at-home respiratory baseline polygraphic study (NOX-T3®, ResMed, Kista, Sweden) without any respiratory support. At the 8-week evaluation visit and after 1 year of treatment, the polygraphy was repeated, but with the use of the selected appliances. Interpretation of the polygraph recordings was done by two experienced hospital technicians at the Västmanland County Hospital Physiology Unit, who were blinded to the type of oral appliance used. A minimum of four interpretable hours of sleep was requested; if this was not possible, the polygraph examination was repeated on another night. Noxturnal™ software (ver. 3.3.0-6715; https://noxmedical.com/products/noxturnal-software/) was used for the full-night analysis of the polygraph data for each participant. The analysis settings were as follows: apnoea was scored where there was a 90% drop in the flow signal for 10–120 s and hypopnoea was scored when there was a 30% drop in the flow signal for the same time followed by a 3% drop in saturation. No electroencephalogram recordings were made.

The treatment commenced 2–3 weeks following baseline. At the check-up visit 2 weeks after the start of treatment, and if needed based on the subjective effect, the appliance was adjusted. An 8-week evaluation (median 56, interquartile range, 45–79 days of treatment) was performed and presented in Isacsson et al. [8]. The appliance was adjusted if needed, based on the 8-week evaluation. Patients with unfavourable polygraphic data persisting after adjustments were discontinued from the study and referred for CPAP treatment. This study comprised evaluation of the baseline to the 1-year data including clinical measures, iterated questionnaires, and a home-based polygraphic study with the concomitant use of the appliance. The full study protocol is available at http://www.medfarm.uu.se/ckfvasteras/forskning/studieprotokoll

### Study population

The patients had an established diagnosis of OSA and were referred to participating dental specialist clinics by physicians, with requests for treatment. The enrolment period lasted from March 2014 to April 2016 and the 1-year follow-up from May 2016 until July 2017. Patients were eligible if they had a minimum AHI of 15 according to the referral, an oral status allowing retention of an appliance, a maximum mandibular advancement capacity of $\geq$6 mm, had given informed consent, understood and could communicate in Swedish, understood the instructions on how to apply the portable polygraphic equipment at home, and had a valid baseline polygraphic evaluation. Exclusion criteria were: patients aged $<$18 years; a body mass index (BMI) $>$35 kg/m$^2$, functional jaw problems subjected to treatment during the past year; pain or locking of the jaw at baseline; being judged not able to follow study instructions (at the discretion of the investigator); hypersensitivity to the components of the appliances; and CPAP or appliance treatment during the past month.

### Randomization, masking and monitoring

Randomization was generated by an independent agent using Nquery Advisor (Statistical Solutions Ltd., Cork, Ireland) in blocks of 12. The study was blinded until completion of the 8-week evaluation (for details see Isacsson et al. [8]) but thereafter unmasked. The biomedical analysts who evaluated the polygraphy were blinded to the choice of treatment modality throughout the study. All participating dentists were certified or experienced in dental sleep medicine. Monitoring and data management were performed by two independent investigators.

### Appliances and mandibular advancement

The Narval™ bibloc appliance (hereafter the bibloc appliance) manufactured by ResMed (Kista, Sweden) allows adjustment of the mandibular advancement chairside without support of a dental technician (Figure 1(a)). A linking arm at each side connects the lower and upper pieces of the construction. No additional arrangements were allowed for connection of the upper and lower parts of the device. The one-piece monobloc appliance is made of heat-cured acrylic resin and is retained with clasps on the teeth (Boxholm Tandteknik, Boxholm, Sweden and the Public Dental Service,

