Mandibular Advancement Appliances in Pediatric Obstructive Sleep Apnea: An Umbrella Review

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Abstract

Introduction Obstructive sleep apnea (OSA) is defined as intermittent partial or complete collapse of the upper airway during sleep. It is a common condition in childhood, with an incidence ranging from 1.2% to 5.7%, and it can harm several aspects of children’s life, such as cognitive, metabolic and cardiovascular functions, among others. There are treatment options, such as adenotonsillectomy, myofunctional therapy, mandibular advancement appliances (MAAs), rapid maxillary expansion, and positive airway pressure devices, but there is still doubt about which method is more suitable for the treatment of OSA in children.

Objective To analyze the effectiveness of MAAs in the treatment of pediatric OSA.

Materials and Methods The search was conducted in August 2021 in different electronic databases, such as PubMed, EBSCO (Dentistry & Oral Sciences Source), LILACS, Ovid, SciELO, Web of Science, EMBASE BIREME, BBO BIREME, and the Cochrane Library.

Results Only three systematic reviews and two meta-analyses were included in the present study. All studies showed improvement in the score on the apnea-hypopnea index after using MAAs in the treatment of pediatric OSA.

Conclusion Although more randomized studies are needed, based on the present umbrella review, MAAs must be considered part of the multidisciplinary treatment for pediatric OSA.

Keywords

► mandibular advancement
► obstructive sleep apnea
► children

Introduction

Obstructive sleep apnea (OSA) is defined as intermittent partial or complete collapse of the upper airway during sleep. It is a common condition in childhood, with an incidence ranging from 1.2% to 5.7%, and it can harm several aspects of children's life, resulting in attention deficit, learning delay, memory consolidation impairment, aggressive...
behavior, metabolic disorders, cardiovascular disease, and nocturnal enuresis, for example.

Unlike the cases in adults, pediatric OSA is most related to adenotonsillar hypertrophy, which narrows the upper airway. Obesity is also among the main causes of pediatric OSA, but its complexity can also be explained by other factors, such as craniofacial type and neuromuscular tone.

The choice of treatment for pediatric OSA considers age, severity of symptoms, clinical findings, presence of comorbidities and polysomnographic results. Nowadays, there are many treatment options, such as adenotonsillectomy, myofunctional therapy, mandibular advancement appliances (MAAs), rapid maxillary expansion (RME), and positive airway pressure, but not all of them have the same efficacy and tolerance.

Adenotonsillectomy is still the most performed treatment in cases of pediatric OSA, and it has been highly effective throughout the years in non-obese children, even resulting in an improvement in oximetry results. However, some studies have reported that adenotonsillectomy is curative in 25% to 75% of the patients.

Continuous positive airway pressure (CPAP) is considered the first-line treatment in pediatric OSA without adenotonsillar hypertrophy, although with low tolerance (25% to 50%) and risk of craniofacial sequelae after long-term use. Myofunctional therapy helps tongue repositioning, improves nasal breathing, and increases muscle tone, preventing residual apnea after adenotonsillectomy and increasing CPAP adherence.

Another therapeutic resource can be found in MAAs: mandibular advancement is well established in adult OSA treatment; in children, the aim is to correct mandibular retrusion through redirection and stimulation of anterior mandibular growth, in a passive or active manner, which can be achieved through different appliances, such as the Herbst, Frankell II, twin-block, and others.

Functional orthopedic appliances have been used to treat mandibular retrusion in children and teenagers and, recently, to treat OSA. They are able to increase upper airway space, reduce airway collapsibility, and improve muscle tone. Thus one risk factor for adult OSA may have been solved.

The main goal of the present umbrella review was to analyze the effectiveness of MAAs in the treatment of pediatric OSA by means of apnea-hypopnea index (AHI) variability.

Materials and Methods

The present umbrella review followed the checklist of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

Inclusion Criteria

- Population: children and adolescents (age ≤ 18 years) diagnosed with OSA without craniofacial syndromes.
- Intervention: MAAs.
- Comparison: with and without a control group.
- Outcome: AHI.
- Study design: systematic review and meta-analysis.

Search Strategy

A systematic search was conducted until August 2021 in the following electronic databases: PubMed, EBSCO (Dentistry & Oral Sciences Source), LILACS, Ovid, SciELO, Web of Science, EMBASE BIREME, BBO BIREME, and the Cochrane Library. The search terms were sleep apnea, obstructive, OSA, sleep disordered breathing, mandibular advancement, oral appliances, mandibular protractor, orthodontic treatment, children, and pediatric.

