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Mandibular Advancement Devices in Patients with Symptoms of Obstructive Sleep Apnea: A Review

M. Wojda, P. Jurkowski, A. Lewandowska,
E. Mierzwińska-Nastalska, and J. Kostrzewa–Janicka

Abstract

Obstructive sleep apnea (OSA) is a sleep disorder resulting from the repetitive narrowing and collapse of the upper respiratory tract. The results of previous epidemiological studies confirm a significant impact of OSA on the health situation around the world. Untreated OSA is associated with many adverse health effects, such as hypertension, coronary artery disease, stroke, atrial fibrillation, congestive heart failure, and daytime sleepiness. Excessive mortality of OSA patients, especially in men under 50 years of age, associated with advanced disease, obesity, cardiovascular complications, and a greater risk of road accidents, requires an urgent extension of the diagnostic–therapeutic database dealing with this problem. It is estimated that in the adult population, OSA occurs in 4% of men and in 2% of women. In recent years, intraoral devices have become an increasingly common method of OSA and snoring treatment. Nevertheless, the use of devices producing continuous positive airway pressure (CPAP) remains the most effective treatment method. However, intraoral devices have the advantage of not requiring a source of electricity and are less troublesome in everyday use. Intraoral devices are well tolerated by the majority of patients, and their therapeutic efficacy is confirmed. Since such devices become commoner, the purpose of this work was to present the procedures, indications, and recommendations involved with intraoral devices while taking into consideration a variety of dental conditions. The side effects of the use of intraoral devices and their influence on the entire stomatognathic system were also described.

Keywords

Continuous positive airway pressure · Intraoral device · Mandibular advancement appliance · Obstructive sleep apnea · Snoring · Stomatognathic system

1 Background

Obstructive sleep apnea (OSA) is characterized by repeated episodes of collapse (apnea) or narrowing of the upper respiratory tract (shallow breathing) at the level of the throat with preserved and in most cases increased, respiratory muscles work. The above episodes most often lead to a reduction in the oxygenation of arterial blood and usually result in waking up from sleep, although most awakenings remain unconscious. An

M. Wojda (✉), P. Jurkowski, A. Lewandowska,
E. Mierzwińska-Nastalska, and J. Kostrzewa–Janicka
Department of Prosthodontics, Warsaw Medical University, Warsaw, Poland
e-mail: monikawojda@op.pl

increase in the muscle tone of the upper respiratory tract and the sudden opening of the throat during awakening causes an increase in the vibration of soft tissues. This is manifested by very loud snoring during the restoration of proper breathing (Hudgel 1992). Untreated OSA is associated with many adverse health effects, such as hypertension, coronary artery disease, stroke, atrial fibrillation, congestive heart failure, and daytime sleepiness (Young et al. 2002).

The primary assessment in the everyday medical practice which allows for an unambiguous diagnosis of the disease is polysomnography (PSG). In turn, the sleepiness questionnaire developed in 1991 by Johns (1991) at the Epworth Hospital in Melbourne is simpler to implement, which is one of the criteria for diagnosing OSA. The Epworth Sleepiness Scale consists of eight questions concerning the possibility of falling asleep during specific life situations. The patient has a choice of four options: 0, no possibility of falling asleep, to 3, a high probability of falling asleep during a given situation. The sum of the points obtained can be from 0 to 24. Excessive daytime sleepiness is diagnosed when the sum of the points is $\geq$10.

Both conservative and surgical methods have been used to treat OSA. A change in lifestyle, weight loss, the discontinuation of drugs influencing breathing, as well as stopping alcohol and drug abuse are referred to as behavioral treatment and are also important for the effectiveness of treatment. A 10% reduction in body weight can result in a 50% decrease in the number of apneas and an increase in the arterial oxygen saturation. As a result, the sleeping pattern is also improved. In the case of anatomical abnormalities predisposing to the development of OSA or hypertrophic changes, surgical treatment is indicated (Hoffstein 2007; Padma et al. 2007; Sharples et al. 2016; Carra et al. 2012). The primary conservative treatment method for apnea is breathing with air delivered to the airways under positive pressure using a continuous airway pressure (CPAP). The beneficial effect of CPAP in patients with OSA is based on the pneumatic stiffening of the upper respiratory tract. The CPAP method is relatively safe; however, its long-term use is subject to certain complications. Patients treated with persistent positive airway pressure have local nasal injuries such as necrosis, irritation and mucosal edema, or nasal septum distortion. Approximately 40% of patients develop upper respiratory tract complaints, such as a runny nose, sneezing, and dryness of the mucous membrane. Often gas accumulates in the stomach as a result of swallowing air. Sometimes, the treatment may be ineffective and lead to the development of atelectasis. There may also be complications related to improperly fitting equipment (skin abrasions, sores, and irritations of the skin of the nose and conjunctiva), which results in the escape of air around the ill-fitting mask. The most serious complications that may arise during the use of this method include an intracranial embolism, bacterial meningitis, severe nosebleeds, subcutaneous edema, and arrhythmias. However, these are isolated and currently very rare cases (Standards of Practice Committee of American Sleep Disorders Association 1995).