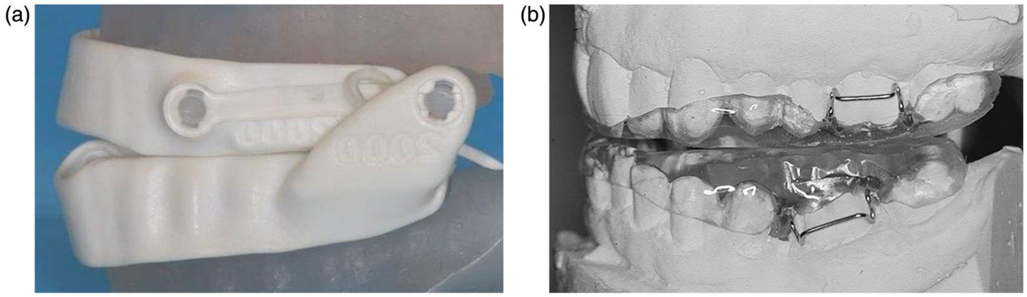

Figure 1. Design of the bibloc (a) and monobloc (b) appliances used in the study.

Orebro, Sweden) (Figure 1(b)). This appliance does not allow any jaw movements. Adjustments of the mandibular advancement required support by a dental technician.

A bite index using the George Gauge instrument [10] was constructed to advance the mandible 75% of the maximum capacity (i.e. at least 5 mm advancement). In this study, the mean mandibular advancement was 9.0 mm (standard deviation, SD ±1.9 mm) in both groups. The patients were encouraged at onset to use the appliance during full sleep every night.

### Outcomes

The primary outcome was the absolute change in the AHI from baseline to the 1-year follow-up with concomitant use of the oral appliance. Secondary outcomes were: oxygen desaturation index (ODI); the apnoea index (AI); arterial oxygen saturation ($SpO_2$); and subjectively estimated sleep efficiency. Treatment compliance was evaluated by asking the patient to complete a questionnaire recording the number of nights and the proportion of sleeping time for which the appliance was used in the past week.

### Adverse events

Spontaneously reported adverse experiences, as well as adverse events registered by the investigator, were recorded throughout the study period. Each adverse experience was evaluated by the investigator, and its association with the study treatment was recorded as probable, possible or unlikely.

### Statistical analysis

The statistical details of this equivalence study can be found in our previous publication regarding the primary outcome of short-term efficacy as measured by the AHI [8]. Descriptive analyses of secondary variables are presented for the per-protocol (PP) population, with sensitivity analyses for the AHI using both the intention-to-treat (ITT) population with baseline-observation-carried-forward (BOCF) adjustments for missing follow-up data, as well as compliance-adjusted PP data (using self-reported mean proportions of times per night that each appliance was used). Any difference in the AHI within each group was compared between groups using a two-sided confidence interval (CI) approach, a level of equivalence between treatments of ±5 AHI units (based on a reasonable estimate of the night-to-night polygraphic recording variation) and a 5% significance level ($p$ values for testing the lower and upper limits of the CI both needed to be $<.025$). All $p$ values reported here should be interpreted descriptively because of the use of multiple testing.

## Results

Of the 313 patients enrolled, 192 completed the 1-year follow-up: 88 in the bibloc group and 104 in the monobloc group. The trial profile and reasons for withdrawal are shown in Figure 2. The two groups were well matched for all baseline characteristics except for the proportion of patients with mild OSA, which was greater in the monobloc group, and a greater proportion of moderate OSA in the bibloc group, but these differences were not statistically different (Table 1).

The patients' own report of compliance in terms of the median number of nights using the appliance during the week before the 1-year follow-up was seven nights for both groups (q1; q3 = 6; 7). The mean reported proportion of sleep time in using the appliance per night the past week was 90% (SD 16) in the bibloc group and 87% (SD 24) in the monobloc group, respectively. The mean treatment time to the 1-year evaluation visit was 12.5 (SD 1.5) months in both groups.

For the PP analysis, the effect of reducing AHI was similar for both appliances between the baseline and 8-week evaluation. Although an additional effect was seen from the 8-week evaluation to the 1-year follow-up, the mean paired differences were modest but statistically equivalent (Figure 3). However, in the main analysis (baseline to 1-year evaluation), the mean paired differences were not statistically equivalent when comparing the bibloc with the monobloc group (Table 2). Neither correction for the severity of AHI nor sensitivity analyses supported the finding of a 1-year equivalence in efficacy between the two appliances (Table 2).