Study Selection

Two reviewers (CCM and FRA) independently selected the articles, and only full-text articles were included.

Data Collection

The following data were extracted from each study included: author, year of publication, study design, age of the sample, treatment, and AHI before and after MAAs.

Risk of Bias in Individual Studies

To evaluate the risk of bias in individual studies, the University of Bristol's Risk of Bias in Systematic Reviews (ROBIS) tool was used. Two reviewers (CCM and FRA) independently evaluated the quality of the studies.

Both in terms of the criteria for the eligibility of studies and the methods, the articles included were considered to have low potential for bias. In the synthesis and results criterion, only one article was classified as presenting an unclear risk of bias. In the overall risk of bias assessment, the articles were classified as low risk, as they considered the heterogeneity of the data (Table 1).

Results

The flow chart of the selection process is illustrated in Figure 1. A total of 36 articles were identified: 4 in EBSCO, 8 in PubMed, 8 in LILACS, 9 in EMBASE BIREME and BBO BIREME, 6 in the Cochrane Library, and 1 through other sources; 32 articles remained after duplicates were removed. Then, 27 articles were excluded after screening the titles, abstracts, study designs, and full text availability. Five articles remained: three systematic reviews and two meta-analyses.

The results of the present umbrella review are organized in Table 2, followed by the studies included in each systematic review and meta-analysis, in Table 3. The selected articles were published between 2015 and 2021. The sample sizes ranged from 32 to 269 individuals aged between 3.5 and 14 years.

Several types of MAAs were used, such as single acrylic plate, twin-block, two acrylic plates (Planas), Herbst + RME, Bioajusta X, modified monoblock, Myobrace/MyOSA, Andresen activator, Frankel II, and a thermoplastic intraoral appliance.
In addition, different protocols regarding the period of use were established, ranging from 3 weeks to 20 months. In most studies, the MAAs treatment had a minimum duration of 6 months, with the exception of a subgroup treated for 3 weeks in the study by Yanyan et al.\textsuperscript{17} Long-term treatment (6 to 12 months) was more effective than short-term treatment. In general, MAAs were well tolerated in the pediatric population, with only 14 treatment dropouts (6 controls and 8 patients treated with MAAs), in the included studies.

All studies presented a reduction in the AHI after treatment with MAAs, except those in the study by Rădescu et al.\textsuperscript{31} In two studies,\textsuperscript{18,19} although there was a reduction in the AHI, it could not be statistically analyzed due to the considerable heterogeneity of the data. In the other 3 studies,\textsuperscript{17,20,21} a reduction of at least 50% in the AHI was observed, which was considered as therapeutic success, even if the scores were not within the normal range.

### Discussion

In the last decade, several studies\textsuperscript{19,21} have reported that multidisciplinary (including orthodontic) treatments for pediatric OSA can really improve not only snoring, but also apnea through growth balance correction.

Mandibular advancement combined with RME is an alternative treatment method for pediatric patients with sleep respiratory disturbances.\textsuperscript{17,21}

In 1860, RME was reported for the first time as an orthodontic treatment for the correction of maxillary constriction. However, RME was linked to OSA treatment, since it was able to reduce, in children, nocturnal enuresis, a common OSA symptom. Nowadays, RME is often performed through a fixed intraoral orthodontic appliance, gradually adjusted throughout the treatment.\textsuperscript{21}

According Yanyan et al.,\textsuperscript{17} high-quality meta-analyses support mandibular advancement in OSA patients, even in severe cases, as long as the treatment is established before pubertal peak. Long-term treatment (of at least 6 months) is superior to the short-term treatment. Mandibular advancement appliances improve the AHI and increase posterior airway space, reducing airway collapsibility. From the orthodontic perspective, MAAs also promote dentoalveolar changes and bone growth.\textsuperscript{17}

Several factors contribute to OSA occurrence, such as obesity and adenotonsillar hypertrophy, conditions that narrow the superior airway. Other conditions are abnormalities in craniofacial growth, such as atresic maxilla, mandibular retrognathia, increased vertical growth, and neuromuscular disorders.\textsuperscript{18,20}

A significant number of children do not respond to adenotonsillectomy, which is still the primary treatment for OSA, and most of them do not tolerate CPAP therapy. Therefore, functional orthopedic appliances, if correctly prescribed, are well tolerated and are able to increase airway space during sleep, reduce airway collapsibility, and improve muscle tone.\textsuperscript{18,20}

As the functional appliance brings the jaw forward, an increase in the superior airway space occurs. Therefore, the

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**Table 1** Risk of bias in the included studies according to the ROBIS tool.

