Systematic Review Article

Oral appliance–generated malocclusion traits during the long-term management of obstructive sleep apnea in adults: *A systematic review and meta-analysis*

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ABSTRACT

Objectives: To identify malocclusion characteristics generated after using oral appliances (OAs) for at least 5 years for the management of snoring and obstructive sleep apnea (OSA) in adults.

Materials and Methods: PubMed, MEDLINE (Ovid), Scopus, CINAHL, and Informit were searched without language restrictions through January 20, 2021. Unpublished literature was searched on ClinicalTrials.gov, the National Research Register, and the Pro-Quest Dissertation Abstracts and Thesis database. Authors were contacted when necessary, and reference lists of the included studies were screened. Risk of bias was assessed through the revised Cochrane Risk of Bias tool for randomized controlled trials (RoB2) and Non-Randomized Studies of Interventions for non-RCTs and uncontrolled before–after studies (ROBINS-I). A random-effects meta-analysis was conducted only on studies that used the same OAs to exclude biomechanical differences. Risk of bias across studies was assessed with the Grading of Recommendations, Assessment, Development and Evaluation tool.

Results: A total of 12 studies were included in the final qualitative synthesis. Eight included studies had high, one had moderate, and three had low risks of bias. Significant progressive decreases of overjet (OJ; −1.43 mm; 95% confidence interval [CI], −1.66 to −1.20) and overbite (OB; −1.94 mm; 95% CI, −2.14 to −1.74) associated with maxillary incisor retroclination and mandibular incisor proclination were reported long term. Although most studies showed no sagittal skeletal changes, some degree of vertical skeletal changes were noted.

Conclusions: Based on a very low evidence level, inevitable anterior teeth positional changes seem to be a common long-term adverse effect of OAs. The magnitude of those changes could be considered clinically irrelevant for most pretreatment occlusions, but in occlusions with limited OJ and OB, it may be worth clinical consideration. (*Angle Orthod.* 2022;92:255–264.)

KEY WORDS: Obstructive sleep apnea; Snoring; Oral appliance; Malocclusion

INTRODUCTION

Because the management of obstructive sleep apnea (OSA) with oral appliances (OAs) is not curative, patients may use OAs throughout their life. There is consensus on OAs producing progressive tooth movement during mandibular advancement and occlusal modifications. Because many patients will be

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treated for a protracted period, OA-generated malocclusions often become significant over the long-term and may require treatment to reverse the dentoskeletal adaptations that may occur. Typical changes include reducing overjet (OJ) and overbite (OB), changes in facial height, and the development of anterior crossbites and posterior open bite.[1]

From a biomechanical perspective, as with any orthodontic appliance worn for at least 6 continuous hours,[2] OAs move teeth.[1] However, the exact mechanism of action of OAs is still not fully understood. Inserting an OA in a carefully manipulated forward mandibular position will disrupt the muscular balance around teeth. Multiple forces applied by OAs may differ in prone, supine, and rotated body positions during sleep, and head posture changes that occur during sleep can also alter the magnitude and direction of the force.[3] The maxillary incisors are subjected to a palatal force, whereas the mandibular incisors are subjected to a labial-directed force.[4] Forces of more than 1 kg (1387.36 g) during sleep were found in a sample of adult patients with OSA following 11.4 $\pm$ 2.4 mm mandibular advancement (120.6 gF per millimeter of advancement).[3]

A systematic review of studies evaluating OA-generated malocclusion traits in the very long term has not been previously performed. Previous systematic reviews on the subject either pooled studies of short duration[5–8] (eg, the duration of treatment with OAs ranged from 6 months to a mean follow-up of 4 years),[8] whereas others considered 1 year as long-term use and included studies that had at least 1 year as long-term use[5] or combined data of follow-ups of 2 or 3 years up to 11 years.[6,7] These systematic reviews also included meta-analyses that plotted different appliance types/designs and combined short-term and long-term dentoskeletal effects.[5,6] Therefore, the aim of this study was to systematically review studies that reported dentoskeletal features produced by the long-term (average of more than 5 years) use of OAs in the management of adult OSA.

MATERIALS AND METHODS

Protocol

This study complied with the Preferred Reporting Item for Systematic Review and Meta-Analyses (PRISMA) statement.[9] The protocol was not registered.

Eligibility Criteria

The following selection criteria were applied for the review:

- Participants were aged >18 years and managed for snoring and/or OSA.
- The intervention was at least 5-year use of any OA.
- Outcome measures were dentoalveolar changes to OJ, OB, upper incisor inclination (Angle from upper incisor to cranial base [U1–SN]) and lower incisor inclination (Lower incisor [L1]–mandibular plane [MP]). Secondary outcomes were sagittal (Sella to Nasion to A point angle [SNA], Sella to Nasion to B point angle [SNB], A point to Nasion to B point angle [ANB]) and vertical (Mandibular plane to anterior cranial base angle [SN-GoGn]) skeletal changes as measured on lateral cephalograms.
- The study designs were randomized controlled trials (RCTs) cohort and before–after studies.
- Exclusion criteria were animal studies, studies not written in English, patients aged younger than 18 years, other reasons for treatment, tongue-retaining devices or combination therapy (eg, continuous positive airway pressure [CPAP] or surgery), less than the average follow-up of at least 5 years, and irrelevant outcomes (eg, efficacy or comparison of other treatment modalities).