Although there was a greater reduction in the AHI in the bibloc group, the proportion of responders defined as having an AHI $<10$ at the 1-year follow-up was 68% in the bibloc group and 65% in the monobloc group. Responders to the treatment classified according to different cut-off AHI values are described in Table 3. The subgroup of patients with severe OSA showed the greatest absolute improvements in both AHI and ODI for both treatment modalities.

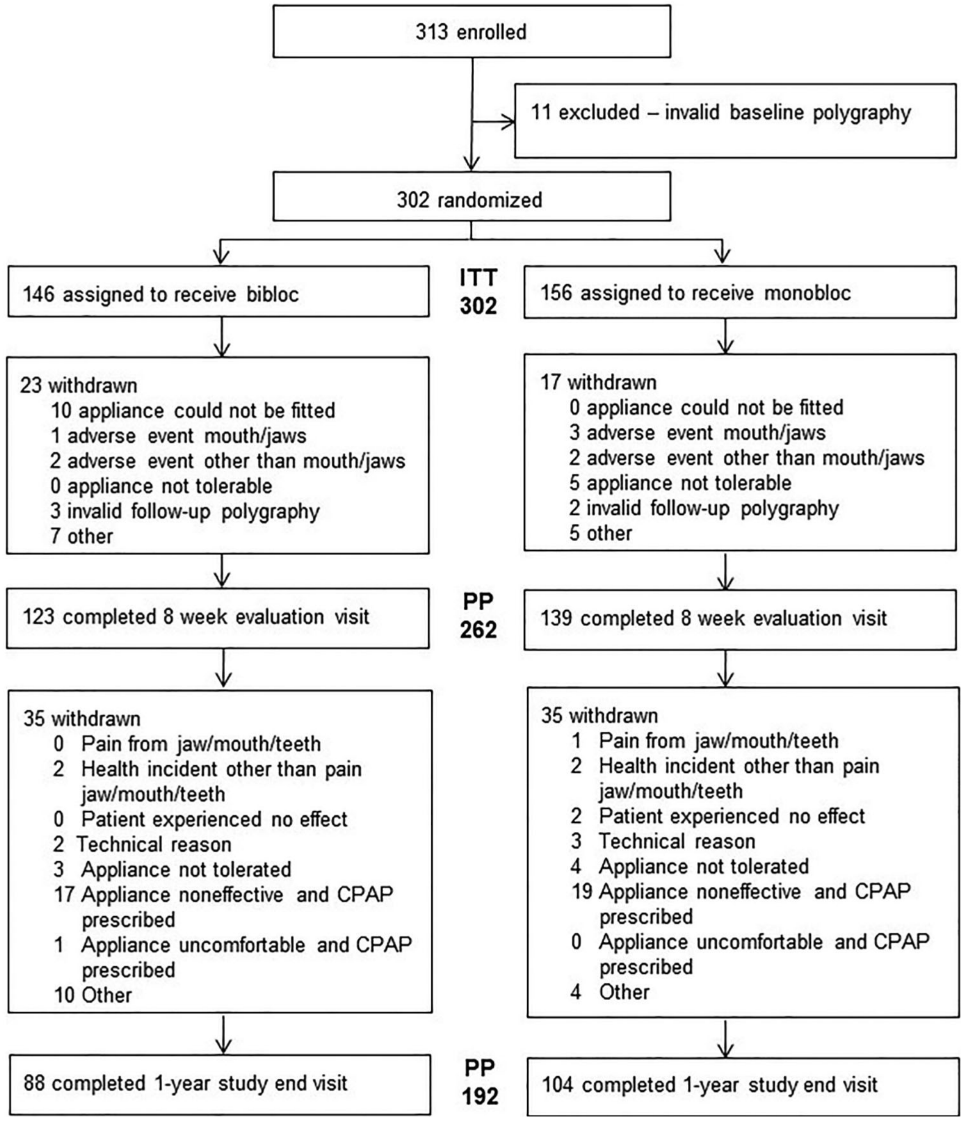


**Figure 2.** Trial population profiles. ITT: intention-to-treat; PP: per protocol.

Improvements in the AI, longest period of apnoea and lowest $SpO_2$ were similar in both groups (Table 4).

