



REVIEW ARTICLE

The role of orthodontics in management of obstructive sleep apnea

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Abstract Dental sleep medicine is the field of dental practice that deals with the management of sleep-related breathing disorders, which includes obstructive sleep apnea (OSA) in adults and children. Depending on the developmental age of the patient and the cause of the apnea dental treatment options may vary. For adult patients, treatment modalities may include oral appliance therapy (OAT), orthognathic surgery and surgical or miniscrew supported palatal expansion. While for children, treatment may include non-surgical maxillary expansion and orthodontic functional appliances. Many physicians and dentists are unaware of the role dentistry, particularly orthodontics, may play in the interdisciplinary management of these disorders. This review article is an attempt to compile evidence-based relevant information on the role of orthodontists/sleep dentists in the screening, diagnosis, and management of sleep apnea. Oral sleep appliance mechanisms of action, selective efficacy, and the medical physiological outcomes are discussed. The purpose of this review is to provide a comprehensive understanding of how orthodontists and sleep physicians can work in tandem to maximize the benefits and minimize the side effects while treating patients with OSA.
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1. Introduction

Sleep-disordered breathing (SDB) is a blanket term that encompasses a spectrum of chronic conditions ranging from the least intense being primary snoring (PS) to the most intense being obstructive sleep apnea (OSA). OSA is when complete (apnea) or partial (hypopnea) cessation of breathing happens many times throughout the night due to collapsing of the upper airway (UA). Primary snoring, on the other hand, is narrowing in the UA leading to vibrations of tissue without cessation of breathing (Gottlieb and Punjabi, 2020).

Evidence found OSA to be an independent risk factor for cognitive dysfunction, metabolic disorders, and cardiovascular disease including hypertension, cardiac arrhythmia, heart failure, ischemic heart disease, and stroke (Javaheri et al., 2017; Gottlieb and Punjabi, 2020). The pathogenesis of these consequences was found to be related to what happens during OSA respiratory events including intermittent hypoxia, oxidative stress, increase of sympathetic activities, and endothelial dysfunction (Javaheri et al., 2017).

The prevalence of OSA has been on the rise (Alqarni, 2016). In Saudi Arabia, the prevalence of OSA is reported to be 5% in women and 12% in men (Wali et al., 2017). OSA was found to be an underdiagnosed condition (Fuhrman et al., 2012; Ravesloot et al., 2012; Costa et al., 2015). Orthodontists/sleep dentists may have a valuable role in the screening and interdisciplinary management of these conditions.

2. Screening

According to the clinical practice guidelines released by the American Academy of Sleep Medicine (AASM) and the American Academy of Dental Sleep Medicine (AADSM), diagnosis and follow-up of OSA and PS should be done by sleep physicians (Ramar et al., 2015). Having said that, dentists are uniquely positioned to screen and detect potential patients with OSA given the frequency of the recommended dental visits and the inclusion of UA assessment in routine dental exam-

ination (Behrents et al., 2019). The appropriate use of screening tools can help reduce the problem of underdiagnosis of OSA. However, less than fifty percent of dentists can identify common signs and symptoms of OSA (Levendowski et al., 2008; Alansari and Kaki, 2020). This warrants special attention to what is, or is not, being taught in dental curriculums and continuing education courses.

2.1. Signs and symptoms

To screen patients, OSA-related sign and symptom questions must be incorporated in routine history taking. Heavy habitual snoring is one of the most common symptoms of OSA (Choi et al., 2011), but the hallmark symptom is repetitive upper airway obstruction during sleep leading to apneas and/or hypopneas (Dempsey et al., 2010). Other nocturnal symptoms of OSA may include waking up gasping for air, nocturia, and nocturnal sweating (Veasey and Rosen, 2019). Bruxism has been heavily linked to OSA respiratory events (Balasubramaniam et al., 2014). Nocturnal enuresis is a common occurrence in children with OSA (Tan et al., 2013). Mouth breathing has also been linked to a higher risk of OSA (Kim et al., 2011).

OSA patients may experience waking up with headache and dry mouth. However, the hallmark diurnal symptom of OSA is excessive daytime sleepiness that interferes with a person's ability to function, reduces quality of life, and increases the risk of road traffic accidents (Veasey and Rosen, 2019). On the other hand, OSA in children is sometimes associated with Attention Deficit Hyperactivity Disorder (ADHD) (Tan et al., 2013). Other daytime symptoms may include low cognitive functioning affecting concentration, learning, and remembering among other cognitive manifestations (Veasey and Rosen, 2019). There is also a strong coexistence of Gastro-Esophageal Reflux Disease (GERD) in OSA patients. The reported incidence of GERD is as high as 65% in OSA patients while in the general population it is around 25% (Morales et al., 2016).