Information Sources, Search Strategy, and Study Selection

The following five electronic databases were searched: MEDLINE (PubMed), MEDLINE (Ovid), Scopus, CINAHL, and Informit. Language restrictions were not applied. Unpublished literature was searched electronically by using ClinicalTrials.gov (www.clinicaltrials.gov) and the National Research Register (www.controlled-trials.com) with the terms "obstructive sleep apnea" and "oral appliance." The date of the last search was January 20, 2021. Authors were contacted to identify unpublished or ongoing clinical trials and to clarify data as required. Reference lists of the included studies were screened for relevant studies.

Assessment of inclusion in the review, assessment of the risk of bias, and data extraction were performed independently and duplicated by two investigators (Drs Karadeniz and Lee) who were not blinded to the authors or the research results. Disagreements were resolved by discussion and consultation with a third author (Dr Flores-Mir).

A data extraction form was developed to record study design, participants, initial diagnosis, appliance used, number of years, and outcome data of interest.

Risk of Bias/Quality Assessment in Individual Studies

Studies were assessed for quality using different tools according to the classification of studies. The Cochrane Risk of Bias 2 tool was used to assess

RCTs. The Non-Randomized Studies of Interventions (ROBINS-I) tool[10] was used to assess cohort studies and uncontrolled before–after studies. The Risk-of-Bias Visualization[11] web application was used to produce figures to display the risk-of-bias assessments.

Summary Measures and Approach to Synthesis

The primary outcome was to determine the dentoskeletal malocclusion traits of OA therapy, and the secondary outcome was to identify additional malocclusion traits during the management of snoring/OSA in adults.

Risk of Bias Across Studies

The risk of bias across studies was applied for OB and OJ by using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) Pro software (GRADEpro GDT; available from gradepro.org[12]).

Meta-analysis

Statistical heterogeneity was assessed by inspecting a graphic display of the estimated treatment effects in conjunction with 95% confidence intervals (CIs). Heterogeneity was assessed using the I^2 statistic. Conventionally, I^2 values of 25%, 50%, and 75% indicate low, moderate, and high heterogeneity, respectively. All analyses were conducted using a random-effects model.

RESULTS

Study Selection and Characteristics

Database searching initially identified 1717 studies (Figure 1). After removing duplicates, screening abstracts, and assessing these studies for eligibility, 12[4,13–23] studies were included for qualitative synthesis. Of these 12 studies, one was an RCT,[4] three were prospective cohorts,[15,18,19] three were retrospective cohorts,[20–22] and five uncontrolled before–after studies[13,14,16,17,23] (Table 1).

Risk of Bias Within Studies

Overall, four of the cohort studies had a high risk of bias and two had a low risk, four of the before–after studies had a high risk and one had a low risk, and the RCT had a low risk of bias (Figure 2).

Of the seven specified biases in the ROBINS-I quality assessment, confounding bias was moderate for most of the studies[14,16–18,20–23] because of the inability of studies to control confounding variables such as the quality of remaining dentition or amount of periodontal support. Two studies had a serious risk of selection bias as participants with mesial occlusions were omitted.[18] Three studies[20–22] did not indicate whether there was a consecutive inclusion of participants. Bias attributed to deviations from intended interventions related to patients crossing over between interventions (different appliances) resulted in serious bias.[18,20–22] Serious missing data bias was identified because the proportion for participants with Class III was significantly less than Class I and Class II Divisions 1 and 2.[20–22] Five studies[18–22] did not report whether assessors were blinded to the intervention received. In the end, four analyzed studies had a serious risk of bias, and two studies had a low risk of bias.

Results of Meta-analysis

A meta-analysis was conducted with only three studies[16,20,22] that used the same OA (Klearway; Space Maintainers Ltd, Vancouver, Canada) to exclude biomechanical differences. The pooled mean difference values and forest plots for OB and OJ were computed using the Revman version 5.3 (The Cochrane Collaboration) software. All other data were found not to be adequate as a result of the high methodological heterogeneity among the studies compared (eg, studies used either a different appliance or measured variables differently). The mean difference value of all included studies was calculated as posttreatment scores − pretreatment scores, with negative values indicating a decrease in the outcome of interest.