Treatment-related adverse events were generally mild and transient and occurred in 39% and 33% of patients in the bibloc and monobloc groups, respectively (Table 5).

## Discussion

To our knowledge, this is the largest prospective randomized controlled trial with a 1-year evaluation comparing a bibloc with a monobloc appliance in the treatment of patients with OSA. The effects of the bibloc and monobloc appliances in lowering the AHI were similar between the baseline and 8-week evaluation. After a considerable reduction in the first 8 weeks, the change in AHI in the following months was lower. The difference did not fall within the defined equivalence limits between the short- and long-term evaluations when analyzing the PP population; thus, the absolute difference in the AHI was 5.0, which must be considered clinically relevant. However, in the sensitivity analyses including the ITT population (Table 2), the influence of dropouts – more frequent in the bibloc group – revealed significant equivalence between the groups with an AHI difference of 2.2. The higher proportion of treatment-related adverse events among bibloc users should also be balanced against the better reduction in the AHI.

The responder rates were similar in absolute numbers and proportions even though there were more patients with mild OSA in the monobloc group, which might have influenced any comparison between the two modalities. From a clinical perspective, the small differences between the two groups should not prevent the application of either of the devices, as they both gave good reductions in the AHI.

The overall AHI improvements with both treatment modalities in this study significantly reduced the AHI by a mean of 12–17 events/hour, with greater absolute effects in patients with severe OSA, which is consistent with a previous systematic review [11]. The 8-week results [8] indicated equivalent outcomes between treatments, supporting the findings of Ahrens et al. [11]. Possible reasons for these inconsistent results might include open labelling, lack of randomization, selection of the appliance being determined by resource availability (in the retrospective study by Lettieri et al. [5]), and variations in the duration of follow-up. In a review of systematic reviews of bibloc versus monobloc appliances, Sato and Nakajima [12] reported a high degree of heterogeneity between study results, which precluded a valid meta-analysis. When the results of our 1-year study are compared with those of the preceding 8-week follow-up of the same sample of patients [8], one must also include time factors when interpreting outcomes.

**Table 1.** Patient demographics and baseline characteristics of the per-protocol population.

| | Bibloc $n=88$ | Monobloc $n=104$ | $p$ Value |
|---|---|---|---|
| Male gender, $n$ (%) | 67 (76) | 74 (71) | .436* |
| Age (years) | 55 (11.4) | 55 (10.7) | .974† |
| Weight (kg) | 87 (13.0) | 86 (14.0) | .672† |
| BMI | 28 (3.3) | 28 (3.3) | .867† |
| Neck circumference (cm) | 40 (3.0) | 40 (3.5) | .425† |
| Actual smoking, $n$ (%) | 10 (11) | 8 (8) | .421* |
| Actual use of snuff, $n$ (%) | 19 (22) | 19 (18) | .587* |
| Respiratory variables | | | |
| AI (events/h) | 13 (9.9) | 11 (11.2) | .380† |
| Longest apnoea incident (s) | 41 (17.9) | 44 (28.1) | .351† |
| AHI (events/h) | 25 (12.9) | 23 (13.6) | .229† |
| ODI (events/h) | 24 (12.8) | 22 (13.0) | .182† |
| Lowest $SpO_2$, % | 82 (5.1) | 82 (5.2) | .954† |
| Average $SpO_2$, % | 93 (1.8) | 93 (1.5) | .105† |
| $SpO_2$ time <90%; % of sleep time | 11 (19.1) | 7 (12.6) | .111† |
| Estimated sleep efficiency (%) | 89 (14.1) | 91 (9.2) | .333† |
| OSA severity, categorized by AHI, $n$ (%) | | | |
| Mild (AHI <15) | 18 (21) | 36 (35) | .089* |
| Moderate (AHI 15–29) | 42 (48) | 39 (37) | |
| Severe (AHI ≥30) | 28 (32) | 29 (28) | |