2.2. Examination

As a part of the routine dental examinations, which is recommended every 4 to 6 months, dentists can recognize a small UA and other anatomic risk factors and manifestations of OSA. Obesity, for example, is the number one risk factor for obstructive sleep apnea in adults. The risk for obstructive sleep apnea correlates on a continuum with obesity (BMI \geq 35 kg/m²) and large neck circumference (> 16" Female, > 17" Male). Weight loss and weight gain have been associated consistently with decreasing and increasing OSA severity (Ramar et al., 2015; Levine et al., 2018). Therefore, dentists must record patients' height, weight, and neck circumference (Behrens et al., 2019).

Other OSA risk factors may include having a large tongue (macroglossia), tonsils (tonsillar hypertrophy), adenoids (adenoid hypertrophy), and/or uvula. The tongue size is assessed relative to the oral cavity by evaluating the presence of scalloping, and relative to the pharyngeal size by using the "Mallampati Score" (Mallampati et al., 1985; Nuckton et al., 2006). Tonsillar size may be assessed using "Brodsky Grading Scale" (Brodsky, 1989; Jara and Weaver, 2018). The higher the score, for both the Mallampati's and the Brodsky's, the higher the risk of UA collapsibility and the higher the risk for OSA. Adenoid hypertrophy is the number one risk factor for OSA in the pediatric population. Having said that, adenoids cannot be visualized looking inside the mouth. Dentists can take clinical history by asking about the presence of recurrent otitis media, difficulty breathing through the nose, snoring, and/or sleep apnea. Clinical examination involves testing hyponasality and observing mouth breathing, yet, both tests lack sensitivity (Torretta et al., 2011). Patients with chronic adenoid hypertrophy may present with facial features known as the "adenoid face" which includes a narrow high arched palate, increased facial height, anterior open bite, and/or lip incompetence (Flores-Mir et al., 2013). Lateral cephalometric radiographs can also be used but it has been documented that they overestimate the size of adenoids. Using Cone Beam Computed Tomography (CBCT) increases sensitivity but only when interpreted by a trained evaluator (Pachêco-Pereira et al., 2016). The uvula is considered enlarged if it's wider than 10 mm or longer than 15 mm, measured physically or radiographically (Ryu et al., 2015; Chang et al., 2018). All previously mentioned soft tissue risk factors including, fat deposition, tongue, tonsils, adenoids, and uvula can be examined dimensionally or volumetrically using magnetic resonance imaging (MRI) (Schwab et al., 2003).

Other anatomic risk factors may include small jaws (micrognathia) and retruded jaw position (retrognathia) (Lowe et al., 1995). Inferiorly placed hyoid bone relative to the mandible was shown to be an indicator of low muscle tonicity and has been linked with OSA. This can be evaluated sagittally using lateral cephalometric radiographs or coronally using CBCT (Vieira et al., 2011).

OSA may have some oral manifestations which are brought about from different origins. Mouth breathers, for example, may experience dry mouth, throat infections, gingivitis, periodontitis, and/or halitosis (Al-Jewair et al., 2015). While OSA patients who brux may exhibit tooth attrition, tooth mobility, and bone loss (Kato et al., 2003; Yap and Chua,

2016). OSA patients who suffer from GERD may display dental erosion especially in the palatal and lingual cusps, dental caries, **dry mouth**, halitosis, redness of the uvula and palatal mucosa (Demeter and Pap, 2004).

2.3. Questionnaires

Once some of the signs and symptoms and risk factors of OSA are recognized, it's an opportunity to identify potential patients through the use of simple screening questionnaires (Levine et al., 2018). There are many available questionnaires to screen for OSA in adults and children. The most commonly used for adults are Epworth Sleepiness Scale (ESS) (Johns, 1991), STOP-Bang questionnaire (Chung et al., 2008), and Berlin questionnaire (Netzer et al., 1999), while for children is the Pediatric Sleep Questionnaire (PSQ) (Chervin et al., 2000). The ESS is very popular because it takes the least amount of time to fill out. Having said that, it has the lowest diagnostic value because it measures the general level of sleepiness that is not necessarily diagnostic for OSA. Therefore, ESS can be used to track sleepiness in OSA patients but not for screening. STOP-Bang and Berlin questionnaires, on the other hand, determine the risk for sleep apnea. Both questionnaires ask about many signs, symptoms, and risk factors of OSA including snoring, sleepiness, witnessed apnea, obesity, and hypertension among others. The PSQ asks about similar features in addition to inattentive or hyperactive behavior and other pediatric OSA features.