Of the three studies included in the meta-analysis, Chen et al.[20] showed the highest difference in OB and OJ from before to after treatment, which tended to be progressive. When considering the three studies (two studies with a mean follow-up of 7 years and one study of 11 years), the average decrease for OB was −1.94 mm (95% CI, −2.14 to −1.74; Figure 3A) and for OJ was −1.43 mm (95% CI, −1.66 to −1.20; Figure 3B). If only the two studies with an average follow-up close to 7 years were considered, in those the average decrease for OB was −2.09 mm (95% CI, −2.35 to −1.84; Figure 3C) and for OJ was −1.49 mm (95% CI, −1.77 to −1.21; Figure 3D).

Risk of Bias Across Studies

The GRADE assessment revealed a very low quality of evidence across outcomes (Table 2).

DISCUSSION

During snoring and OSA management with OAs, there is significant potential for malocclusion to be generated in patients with Class I and III malocclusions, where patients with Class II malocclusion may benefit from the adverse effects. In this context, patients should be

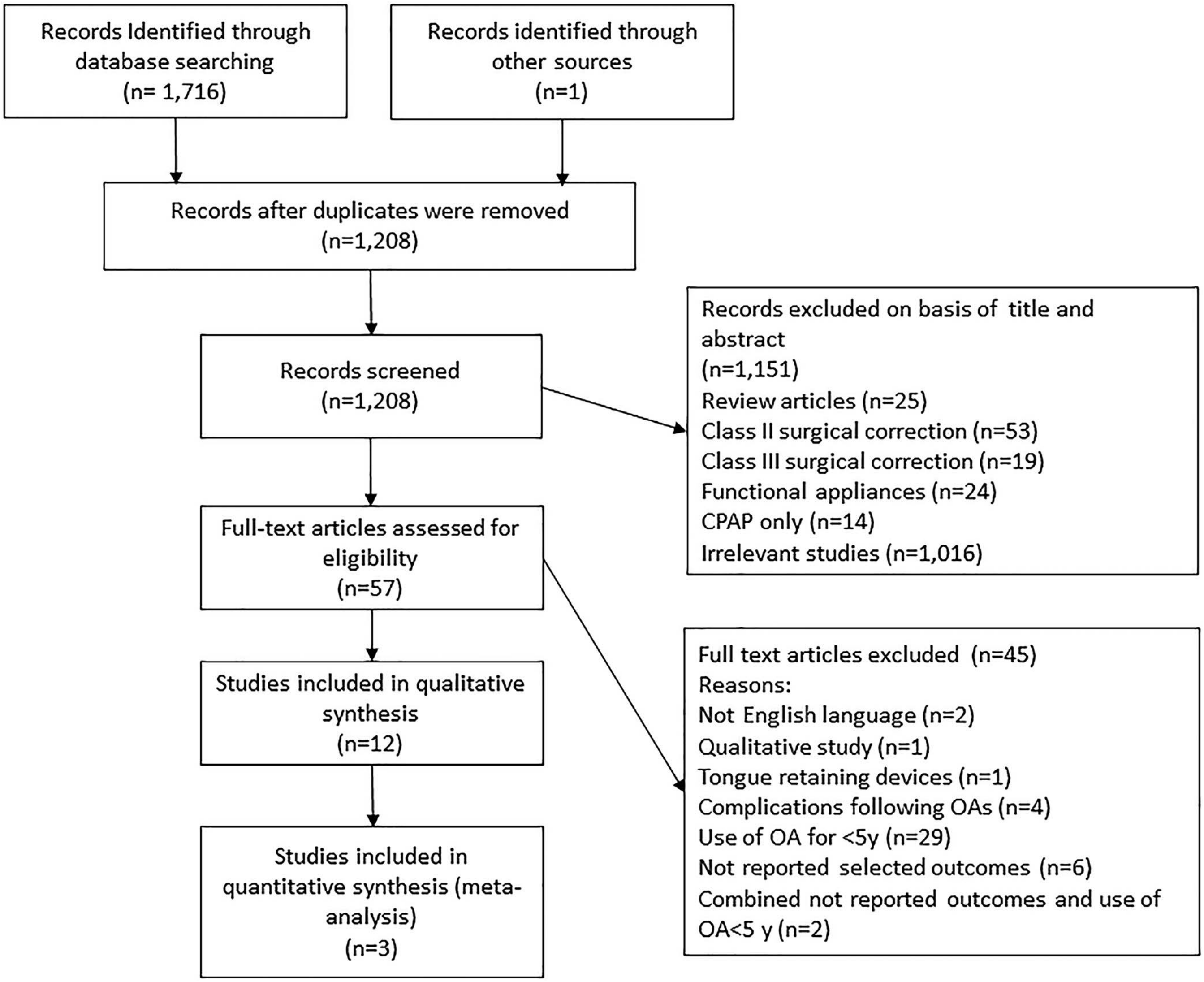

Figure 1. PRISMA diagram of article retrieval.

informed of the risk of developing malocclusion that may require orthodontic and/or orthognathic surgery to reverse the adverse dental effects. As orthodontists may be asked to manage OA-generated malocclusions, they need to be aware that the patient will not be able to wear the OA during treatment; therefore, the patient may need to use CPAP therapy during the period of orthodontic care. Communication with the physician helps to ensure that the patient's OSA is still being managed appropriately. Should the patient return to using an OA for OSA after orthodontic treatment, then the malocclusion may also return.