AI: apnoea index; AHI: apnoea–hypopnoea index; BMI: body mass index; ODI: oxygen desaturation index; $SpO_2$: oxygen desaturation level.
Numbers in the analysis of neck circumference in the bibloc group, $n=86$. Numbers in the analysis of smoking in the monobloc group: $n=101$ and of snuff use $n=103$. Data are shown as the number of patients (%) or mean (±SD).
*Differences between the bibloc and monobloc outcomes were evaluated using Pearson's chi-squared test.
†Differences between bibloc and monobloc outcomes were evaluated using Student's $t$ test.

Compliance to any treatment for OSA is essential for its efficacy. In this study, the patients in both groups used their appliances to a similarly high extent. The self-report of a median seven nights per week and 89–91% of sleep time in the two groups should be interpreted with caution, given that such subjective reports in general terms were shown to be overestimated by 30 min [13]. However, Vanderveken et al. [14] used microsensor chips embedded in the appliances and found nonsignificant differences between the objective measurements and the self-reported use of the appliance. As the provider of the bibloc appliance used in our study (Narval™, ResMed, Kista, Sweden) could not add a microsensor, subjective reports were our only option in measuring treatment compliance. Extrapolating from previous findings to our study, we can assume that the compliance to treatment by our patients was probably good; however, the lack of an objective compliance measure remains a shortcoming.

Several types of appliances are available commercially for the treatment of OSA, aiming to prevent the collapse of pharyngeal structures during sleep [15]. Treatment outcomes can depend on the patient's acceptance of the appliance. There are also different phenotypic traits for OSA patients and 69% are reported to have one or more nonanatomical traits [16,17]. As appliances target an anatomical imbalance, it is likely that they are not effective in all patients. Previous studies on the Narval™ appliance reported successful treatment response rates (>50% reduction of baseline AHI) of about 60% [7,18], which is similar to the results in this study. Using an AHI response criterion at follow-up of <10, Bloch et al. [19] reported 67% bibloc and 75% monobloc responders, that is, only slightly higher than the response rate in our study. The gradient of effect in relation to baseline OSA

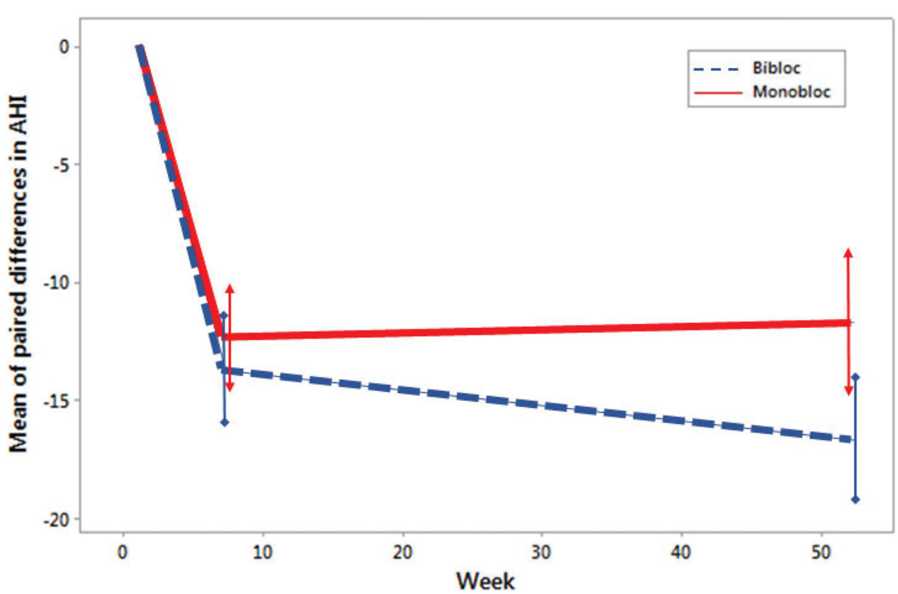


**Figure 3.** The lines represent the mean of paired differences in the apnoea–hypopnoea index (AHI) for bibloc and monobloc appliance treatment from baseline to the 1-year follow-up, with 95% confidence interval (CI) values.