3. Diagnosis

Dentists have a very important role in screening and referring potential patients who are found to be at risk of SDB. Diagnosis, on the other hand, should be done by specialized sleep physicians. Physicians decide whether to send the patient for an overnight in-lab sleep test called polysomnography (PSG) or an overnight home sleep apnea test (HSAT) (Ramar et al., 2015; Levine et al., 2018). If an OSA diagnosis is confirmed, the patient is then categorized into having mild, moderate, or severe OSA depending on the Apnea-hypopnea Index (AHI), which is the number of respiratory events they had per hour during sleep (Sleep-related breathing disorders in adults, 1999). Physicians will then decide on the best course of action for each patient and will officially refer the patient to the orthodontist/sleep dentist if it's indicated (Ramar et al., 2015; Levine et al., 2018).

4. Management

4.1. Management of adult patients

Positive Airway Pressure (PAP) therapy is the gold standard intervention for OSA. It is the most efficacious in eliminating obstructive breathing events and improving nocturnal oxygen saturation. Having said that, poor PAP tolerance and compliance have been heavily documented in the literature (Vanderveken and Hoekema, 2010). Therefore, it would be a disservice to patients if alternative therapies besides PAP devices are not offered.

4.1.1. Oral appliance therapy (OAT)

Oral sleep appliances are the leading device alternatives to PAP devices. Tolerance for and adherence to oral sleep appliances have been reported to be high (Hoekema, 2006). High adherence was reported subjectively through self-reports and confirmed through objective measurement of adherence using microsensors (Sutherland et al., 2021).

In 2013, The American Academy of Dental Sleep Medicine (AADSM) accepted an evidence-based definition of an effective oral appliance for the treatment of obstructive sleep apnea and primary snoring (Scherr et al., 2014). This definition outlines the purpose, physical features, and function of sleep appliances. Sleep appliances in this definition are mandibular advancement devices. They work by moving the mandible forward to reopen the UA. It has been proven that advancing the mandible to maintain an open UA during sleep is the most effective mechanism for OAT.

The efficacy and effectiveness of OSA treatment have been assessed in the literature by measuring a myriad of outcomes. These include PSG measures, such as respiratory events and oxygen saturation, and non-PSG parameters, such as the ESS, quality of life, and cardiovascular, cognitive, and behavioral measures (Sutherland et al., 2015a; Sutherland Kate et al., 2014). A therapeutic response to OAT is defined as achieving having less than five respiratory events per hour while a partial therapeutic response is defined as achieving a fifty percent reduction in pretreatment respiratory events but not less than five per hour. Response to OAT is not unanimous and shows intra-individual variability. Unlike PAP which will prevent airway collapse in almost all patients if sufficient pressure is applied, OAT shows a complete therapeutic response in only a third of patients and partial response in another third. Even though PAP is more efficacious in reducing respiratory events and improving oxygen saturation, both were found to be equally effective in improving health outcomes, including blood pressure, endothelial function, and subjective and objective sleepiness (Sutherland et al., 2015a; Sutherland Kate et al., 2014). This is explained by the higher adherence to OAT when compared to adherence to PAP appliances (Sutherland et al., 2015a).

Better response to OAT has been linked to severity of AHI with patients responding better if they have mild to moderate AHI (Cistulli and Sutherland, 2019). However, weak correlation has been reported between AHI and OAT outcomes (Lim et al., 2017). In patients with severe AHI evidence is showing a greater response when combining OAT and PAP (El-Solh et al., 2011). Other patient features that have been associated with better OAT response include being young and having smaller neck circumference and lower BMI. However, not having these features does not preclude from having OAT. No difference was found when comparing OAT response in patients with hypopnea predominant versus apnea predominant OSA. Positional OSA (supine-dependent) was reported to respond better to OAT than non-positional OSA, however, the opposite was also reported (Sutherland et al., 2015b). In patients with positional OSA evidence is showing a greater response when combining OAT and position therapy (Dieltjens et al., 2015).