Decreased OJ and OB

All of the studies investigated reported a significant reduction in incisor OJ and OB. The least amount of change was found with soft elastomeric nonadjustable monoblocs[18] and small mandibular advancements of <6 mm compared with hard acrylic monoblocs. In addition, larger vertical displacement of the mandible (11 mm) was related to smaller OJ reduction. Long-term OB and OJ changes were close to 2 mm for OB and 1.5 mm for OJ. Comparing between 7 years and 11 years of follow-up (two studies with a mean follow-up of 7 years and one study of 11 years) did not convey clinically relevant differences (0.15 mm more for OB and 0.06 mm for OJ).

Dentoalveolar Changes According to the Initial Malocclusion

Patients with a large OJ at baseline normalized their dental occlusion during long-term treatment with OAs. Favorable dentoalveolar changes occurred in patients

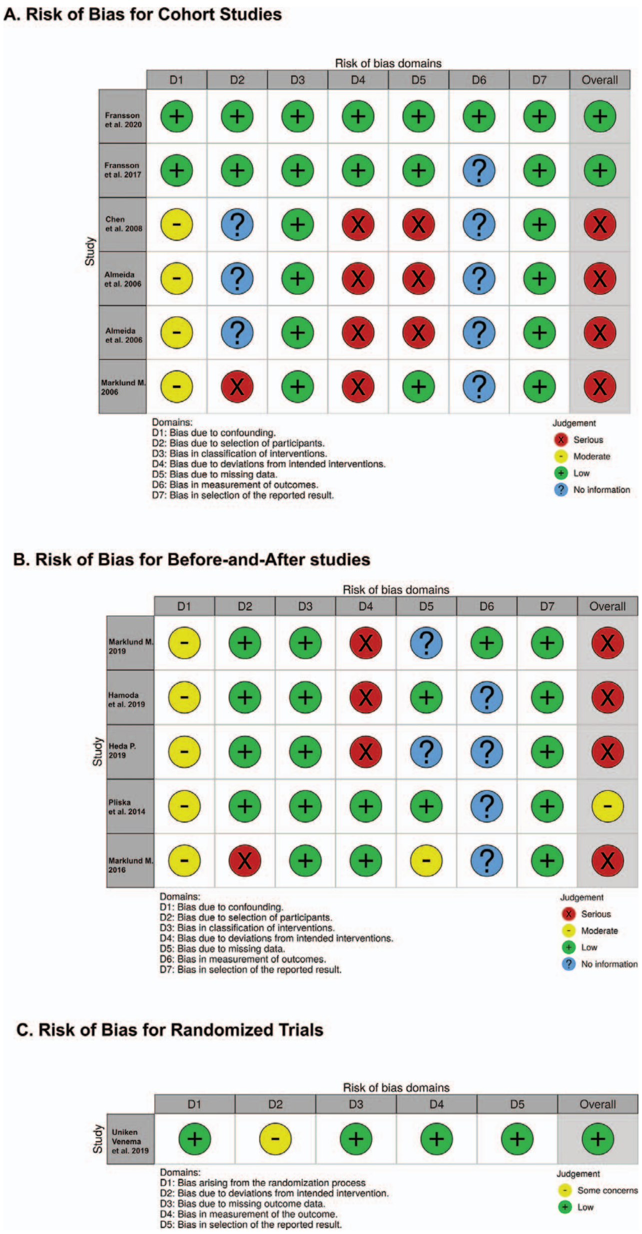

Figure 2. Summary of risk bias among (A) cohort studies (ROBINS-I tool), (B) before–after studies (ROBINS-I tool), and (C) RCTs (Cochrane Risk of Bias 2 tool).

with Class II Division 1[15,17,18,22] or Class II Division 2 malocclusion,[22] as forces from OAs caused proclination of mandibular incisors and retroclination of maxillary incisors. Patients with Class II Division 1 malocclusions with the most significant baseline OJ experienced the greatest benefit from OJ reduction.[17,18] Almeida et al.[22] suggested that deeper OB correlated with a greater reduction in OB, and the greater the initial OJ, the greater the decrease in OJ. However, OAs may aggravate a preexisting Class I or Class III malocclusion.[15,17,22]

Angular Changes in Incisor Position

Maxillary incisor retroclination (U1–SN) and mandibular incisor proclination (L1–MP) findings were consistent in all studies.[13–15,21] This suggests that changes in incisor inclination may contribute to OJ and OB reduction. However, cephalometric measurements showed a high standard deviation attributed to a wide range of individual responses to tooth movement. Changes in incisor angulation were probably attributed to anteriorly directed forces exerted by OAs on the mandibular teeth and posteriorly directed forces exerted on the maxillary teeth.