**Table 2.** Outcomes of the apnoea–hypopnoea index (AHI) in the per-protocol population and the intention-to-treat population sensitivity analyses.

| | Bibloc | | | | Monobloc | | | | Equivalence test | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $n$ | Mean AHI | Mean AHI at evaluation | Mean of paired differences (95% CI) | $n$ | Mean AHI | Mean AHI at evaluation | Mean of paired differences (95% CI) | Difference (95% CI) | $p$ Value |
| PP 1-year vs. baseline | 88 | 25.4 | 8.6 | −16.7 (−19.4 to −14.1) | 104 | 23.1 | 11.3 | −11.8 (−14.9 to −8.7) | −5.0 (−9.0 to −0.9) | .494 |
| By AHI severity, PP 1-year vs. baseline | | | | | | | | | | |
| Mild (baseline AHI <15) | 18 | 8.9 | 5.2 | −3.7 (−5.8 to −1.7) | 36 | 9.2 | 7.9 | −1.3 (−3.9 to 1.3) | −2.4 (−5.7 to 0.8) | .058 |
| Moderate (baseline AHI 15 − 29) | 42 | 22.0 | 8.1 | −13.8 (−16.1 to −11.5) | 39 | 22.9 | 12.7 | −10.2 (−15.3 to −5.1) | −3.6 (−9.2 to 1.9) | .309 |
| Severe (baseline AHI ≥30) | 28 | 41.1 | 11.6 | −29.5 (−33.6 to −25.4) | 29 | 40.5 | 13.6 | −26.9 (−31.4 to −22.4) | −2.6 (−8.6 to 3.3) | .213 |
| Sensitivity analyses | | | | | | | | | | |
| ITT 1-year vs. baseline | 146 | 26.8 | 8.6[a] | −10.1[b] (−12.2 to −8.0) | 156 | 25.2 | 11.3[a] | −7.8[b] (−10.1 to −5.6) | −2.2 (−5.3 to 0.8) | .037 |
| PP 1-year adjusted for compliance vs. baseline | 74 | 23.5 | 8.0 | −14.2 (−17.0 to −11.4) | 93 | 22.6 | 11.7 | −10.3 (−13.4 to −7.2) | −3.8 (−8.0 to 0.3) | .291 |

ITT: intention-to-treat; PP: per protocol; AHI: apnoea–hypopnoea index.
The greater of the two $p$ values (one for each tail) is presented; significance is indicated where $p<.025$. Missing observations for compliance at the 1-year follow-up: 14 for the bibloc and 11 for the monobloc groups.
[a]Excluding missing observations: 58 for bibloc and 52 for monobloc.
[b]Baseline observation carried forward.

**Table 3.** Treatment outcomes listed as the proportions of responders following 1 year of treatment in the per-protocol population.

| Responder definition | Bibloc ($n=88$) | Monobloc ($n=104$) | Percentage difference between groups (95% CI) |
|---|---|---|---|
| Evaluation visit AHI <5 | 28 (32) | 36 (35) | −2.8 (−16.2 to 10.6) |
| Evaluation visit AHI <10 | 60 (68) | 68 (65) | 2.8 (−10.6 to 16.2) |
| 50% reduction of baseline AHI | 64 (73) | 64 (61) | 11.2 (−2.0 to 24.4) |
| Evaluation visit AHI <10 and ≥50% reduction of baseline AHI | 51 (58) | 56 (54) | 4.1 (−10.0 to 18.2) |
| Evaluation visit AHI <10 and/or ≥50% reduction of baseline AHI | 73 (83) | 76 (73) | 9.9 (−1.7 to 21.5) |
| Evaluation visit ODI <5 | 31 (35) | 39 (37) | −2.3 (−15.9 to 11.4) |
| Evaluation visit ODI <10 | 61 (69) | 69 (66) | 3.0 (−10.3 to 16.2) |
| 50% reduction of baseline ODI | 61 (69) | 61 (59) | 10.7 (−2.8 to 24.2) |
| Evaluation visit ODI <10 and ≥50% reduction of baseline ODI | 50 (57) | 52 (50) | 6.8 (−7.3 to 20.9) |
| Evaluation visit ODI <10 and/or ≥50% reduction of baseline ODI | 72 (82) | 78 (75) | 6.8 (−4.8 to 18.4) |