Difficulties in accepting the CPAP treatment and the interest of other specialists in the subject of apnea allowed the introduction of new therapeutic solutions. These therapeutic methods aim at increasing the diameter of the upper respiratory tract by retracting the base of the tongue or protruding the mandible. This effect is provided by the mandibular advancement device (MAD), which functions by maintaining the mandible in a protruded position, displacing the tongue anteriorly via the genioglossus muscle, and changing the position of the hyoid bone, thus widening the upper respiratory tract (Sharples et al. 2016). It has been found that the use of MADs only for the stimulation of the genioglossus muscle without protruding the mandible does not affect the number of episodes of breathing obstructions during sleep (Fransson et al. 2002; Mehta et al. 2001).

The monoblock, which protrudes the mandible, was used for the first time by Robin (1934) in children with micrognathia. Currently, various types of devices are used to counteract

OSA. The devices may vary in construction, size, material, the way they adapt to teeth, the coverage of the teeth, and the possibility of vertical and lateral movements of the mandible. They can be standardized devices, prefabricated devices of the "boil and bite" system for self-adjustment by the patient or with the help of a dentist, devices with a smooth or step adjustment of the mandibular protrusion, or devices prepared individually for the patient. MAD appliances usually consist of two splints adapted to the shape of the dental arches that are placed on the teeth. Several randomized trials compared the effectiveness of different designs of devices that protrude the mandible (Ghazal et al. 2009; Lawton et al. 2005). Preliminary results of the studies show more favorable changes in both the clinical symptoms and the parameters assessed in polysomnography in the case of one-part devices (Bloch et al. 2000). However, 2-year observational studies show no differences in the long-term efficacy between single and two-part appliances (Ghazal et al. 2009). Two-part devices require an adaptation period consisting of gradually increasing the degree of mandibular protrusion up to an optimal therapeutic effect lasting up to even 8 weeks after a 4-week adaptation period. This long period before the full implementation of treatment is considered a disadvantage in cases where there is a need to quickly implement fully effective treatment. Kato et al. (2000) have presented a view that for every 2 mm of mandibular protrusion, there is an increase in the therapeutic effectiveness of the device by about 20%. Setting the mandible in a position that is 70% of the maximum protrusion is a compromise between the effectiveness of the device and its potential side effects. With regard to the vertical dimension of occlusion, it is believed that it should remain at a minimum level, because increasing the vertical dimension by opening the mandible leads to the tongue moving down and posteriorly, thereby reducing the airway patency (Pitsit et al. 2002; Bernhold and Bondemark 1998).

2 Indications, Contraindications, and Side Effects of Mandibular Advancement Devices (MAD)

The use of MAD treatment according to the Polish Society of Lung Diseases is indicated in patients with asocial snoring and a mild form of OSA, which does not improve after behavioral therapy. The American Academy of Sleep Medicine (AASM) and the American Academy of Dental Sleep Medicine (AADSM), akin to the British authors, indicate the use of dental appliances in patients with snoring without OSA, with mild OSA in combination with a reduction in the risk factors for sleep apnea, and with moderate-to-severe OSA in those who do not tolerate CPAP, do not express consent for their use, or do not qualify for surgical treatment (Standards of Practice Committee of American Sleep Disorders Association 1995). The guidelines recommend as a standard that sleep physicians consider the prescription of oral appliances, rather than no treatment, for adult patients. It is recommended that patients with severe OSA begin treatment with CPAP. Similarly, treatment with CPAP is more preferable than with MAD in patients requiring urgent treatment (e.g., drivers who fall asleep at the wheel) or patients with comorbidities, because CPAP is effective immediately, while MAD therapy requires an adaptive period until optimal therapeutic benefit is obtained (Kushida et al. 2006). It is suggested that a qualified dentist should make a custom, adjustable intraoral device and should follow up control visits in order to limit the side effects of therapy or occlusal changes. However, to improve sleep or confirm the effectiveness of MAD treatment, sleep medicine doctors should step in with control checkups (Ramar et al. 2015).