Progression of OA-Generated Malocclusion

Some authors suggested that changes in OJ and OB progressed over time.[4,16,18] Dental changes were irreversible and progressive with a rate of retroclination for upper incisors of –0.5°/year for nearly up to 2 decades of treatment.[14] Proclination of the mandibular incisors was also progressive; however, the rate of proclination seemed to decline with prolonged follow-up and appeared to stop after approximately 19 years of treatment.

Skeletal Changes

The position of the maxilla relative to the cranial base (SNA°) did not change significantly over time. Almeida et al. found a significant difference in one of the study subgroups corresponding to the baseline Class I molar relationship, where a significant decrease of –0.8° was found.[21] Two[14,15] of four studies found that the mandible in relation to the anterior cranial base (SNB°) significantly decreased in a range between –0.6° to –0.7°. A slight posterior rotation of the mandible was confirmed by an increase in MP angle (SN–GoGn) in all three studies[13,14,21] that investigated this variable. This may have been attributed to incisor interferences as the OJ was reduced.

Additional OA-Generated Malocclusion Traits

A Class III molar relationship with a mesial shift of the lower molars repositioned anteriorly in relation to the upper molars was a consistent observation.[4,17,20,23] However, the angle classification was reported only in a few studies.[4,19,20]

Anterior crossbite ranged from 44%[14] to 62%.[16]

Anterior open bite tendency was observed but not quantified.[4] The decreased OB could be beneficial for patients who presented initially with deep OB, but for patients with normal or shallow baseline OB, reducing the OB might cause an open bite in the long run.[20]

Table 1. Study Design; Number of Patients; Age; Sex; Diagnosis; BMI; Appliance Type; Titration Protocol; Mandibular Advancement; Years Used; Compliance; Method of Measuring Outcomes; and Changes to SNA, SNB, SN–GoGN, U1–SN°, L1–MP°, OJ, and OB[a,b]

Study	Study Design	No. of Patients	Age[c]	Sex	Diagnosis	BMI[c] kg/m²	Appliance Type	Titratable Appliance	Full Coverage Appliance
Uniken Venema et al.[4] 2019	RCT	31	50.2 [8.1]	12 males/ 2 females OA 17 males/ 0 females CPAP	Nonsevere OSA (AHI 5–30) Severe OSA (AHI ≥30)	31.3 [5.9]	TAP Bibloc	Yes	Yes
Fransson et al.[15] 2020	Prospective cohort	65	54 [8.3]	35 males/ 10 females	Snoring ODI <5 or OSA ODI ≥5	Males, 29 [3.8] Females, 31 [3.8]	Nonadjustable monobloc	No	Yes
Fransson et al.[19] 2017	Prospective cohort	74	–	63 males/ 14 females	Snoring or OSA, NI	–	Nonadjustable monobloc	No	Yes
Marklund[18] 2006	Prospective cohort	155	Median, 51 IQR (22–74)	127 males/ 28 females	Snoring and OSA, median, AHI 13 IQR (0–76)	Median, 27 IQR (19–42)	Soft elastomeric and hard acrylic monobloc	No	Yes
Chen et al.[20] 2008	Retrospective cohort	70	50 [9.6]	62 males/ 8 females	Primary snoring (RDI <5) Mild OSA (RDI 5–14) Moderate OSA (RDI 15–30) Severe OSA (RDI >30), mean RDI, 28/h	29.3	Klearway	Yes	Yes
Almeida et al.[21] 2006	Retrospective cohort	71	49.7 [9.7]	63 males/ 8 females	Snoring or OSA RDI 28.9 [17]	29.3 [5.9]	Klearway; some started with different OA	Yes	Yes
Almeida et al.[22] 2006	Retrospective cohort	70	50 [9.7]	63 males/ 7 females	Snoring or OSA, RDI 28 [14.9]	29.3 [5.8]	Klearway; some started with different OA	Yes	Yes
Marklund[17] 2019	Before–After	38	Median, 64 IQR (56.7–68.8)	26 males/ 12 females	OSA AHI, median, 10.0 IQR (4.5–22.8)	NI	Monobloc, Somnodent or Narval [d]	NI	NI
Hamoda et al.[14] 2019	Before–After	62	49 [8.6]	52 males/ 10 females	Snoring or Mild to severe OSA, AHI, 30.0 [14.6]	29.1 ± 6.9	Klearway or SomnoDent	Yes	Yes
Heda[13] 2019	Before–After	21	49.52 [11.84]	15 males/ 6 females	Snoring or OSA, NI	NI	Klearway; Somnodent (Flex and Classic) [d]	Yes	Yes
Pliska et al.[16] 2014	Before–After	77	47.5 [10.2]	62 males/ 15 females	Snoring to severe OSA, 29.8 [16.9]	29.4 [7.2]	Klearway	Yes	Yes
Marklund[23] 2016	Before–After	9	Median, 68.1 IQR (60–76.3)	8 males/ 1 females	AHI median, 32.4 IQR (22.2–58.8) (A/F)	26.5 A/B, 26.5 (A/F)	Soft elastomeric, hard acrylic monobloc, and adjustable OAs	Yes	Yes

[a] "Mandibular advancement" provided the mandibular advancement protocol used in the study. The "Vertical" column provides the average vertical opening of the appliances. "Years used" is the average number of years the appliance was used by the patients, and "Compliance" indicates the compliance of the patients to treatment.