AHI: apnoea–hypopnoea index; ODI: oxygen desaturation index.
Data are shown as $n$ (%). Between-group evaluations using Pearson's Chi-squared test were nonsignificant for all responder definitions.

Table 4. Change in baseline polygraphy variables following 1 year of treatment in the per-protocol population.

| | Bibloc | | | Monobloc | | | Difference between groups (95% CI) |
|---|---|---|---|---|---|---|---|
| | *n* | $\bar{d}$(95%CI) | *p* Value* | *n* | $\bar{d}$(95%CI) | *p* Value* | |
| ODI | | | | | | | |
| Total sample | 88 | −15.9 (−18.5 to −13.3) | <.001 | 104 | −10.9 (−13.8 to −8.1) | <.001 | −4.9 (−8.8 to −1.0) |
| Mild group (baseline AHI <15) | 18 | −3.1 (−5.1 to −1.1) | .005 | 36 | −1.1 (−3.6 to 1.4) | .375 | −2.0 (−5.8 to 1.8) |
| Moderate group (baseline AHI 15 − 29) | 42 | −13.0 (−15.2 to −10.8) | <.001 | 39 | −9.8 (−14.4 to −5.2) | <.001 | −3.3 (−8.1 to 1.6) |
| Severe group (baseline AHI ≥30) | 28 | −28.3 (−32.5 to −24.1) | <.001 | 29 | −24.7 (−29.0 to −20.4) | <.001 | −3.6 (−9.5 to 2.3) |
| AI | 88 | −10.1 (−12.0 to −8.1) | <.001 | 104 | −6.9 (−9.3 to −4.5) | <.001 | −3.2 (−6.4 to −0.001) |
| Longest apnoea (sec) | 88 | −18.4 (−22.2 to −14.7) | <.001 | 104 | −18.2 (−23.8 to −12.6) | <.001 | −0.2 (−7.1 to 6.8) |
| Others | | | | | | | |
| Lowest $SpO_2$ (%) | 88 | 3.1 (2.1 to 4.2) | <.001 | 104 | 3.3 (2.3 to 4.3) | <.001 | −0.1 (−1.5 to 1.3) |
| Average $SpO_2$ (%) | 88 | 0.1 (−0.2 to 0.4) | .543 | 104 | −0.3 (−0.5 to −0.1) | .003 | 0.4 (0.1 to 0.7) |
| $SpO_2$ time <90% (% of sleep time) | 88 | −4.1 (−7.6 to −0.7) | .019 | 104 | 0.3 (−2.6 to 3.1) | .861 | −4.4 (−8.8 to 0.01) |
| Estimated sleep efficiency (%) | 88 | 6.2 (3.6 to 8.8) | <.001 | 104 | 1.9 (−0.2 to 4.0) | .074 | 4.3 (1.1 to 7.6) |
| Supine time (min) | 88 | 33.6 (8.7 to 58.5) | <.001 | 104 | 23.3 (2.4 to 44.1) | <.001 | 10.3 (−21.7 to 42.3) |

ODI: oxygen desaturation index; AI: apnoea index; $SpO_2$: oxygen desaturation level; $\bar{d}$ : mean difference.
*Paired *t* tests.