The physical features of an effective appliance include being custom-made, being made of biocompatible materials, engaging both the maxilla and mandible, allowing measurable, incremental (1 mm or less) forward and backward titration of the

mandible with a mandibular advancement the protrusive setting must be verifiable. An effective appliance has to also be retentive, easy to wear and take off by the patient or the caregiver, and has structural integrity for at least 3 years (Scherr et al., 2014).

Once the physician's recommendation for OAT is made, the patient's candidacy needs to be evaluated. The patient must have enough teeth and undercuts for the appliance to be retentive. Teeth and periodontium also must be healthy enough to withstand the pressure subjected to them by the appliance while it is keeping the mandible held forward. Based on the mechanism used to advance and hold the mandible forward, most available sleep appliances fit into one of four categories: push-type, pull-type, interlocking type, and anterior point stop type. Each design has indications and contraindications based on many factors. These factors may include the space available in the mouth, the available and/or missing teeth, the health of teeth and periodontium, the manual dexterity of the patient, habits such as bruxing and mouth breathing, among others. Initial records must be taken before the appliance is fabricated which may include intraoral and extraoral photos, radiographs, and the status of interproximal and occlusal contacts. The first step in fabricating the appliance is deciding how much to advance the mandible. This decision is initially informed by the improvement of subjective symptoms, or the lack of, which may include snoring and perceived depth of breathing.

There is no standard of practice for titration of oral sleep appliances. The best therapeutic mandibular position may be determined subjectively, objectively, or both. Subjective criteria may include improvement in symptoms like snoring and sleepiness and may also include the maximum mandibular advancement position the patient can tolerate (Chan et al., 2010). Objective titration is done during PSG, or HSAT if allowed by the treating physician, with the appliance worn by the patient (Almeida et al., 2009). During PSG titration, the optimum therapeutic mandibular position may be determined according to the best improvement in respiratory events, blood oxygenation saturation, and airflow among other parameters. Titration during PSG is achieved by waking up the patient to manually adjust the oral sleep appliance or by using a remotely controlled appliance (Kuna et al., 2006). Once the orthodontist/sleep dentist achieves final titration the patient is referred back to the treating physician for objective verification of outcomes.

Follow-up with the orthodontist/sleep dentist is done at the 6 months point, at the 1-year point, and annually thereafter. During follow-up, the orthodontist/sleep dentist will evaluate, comfort, adherence, the structural integrity of the appliance, the efficacy of the appliance in controlling subjective symptoms, the presence of side effects, and the need for appliance adjustment or replacement (Levine et al., 2018).

Oral sleep appliances do not cure the OSA, they control it by advancing and holding the mandible and the UA soft tissue structures attached to it to maintain airway patency. Therefore, oral sleep appliance use is expected to be long-term. This leads to potential unwanted side effects (Sheats et al., 2017). Besides, the amount of protrusion by the appliance has been shown to have a direct relationship to the amount of force subjected to the dental structures. Therefore, it is recommended to practice conservative titration by minimally advancing the

appliance just enough to manage the OSA. It was also reported that the side effects increased with appliance protrusion of > 50% maximum protrusion (Aarab et al., 2010).

Side effects of OAT could be short-term or long-term. Short-term side effects may include pain which may originate from the teeth, the temporomandibular joint (TMJ), the muscles of mastication. Other short-term side effects may include soft tissue irritation, dry mouth, excessive salivation, and/or appliance-related anxiety. These side effects may be transient or may last for a long time, especially if not managed timely and correctly. With long-term use of oral sleep appliances, occlusal changes may occur. The most reported occlusal changes include, decrease in overjet and overbite, proclination of the lower incisors, retroclination of the upper incisors, posterior open bite, and/or development of interproximal spaces, especially in between the lower posterior teeth. To minimize occlusal changes with long-term use of the OAT, it is recommended to use a morning occlusal guide, also called a morning re-positioner. This guide is fabricated according to the patient's initial occlusal relationship before OAT initiation. After taking off the sleep appliance in the morning, the patient wears the morning appliance for a short time. The purpose of the morning appliance is to reposition the mandible into its habitual pre-OAT position and to reverse changes that may have occurred in tooth position (Sheats et al., 2017).