[b] A/B indicates at baseline; A/F, at follow-up; AHI, Apnoea–Hypopnoea Index; ANB°, changes to ANB°; BMI, body mass index; Ceph, cephalometric measurements; L1–MP°, changes to lower incisor inclination; Meas, method of measuring outcomes; NI, no information; N/S, not significant; OB, changes to overbite; ODI, Oxygen Desaturation Index; OJ, changes to overjet; RDI, Respiratory Disturbance Index; S/M, study model analysis; SN–GoGn, vertical skeletal changes; SNA°, changes to SNA°; SNB°, changes to SNB°; and U1–SN°, changes to upper incisor inclination.

[c] Standard deviations are shown in brackets.

[d] Information provided by author.

A posterior open bite of ≥2 mm was noted in 38% of patients.[18] Pliska et al.[16] observed a posterior open bite in 51% of the sample, whereas premolars in edge-to-edge or open-bite relationships were found in 14% and molars in 11%.[22] Others recorded posterior open bite occurrence as "yes/no" visually on dental casts.[19]

Some studies[16,20,22] showed significant increases in the number of interproximal open spaces in the maxilla and the mandible, expansion of the lower arch measured by increases in mandibular intercanine and intermolar distances, and a decrease in mandibular crowding. These mandibular changes were associated with lower incisor proclination, possibly causing an enlargement of the mandibular arch length.[22] In contrast, Marklund found incisor crowding.[17]

Table 1. Extended

Mandibular Advancement[c]	Vertical (mm)	Years Used	Compliance	Meas	SNA (°)	SNB (°)	ANB (°)	SN−GoGn (°)	U1−SN (°)	L1−MP (°)	OJ (mm)	OB (mm)
>50% maximum protrusion; AHI 31.7 [20.6] A/B 83.1% [22.2] maximum protrusion, AHI 9.9 [10.3] A/F	NI	10	7 nights/wk; 8 h per night	S/M	–	–	–	–	–	–	−3.5 [1.5]	−2.9 [1.5]
≥75% maximum protrusion and ≥5 mm A/B; 6.5 mm (2.0–10.5) A/F	NI	10	NI	Ceph	N/S	−0.6 [1.4]	–	–	−4.2 [4.0]	3.2 [5.0]	−1.5 [1.89]	−0.7 [1.41]
75% maximum protrusion A/B	NI	10	Every night or several times/wk	S/M	–	–	–	–	–	–	−1.8 (95% CI, −2.5 to −1.2)	−1.5
Median, 5.5 mm A/B IQR (1.0–11.0)	Median, 11	5.4 [0.8] IQR (6.0–17)	≥50% of nights	S/M	–	–	–	–	–	–	−0.69 [0.92][d]	−0.78 [1.06][d]
NI	NI	7.33	≥4 nights/wk	S/M	–	–	–	–	–	–	−1.28 [1.62]	−1.67 [1.5]
Two-thirds or more	NI	7.3, [2.1]	≥4 nights/wk	Ceph	−0.8 Class I group	N/S	0.5 [1.2]	0.7 [1.9]	−3.1 [4.8]	6.6 [5.2]	−2.6 [1.9]	−2.8 [2.5]
Two-thirds or more	NI	7.4 [2.2]	≥4 nights/wk	S/M	–	–	–	–	–	–	−1.24 [1.52]	−1.91 [1.53]
NI	NI	Median, 9.5; IQR, 5.8–14.3	Percent of nights—median, 90; IQR, 81–92	S/M	–	–	–	–	–	–	−1.7 [1.6][d]	−0.9 [1.0][d]
Two-thirds maximum protrusion A/B +0.25 mm	NI	12.6 [3.9]	NI	Ceph	N/S	−0.7 [1.3]	0.4 [1.1]	0.9 [2.1]	−6.1 [5.9]	7.9 [6.2]	–	–
NI	NI	7.89 [3.3]	>4 h/night, >5 nights/wk	Ceph + S/M	NI	NI	0.44 [0.87]	0.88 [1.51]	–	5.13 [3.6]	−1.24 [1.59]	−1.02 [0.96]
Two-thirds maximum protrusion A/B	NI	11.1	Mostly nightly	S/M	–	–	–	–	–	–	−1.9 [1.9]	−2.3 [1.6]
Median, 6.0 mm IQR (6.0–7.0)	NI	Median, 16.5 IQR (16.3–18)	NI	S/M	–	–	–	–	–	–	−1.4 [1.6][d]	−1.7 [1.1][d]