Table 5. The incidence of reported and observed adverse experiences during the treatment period of 1 year in the intention-to-treat population.

| Adverse events | Bibloc (*n* = 146) | Monobloc (*n* = 156) |
|---|---|---|
| Any adverse event | 74 (51) | 92 (59) |
| Upper airway infection | 23 (16) | 29 (19) |
| Complaints/diseases outside the head, jaw and mouth | 28 (19) | 43 (27) |
| Nonspecified complaints involving the mouth/jaws | 29 (20) | 22 (14) |
| Complaints involving teeth | 15 (10) | 12 (8) |
| Treatment-related adverse events[a] | 57 (39) | 51 (33) |
| Nonspecified complaints involving the mouth/jaws | 29 (20) | 21 (13) |
| Complaints involving teeth | 13 (9) | 9 (6) |
| Complaints involving temporomandibular joint | 9 (6) | 10 (6) |
| Complaints involving jaw muscles | 3 (2) | 8 (5) |
| Psychological complaints associated with use of the appliance | 0 (0) | 1 (1) |
| Headache | 3 (2) | 2 (1) |

Data are given as the number and (%) of individuals with events. None of the adverse events differed significantly between the two groups when evaluated using Pearson's Chi-square test.
[a]Association with the intervention rated by the investigator as probable, possible or unlikely.

severity registered in our study as well as in other studies [20,21] highlights the importance of presenting efficacy data based on OSA severity.

The degree of mandibular advancement is a factor influencing the effectiveness of appliance therapy [20–22]. A more pronounced mandibular advancement is not necessary for a treatment advantage [23] and other elements can contribute to determine the outcome for a single patient. It was reported that the amount of mandibular advancement was of importance in treating patients with severe OSA, where a greater advancement received better outcome [24]. In a meta-analysis, Bartolucci et al. [23] found no evidence that a protrusion of more than 50% of the maximum advancement had any benefit. Therefore, it has been recommended to 'titrate' the minimum degree of mandibular advancement to obtain a subjectively optimal effect [13]. Our patients were subjected to an advancement of 75% of the maximal protrusion, which was probably an overkill as the incidence of side effects is larger at increasing degrees of protrusion [21].

Adverse events following the use of oral appliances in the treatment of OSA are common but mild, and usually well tolerated by most patients. Previous assumptions that monobloc appliances lead to a higher incidence of events compared with bibloc appliances [25] could not be confirmed in our study. The overall reported rates of adverse events were similar between the two groups, but the proportion of treatment-related events was greater in the bibloc group. The most previously reported complaints [26] were located in the mouth, jaws, teeth and temporomandibular joint as well as jaw muscles; these findings are supported by our study. The rates of discontinuation of treatment caused by adverse events were low and similar in both groups, which means that the appliances were well tolerated.

The strengths of this study were its design aiming to reduce outcome bias, and through performing the study at three different clinics with independent evaluators of the respiratory recordings and the clinical outcomes. It gives a realistic view of treatment effectiveness in general. A limitation of our study was the dropout rate, which was higher in the bibloc group. The major reason for discontinuation was a lack of efficacy and the consequent change to CPAP treatment.

## Conclusions

Treatment with both bibloc and monobloc appliances positively and significantly reduced the rates of respiratory disturbances, but at the 1-year follow-up, they were not statistically equivalent in treating OSA, with a greater reduction of AHI values with the bibloc appliance. However, the higher proportion of treatment-related adverse events and higher proportion of dropouts among bibloc users should also be balanced against the advantages of a greater reduction in the AHI.

## Acknowledgements

We thank the patients who participated in this study. We also thank the participating dental doctors: Anna Avdelius, Clara Fodor, Thomas List, Eva Ortlieb, Mohamad Schumann, Magnus Sturebrand, Livia Trepp and Eva Wiman-Eriksson for their clinical work. We thank the biomedical analysts, Helena Qvistberg and Monica Quarford, as well as the research coordinators at the clinical sites, Karin Palmgren, Gunilla Erixon and

Eva-Lena Granberg, with Kristina Ekman serving as monitor and data manager.

## Disclosure statement

GI participated and obtained remuneration on one advisory board organized by ResMed, in France, February 2016. No potential conflict of interest was reported by the author(s).

## Funding

This study was supported by grants from the Uppsala-Örebro Regional Research Council, Västmanland County Council and the Public Dental Service, Region Örebro County.

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