<table>
<thead>
<tr>
<th>Author/year</th>
<th>Eligibility</th>
<th>Identification and selection</th>
<th>Data collection</th>
<th>Synthesis and results</th>
<th>Risk of bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yanyan et al., 2019\textsuperscript{17}</td>
<td>Y/Y/Y/PY</td>
<td>PY/NI/Y/Y/Y</td>
<td>Y/PY/Y/Y/Y</td>
<td>Y/Y/PY/PY/PN/PY</td>
<td>Low</td>
</tr>
<tr>
<td>Bariani et al., 2021\textsuperscript{18}</td>
<td>Y/PY/Y/PY</td>
<td>PY/NI/Y/Y/Y</td>
<td>Y/Y/N/NI/NI</td>
<td>Y/N/PY/PY/PN/N</td>
<td>Low</td>
</tr>
<tr>
<td>Nazarali et al., 2015\textsuperscript{19}</td>
<td>Y/Y/Y/PY</td>
<td>PY/NI/Y/Y/Y</td>
<td>Y/PY/PY/PY</td>
<td>Y/PY/PY/PY/PY</td>
<td>Low</td>
</tr>
<tr>
<td>Carvalho et al., 2016\textsuperscript{20}</td>
<td>Y/Y/Y/PY</td>
<td>PY/NI/PY/Y</td>
<td>Y/Y/Y/Y</td>
<td>Y/Y/Y/Y/Y</td>
<td>Low</td>
</tr>
<tr>
<td>Huynh et al., 2015\textsuperscript{21}</td>
<td>Y/Y/Y/PY</td>
<td>PS/S/S/S/S</td>
<td>Y/PY/PY/PY</td>
<td>Y/Y/PY/PY/Y</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Abbreviations:** N. no; NI, no information; PN, probably no; PY, probably yes; ROBIS, Risk of Bias in Systematic Reviews; Y, yes.

**Fig. 1** Flow chart of the selection process of studies.
<table>
<thead>
<tr>
<th>Study</th>
<th>Study design</th>
<th>Age</th>
<th>Treatment duration</th>
<th>ΔAHI</th>
<th>AHI reduction (%)</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yanyan et al., 2019</td>
<td>Meta-analysis</td>
<td>No significant subgroup difference ($I^2 = 0%$; $p = 0.59$)</td>
<td>Difference in treatment duration was observed: 3 weeks, 6 months, 10-12 months ($I^2 = 65.9%$; $p = 0.05$); long-term treatment (6 months, 10-12 months) may be more effective</td>
<td>-1.75 events/h (95% confidence interval: $-2.07$–$1.44$; $p = 0.00001$)</td>
<td>50% for mild (1.72/3.5), 57% for moderate (4.27/7.5), and 76% for severe (10.69/14.08) cases</td>
<td>MAAs can be effective for mild to severe OSA before the end of pubertal peak; long-term treatment (of at least 6 months) may be more effective</td>
</tr>
<tr>
<td>Bariani et al., 2021</td>
<td>Systematic review</td>
<td>7.61 ± 1.99 years</td>
<td>7.71 ± 5.13 months</td>
<td>12 studies reported reduced AHI after treatment (could not be statistically analyzed due to the considerable heterogeneity of pooled data)</td>
<td>Could not be statistically analyzed due to the considerable heterogeneity of pooled data</td>
<td>FOA can be considered a potential additional treatment in children with OSA</td>
</tr>
<tr>
<td>Nazarali et al., 2015</td>
<td>Systematic review</td>
<td>8.71 ± 1.67 years</td>
<td>9.6 ± 2.89 months</td>
<td>Could not be statistically analyzed due to heterogeneity of pooled data</td>
<td>≥ 50% (1 study used RDI)</td>
<td>MAAs may improve AHI scores</td>
</tr>
<tr>
<td>Carvalho et al., 2016</td>
<td>Systematic review</td>
<td>7.1 ± 2.6 years</td>
<td>6 months</td>
<td>-4.5 events/h ($p &lt; 0.001$)</td>
<td>50% in 9 of the 14 subjects</td>
<td>64.2% of success</td>
</tr>
<tr>
<td>Huynh et al., 2015</td>
<td>Meta-analysis</td>
<td>6.37 ± 1.72 years</td>
<td>6 months</td>
<td>-4.5 events/h; $p &lt; 0.001$ (Villa et al.); -4.22 events/h; $p = 0.0003$ (Cozza et al.)</td>
<td>≥ 50%</td>
<td>MAAs can help in the management of pediatric snoring and OSA</td>
</tr>
</tbody>
</table>