OA Selection

Several commercial appliances, including the Klearway[16,20] and Thornton Adjustable Positioner (TAP) appliances[4] (TAP type 1; Airway Management Inc., Dallas, Tex) were used. However, a combination of appliances was commonly reported, for example, used Klearway but started with a different appliance[21,22]; others used Klearway or Somnodent (SomnoMed, Plano, TX)[13,14] or a combination of monobloc, Somnodent, and Narval (ResMed, Didcot, UK.).[17] Similarly, nonadjustable hard acrylic monoblocs were continuously replaced with soft elastomeric nonadjustable devices and/or adjustable OAs at the 16-year follow-up.[23] Others used a nonadjustable monobloc appliance[15,19] made of heat-cured methyl methacrylate resin or soft elastomeric and hard acrylic monobloc.[18]

The amount of vertical opening of the appliance was not consistently reported.[4,19]

Adherence and Dentoalveolar Adverse Effects

Self-reported adherence to OA wear was the predominant method used in most studies.[19] Highly compliant patients experienced the greatest reduction in OJ (–3.5 mm) and OB (–2.9mm), with an average treatment use of 7 days/week, 7.8 hours/night; however, those patients, on average, did not grade the dental adverse effects as negative or disturbing.[4] Likewise, the statistically significant changes in occlu-