4.1.2. Maxillomandibular advancement (MMA)

In some cases, surgical intervention may be necessary to reduce upper airway collapsibility. MMA is performed by an oral and maxillofacial surgeon in collaboration with an orthodontist. The goal of MMA is to enlarge the UA by advancing the suprahyoid musculature, tongue base, and soft palate. The high effectiveness of MMA has been reported in reducing respiratory events, sleepiness, and improving quality of life (Prinsell, 2012; Varghese et al., 2012 Jan 29).

Candidates for MMA include patients with severe OSA and PAP intolerance. In addition, candidates classically have narrowing in the oropharynx, velopharynx, and/or the hypopharynx in the presence of skeletal hypoplasia and/or retrognathia. Having said that, successful MMA has been reported in patients without skeletal hypoplasia or retrognathia (Li et al., 2000). Additionally, preoperative drug-induced sleep endoscopy (DISE) is used to identify OSA patients who may or may not respond to MMA. During DISE, 4 sites are examined and scored for collapse, the velum, oropharynx, tongue, and epiglottis. Patients with complete anteroposterior epiglottic collapse may be less suitable candidates for MMA (Liu et al., 2015).

4.1.3. Surgically assisted rapid palatal expansion (SARPE)

SARPE is a surgical procedure for OSA patients with palatal constriction. Widening the palate has been linked to reduction in daytime sleepiness, posterior tongue displacement, nose obstruction symptoms, nasal airflow resistance, apnea/hypopnea index, and oxygen desaturation (Abdullatif et al., 2016; Vinha et al., 2016). Alternatively, orthodontists can achieve palatal expansion in adult patients using miniscrew assisted rapid palatal expansion (MARPE). MARPE involves inserting miniscrew supported palatal expander to deliver orthopedic force directly to palatal shelves to separate the fused mid-palatal suture (Liu et al., 2017).

4.2. Management of young patients

4.2.1. Rapid palatal expansion (RPE)

Before the midpalatal suture fuses, rapid palatal expansion with the expander resting on the dentition, can be delivered by an orthodontist to separate the palatal shelves. Studies reported long term improvement in PSG and anatomical parameters with such intervention (Pirelli et al., 2015; Villa et al., 2015). Timing of sutural maturation varies greatly with age particularly in adolescents and young adults. Chronologic age cannot be used reliably to determine the suture developmental stage. Using CBCT may be the most reliable diagnostic method to determine sutural maturation and to achieve a clinical decision of conventional RPE versus SARPE for adolescents and young adults (Angelier et al., 2013).

4.2.2. Orthodontic functional appliances

Orthodontic functional appliances are used to correct Class II skeletal disharmony by advancing a retrognathic mandible. Studies have reported improvement in PSG and anatomical parameters (Zhang et al., 2013; Huynh et al., 2016; Huang and Guilleminault, 2017). Regarding Class III skeletal disharmony, studies have found that protraction of the maxilla shows improvement of anatomical parameters. No studies reported any effect of protraction of the maxilla on PSG parameters (Behrents et al., 2019).

5. Primary snoring

Primary snoring is a prevalent condition which is also known as simple non-apneic snoring. It is considered the mildest form of SDB which has no severe medical consequences (De Meyer et al., 2019). Many patients present to the dental clinic with the chief complaint of snoring without being aware of any other symptoms. However, all snoring is considered abnormal and a sleep physician should be making the diagnosis of PS, or the lack thereof (Ramar et al., 2015). This is because snoring is a common symptom of OSA, and the possibility of missing OSA may have serious consequences for the patient. Therefore, ideally, patients with PS should be referred to orthodontist/sleep dentist by their sleep physician with a prescription for OAT (Ramar et al., 2015). High efficacy of OAT for treatment of PS has been reported in reducing the snoring intensity and frequency, improving the quality of sleep for both snorers and bed partners, and their quality of life (Cistulli et al., 2004; Deary et al., 2014; Gjerde et al., 2016).

6. Conclusion

The purpose of this review is to provide evidence-based information on the role of orthodontist/sleep dentist in managing SDB. A declaration is warranted. OSA, in most cases, is a chronic condition. The most effective treatment plans are comprehensive and multidisciplinary because OSA is a complex multifactorial condition. The sleep team, including the orthodontist/sleep dentist, mustn't be intimidated by the trial and failure nature of OSA management. If we try our best to follow evidence-based practices, we do eventually help many patients.

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Ethical statement

This article does not contain any studies with human participants or animals performed by the author.

Patient consent

This type of study does not require informed consent.

CRedit authorship contribution statement

Reem A. Alansari: Conceptualization, Data curation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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