Abbreviations: AHI, apnea-hypopnea index; FOA, functional orthodontic appliance; MAAs, mandibular advancement appliances; OSA, obstructive sleep apnea; RDI, respiratory disturbance index.
<table>
<thead>
<tr>
<th>Study</th>
<th>Study design</th>
<th>Subjects</th>
<th>Age</th>
<th>Interventions</th>
<th>Wearing time</th>
<th>Drop-out</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Villa et al., 2002</td>
<td>Randomized controlled trial</td>
<td>MAAs: 19; control: 13</td>
<td>6.86/C6</td>
<td>An acrylic plate; no treatment</td>
<td>6 months (24h)</td>
<td>0</td>
<td>MAAs: AHI from 7.1 to 2.6; control: unchanged</td>
</tr>
<tr>
<td>Nunes and Francesco-Mion, 2009</td>
<td>Randomized controlled trial</td>
<td>MAAs: 24; control: 16</td>
<td>6-9 years</td>
<td>Bioajusta X appliance; no treatment</td>
<td>6 months</td>
<td>0</td>
<td>MAAs: improvements in breathing and snoring (questionnaire), airway space reduction</td>
</tr>
<tr>
<td>Machado-Júnior et al., 2016</td>
<td>Randomized controlled trial</td>
<td>MAAs: 8; control: 8</td>
<td>8.13/C6</td>
<td>Two acrylic plates; no treatment</td>
<td>12 months</td>
<td>0</td>
<td>MAAs: AHI from 1.66 to 0.30; control: AHI from 1.58 to 1.97</td>
</tr>
<tr>
<td>Idris G. et al., 2018</td>
<td>Crossover-Randomized controlled trial</td>
<td>MAAs: 9; control: 9</td>
<td>9.8/C6</td>
<td>Twin-block; sham MAAs</td>
<td>3 weeks</td>
<td>0</td>
<td>MAAs: improvements in breathing and snoring (questionnaire), airway space gain; control: airway space reduction</td>
</tr>
<tr>
<td>Cozza et al., 2004</td>
<td>Non-randomized controlled trial (prospective)</td>
<td>20</td>
<td>5.91/C6</td>
<td>Modified monobloc</td>
<td>6 months overnight</td>
<td>0</td>
<td>MAAs: AHI from 7.88 to 3.66</td>
</tr>
<tr>
<td>Schütz et al., 2011</td>
<td>Non-randomized controlled trial (prospective)</td>
<td>16</td>
<td>12.6 years/C6</td>
<td>Herbst + RME</td>
<td>12 months (24h)</td>
<td>0</td>
<td>MAAs: AHI from 4.8 to 1.3 and airway space improvement; control: AHI from 3.7 to 2.9 and airway space improvement</td>
</tr>
<tr>
<td>Zhang et al., 2013</td>
<td>Non-randomized controlled trial (prospective)</td>
<td>46</td>
<td>9.7/C6</td>
<td>Myobrace/MYOSA</td>
<td>10.8 months (24h)</td>
<td>0</td>
<td>MAAs: AHI reduction was statistically significant (p = 0.0425)</td>
</tr>
<tr>
<td>Levrini et al., 2018</td>
<td>Non-randomized controlled trial (prospective)</td>
<td>1</td>
<td>8 years</td>
<td>Andresen activator</td>
<td>16 months</td>
<td>0</td>
<td>MAAs: AHI reduction was statistically significant (p = 0.0425)</td>
</tr>
<tr>
<td>Maspero et al., 2015</td>
<td>Non-randomized controlled trial (prospective)</td>
<td>1</td>
<td>8 years</td>
<td>Andresen activator</td>
<td>16 months</td>
<td>0</td>
<td>MAAs: AHI reduction was statistically significant (p = 0.0425)</td>
</tr>
<tr>
<td>Radescu et al., 2017</td>
<td>Case report</td>
<td>1</td>
<td>1 girl and 1 boy</td>
<td>Andresen activator</td>
<td>14 months</td>
<td>0</td>
<td>MAAs: AHI improvement in a girl, less apnea and oxygen desaturation</td>
</tr>
<tr>
<td>Rose and Schessl, 2006</td>
<td>Case report</td>
<td>1</td>
<td>8 years</td>
<td>Andresen activator</td>
<td>9 months</td>
<td>0</td>
<td>MAAs: AHI and airway space improvements</td>
</tr>
<tr>
<td>Schessl et al., 2006</td>
<td>Case report</td>
<td>1</td>
<td>3.5 years</td>
<td>Andresen activator</td>
<td>14 months</td>
<td>0</td>
<td>MAAs: AHI reduction was statistically significant (p = 0.0425)</td>
</tr>
<tr>
<td>Modesti-Vedolin et al., 2018</td>
<td>Pilot study</td>
<td>18</td>
<td>8.3 ± 3.3 years</td>
<td>Thermoplastic intraoral device (superior and inferior)</td>
<td>3 months</td>
<td>0</td>
<td>MAAs: AHI and airway space improvements</td>
</tr>
</tbody>
</table>