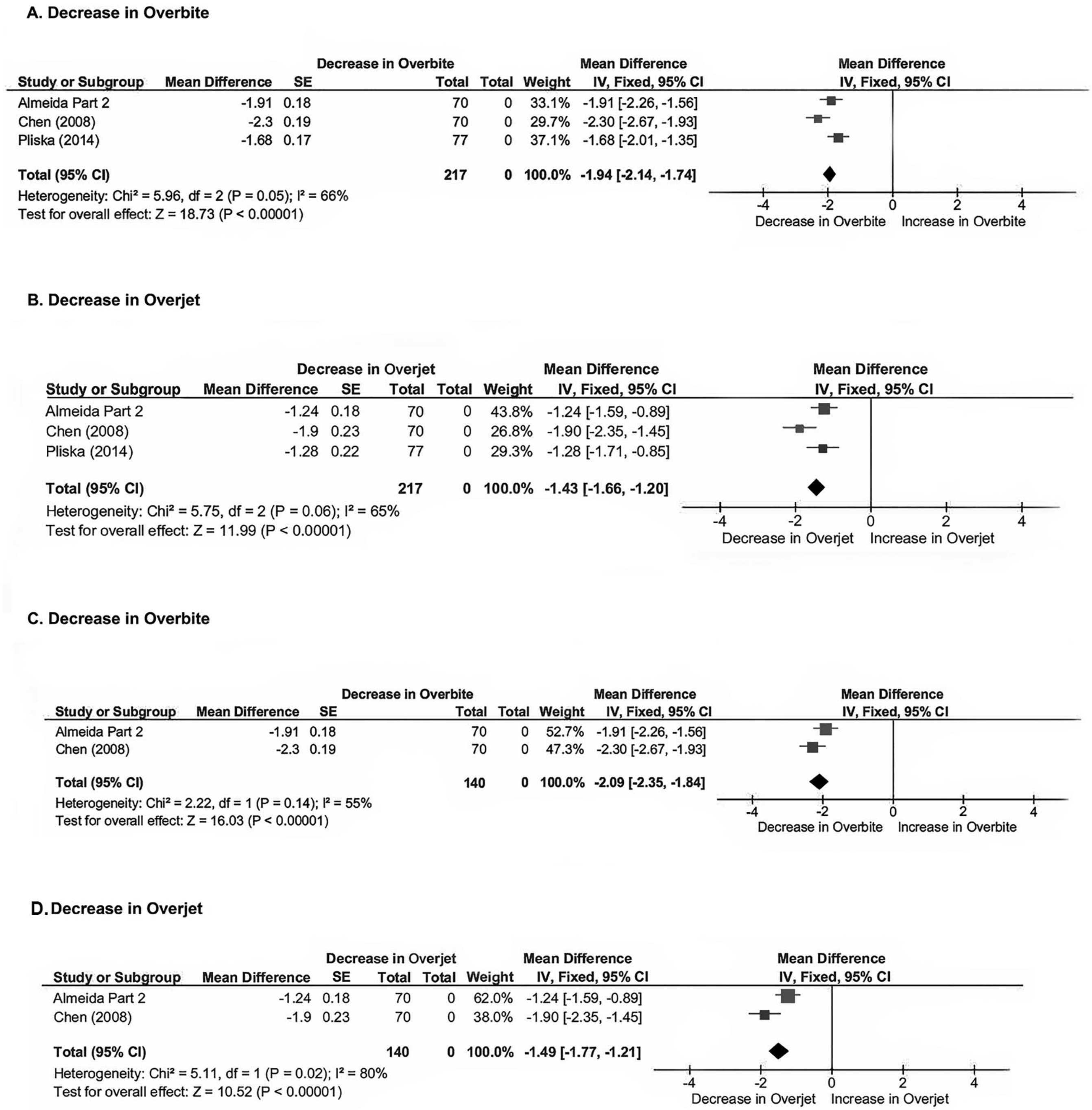

Figure 3. Forest plot evaluating decrease in (A) overbite, (B) overjet, (C) overbite after 7 years, and (D) overjet after 7 years.

sion found by Chen et al.[20] did not result in treatment suspension or cessation.

Smaller reductions in OJ, OB, and the posterior open bite were more common in infrequent users than frequent users (≥50% of nights/week for 5 years).[18]

Mandibular Advancement Protocols

Studies using Klearway[14,16,21,22] reported more than two-thirds of the maximum protrusion (6–10 mm),[21] whereas the TAP[4] was set at 50% of maximum protrusion. Others used 75%[15,19] of the maximum range of protrusion and at least 5 mm of protrusion. Later adjustments were made if needed until symptoms abated or until further protrusion of the mandible resulted in discomfort; however, additional mandibular advancement measurements have not been reported. On the other hand, <6 mm advancements of the

Table 2. Risk of Bias Assessment Across Studies (GRADE)

	Certainty Assessment				Effect		
No. of studies	Risk of Bias	Inconsistency	Indirectness	Imprecision	No. of Individuals	Rate (95% CI)[a]	Quality of Evidence (GRADE)[b]
OJ changes (follow-up: mean 8.3 years; assessed with lateral cephalogram)							
3	Serious	Not serious	Not serious	Very serious	157	−1.78 mm (−3.57 to −0.01)	⊕○○○ very low
OJ changes (follow-up: mean 9.65 years; assessed with study models)							
8	Serious	Not serious	Not serious	Very serious	524	−1.69 mm (−1.00 to −2.38)	⊕○○○ very low
OB changes (follow-up: mean 8.3 years; assessed with lateral cephalogram)							
3	Serious	Not serious	Not serious	Very serious	157	−1.51 mm (−4.32 to −1.30)	⊕○○○ very low
OB changes (follow-up: mean 9.65 years; assessed with study models)							
8	Serious	Not serious	Not serious	Very serious	524	1.71 mm (−1.13 to −2.29)	⊕○○○ very low

[a] The corresponding risk and its 95% CI are based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

[b] High quality (indicated by ⊕): further research is likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate. Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and might change the estimate. Low quality: further research is likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate. Very low quality: we are uncertain about the estimate.

mandible with monoblocs resulted in small OJ reductions after 5 years.[18]

Limitations

Most studies did not differentiate management of snoring from diagnosed OSA and included patients who were able to adapt to changes in their tooth positions or those who benefited from the changes. The use of objective adherence monitoring systems would be beneficial instead of self-reported questionnaires to reduce bias.

It would be reasonable to evaluate risks associated with OA-generated malocclusions versus their effectiveness/efficacy in the long-term treatment of OSA and possibly consider treatment discontinuation. When there is no superior treatment option based on current knowledge, the principle of autonomy dictates that patients have a right to participate in decision making.[24]

Still controversial, though, mouth breathing remains an environmental factor in the development of malocclusion. With the lack of reporting on the mode of respiration, it is impossible to discuss differences in the influence of mouth breathing in the development of OA-generated malocclusion in adults. The natural movement of teeth in an older population is expected as an increase in mandibular anterior crowding continues throughout middle age, that is, beyond 60 years of age.[25] However, OB and OJ remain constant from 20 to 55 years of age.[25,26]

Finally, although a few meta-analyses were possible in the big picture, they included studies with moderate to high risk of bias. In this regard, it could be argued that not conducting meta-analyses was also a reasonable option.

Overall, the body of evidence ranged from very low to low quality as assessed with GRADEpro.

CONCLUSIONS

- Very weak but statistically significant evidence suggests that, although the treatment plan for snoring and OSA with long-term use of OAs does not contemplate tooth movement, it appears that specific tooth movements are an unavoidable effect of this therapy.
- A reduction in incisor OJ and OB through upper incisor retroclination and lower incisor proclination is likely to occur (1.5–2.0 mm).
- Minimal sagittal skeletal changes were noted, with most studies reporting no significant changes to SNA, SNB, and ANB. However, a clockwise rotation of the mandible is likely to occur.
- Although dentoskeletal changes occur, patients are often not aware of them.
- Dental adverse effects must be discussed with the patient considering the initial presentation of the malocclusion before OA therapy is initiated. The severity of these dental adverse effects should be monitored regularly.

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