Abbreviations: AHI, apnea-hypopnea index; MAAs, mandibular advancement appliances; RDI, respiratory disturbance index; RME, rapid maxillary expansion.
AHI will be improved, as long as the patient is wearing the appliance. Yet, if the etiology of the problem is retrognathia or maxillary constriction, skeletal and dentoalveolar correction must be achieved to complete correction of the malocclusion and stability of results.

If these changes are accomplished permanently, pediatric patients no longer need to wear the MAAS, since the skeletal growth is complete and this important OSA predisposing factor will be solved.

Obstructive sleep apnea is related to many diseases and social problems. Many adults begin snoring and experiencing other respiratory disturbances, such as OSA, in childhood; hence, the relevance of early diagnosis and treatment to prevent long-term complications in adult life. These measures also contribute to reduce costs to the healthcare system and improve quality of life.

The diagnosis of OSA is based on anamnesis, physical examination, and laboratory tests, and, to date, polysomnography is the gold-standard examination. Although adenotonsillectomy is widely performed to treat pediatric OSA around the world, recurrence is very common, particularly in children with skeletal deformities, such as mandibular retrognathia, maxillary constriction, or both.

All studies included in the present review showed AHI reduction, except for Rădescu et al., who observed an AHI increase. An early orthodontic treatment with a functional appliance appeared to be an accurate device to correct the molar relationship and reduce overjet in children with retrognathic mandible, but, in this study, the results were lower than expected, and the authors highlighted that pharyngeal surgery should be considered after treatments to one treatment modality, such as adenotonsillectomy. Although none of the studies included reported a cure for OSA (AHI < 1 event/h) after the use of MAAS, the reduction of at least 50% in respiratory events in children who had not undergone adenotonsillectomy, associated with adherence, shows its effectiveness. However, the few studies
analyzed had small samples, except for the one by Bariani et al., in which the sample was larger, but the statistical analysis was not possible due to the heterogeneity of the data. Therefore, the results must be analyzed carefully. This is a relatively new field within sleep medicine, with many questions to be explained.

**Conclusion**

Although more randomized studies are needed, based on the present umbrella review, MAAs must be considered part of a multidisciplinary treatment for children with OSA.

**Highlights**

- Pediatric OSA often has a multifactorial etiology.
- It may be necessary to combine therapies to achieve cure.
- Mandibular advancement appliances are well tolerated and result in a reduction of at least 50% in respiratory events.
- Long-term treatment (from 6 to 12 months) is more effective.
- There is a lack of statistically significant data in this field.

**Conflict of Interests**

The authors have no conflict of interests to declare.

**References**


Mandibular Advancement Appliances in Pediatric Obstructive Sleep Apnea

Cozzi-Machado et al.


36 Karadeniz C, Lee KWC, Lindsay D, Karadeniz EI, Flores-Mir C. Oral appliance -generated malocclusion traits during the long-term management of obstructive sleep apnea in adults: A systematic review and meta- analysis. 316.1