Before patients can be qualified for treatment with dental appliances and after they meet the criteria set out in the indications for MAD treatment, they should have a thorough extra- and intraoral examination. It is estimated that about one-third of OSA patients are excluded from MAD treatment solely on the basis of local dental

factors alone (Petit et al. 2002). The selection of patients in whom treatment with MAD could be effective is difficult due to a large number of factors determining treatment success using this method. There is a widespread belief that having a less severe form of OSA (Gotsopoulos et al. 2002; Mehta et al. 2001), a younger age, a lower body mass index (BMI), and a smaller neck circumference all improve the outcome of MAD treatment (Chung et al. 2010; Mehta et al. 2001). It is also believed that women respond better to this form of treatment (Marklund et al. 2004). In addition, morphological structure of the facial part of the skull and the physiology of the upper respiratory tract affect the therapeutic effect of MAD. On the basis of cephalometric studies, parameters related to the response to MAD treatment were determined. Better results of MAD treatment are achieved in patients with a longer maxilla, smaller overjet, shorter soft palate and facial height, reduced distance between the mandible and hyoid bone, and a smaller retropalatal airway space. It is believed that the success of treatment with MAD devices is affected by the distance from the posterior pharyngeal wall to the soft palate and from the angle formed by the ramus of the mandible with the line running through the sella turcica (Ng et al. 2012; Lee et al. 2010; Mehta et al. 2001; Liu and Lowe 2000). In addition, positive therapeutic effects of MAD are observed in patients whose upper airway collapses during sleep in the oropharyngeal region and in those with lower nasal resistance (Zeng et al. 2008; Ng et al. 2006).

In the qualifying clinical examination for MAD treatment, the number and quality of the remaining teeth, as well as the periodontal and temporomandibular joint health status should be assessed. The prerequisite for OSA treatment with MAD includes at least eight stable teeth in the maxilla and mandible and the ability to determine the centric occlusion with the position of the mandible in 50–75% of the maximum protrusion while leaving a space between the incisors of 3–5 mm that allows for free breathing through the mouth. The greater the mandibular protrusion, the greater is the effectiveness but also the poorer tolerance of the device. After determining the optimal protrusion of the mandible, it is recommended to evaluate the effectiveness of a device with a PSG test, because in some patients the dental prosthesis may increase the number of apneas (Johal and Bottegal 2001; Hans et al. 1997). MAD is contraindicated in cases of temporomandibular dysfunctions, including temporomandibular joint disorder, muscle complaints, lack of proper quantity and quality of teeth, and periodontal disease.

The side effects of MAD appliances have been divided into small and transient as well as moderate, severe, and chronic (Hoffstein 2007). Moderate, severe, and chronic adverse reactions prevent the continuation of treatment. The most common side effects are the following: excessive salivation, dry mouth, allergic reactions to the material used, and pain in the temporomandibular joints. Based on the cephalometric studies and model analysis, changes have been diagnosed after using MAD in the horizontal and vertical occlusal record, disturbances in Angle's classes (Angle 1907), and changes in the upper incisor angle to the base of the skull (1/NS) and in the angle between sella, nasion, and supramentale (SNB). In the studies assessing the use of Herbst devices, which protrude the mandible for 2 years, changes have been diagnosed in the position of incisors and a statistically insignificant reduction in vertical and horizontal occlusion, which was associated with the height of the splint but was unrelated to the extent of mandibular protrusion and to the length of time the devices were used (Battagel and Kotecha 2005; Fransson et al. 2003). In a study evaluating the effect of MAD on the stomatognathic system, Rinqqvist et al. (2003) used splints that did not cover the anterior part of the dental arches, and the mandibular protrusion in that case did not exceed 50%. The authors failed to observe vertical and horizontal occlusal changes or changes in the inclination angle of the upper and lower incisors. Marklund et al. (2004) observed fewer side effects in the case of devices made of elastic material. Bondemark and Lindman (2000) stated, however, that appliances made of hard material, thanks to the support of entire dental arches, are better for preventing occlusal changes. Martinez–Gomis

et al. (2010) showed that most dental changes occur within the first 2 years of use of mandibular protrusion devices.

3 Discussion

Based on the available medical evidence, OSA requires a multidisciplinary plan of treatment. Research confirms that devices that protrude the mandible can be an effective method of treatment in specific clinical cases, especially in early forms of the disease diagnosed on the basis of a clinical examination or in people with cardiovascular disease. Therapeutic efficacy of intraoral devices in OSA has been confirmed during the last decade by a significant number of randomized studies comparing MAD and CPAP modes of treatment (Kostrzewa-Janicka et al. 2016; Sharples et al. 2016; Quinnell et al. 2014; Gagnadoux et al. 2009; Hoffstein 2007; Fergusson et al. 1996). Studies provide the unambiguous evidence that the values of OSA indices decrease after the use of MAD or CPAP. Notably, AHI index decreases to a similar extent after treatment with MAD or CPAP, and these decreases are outstandingly significant in both treatment modes compared to placebo effects (Phillips et al. 2013; Hoekema et al. 2008; Barnes et al. 2004; Engelman et al. 2002; Tan et al. 2002). Likewise, excessive daytime sleepiness is clearly diminished using both treatment options (Aarab et al. 2011). Moreover, the improvements in the patient's condition are long-lasting as they are sustained for up to a 2-year-long follow-up using either treatment option (Doff et al. 2013). These results encourage the use of MAD as an efficacious alternative to CPAP therapy in patients with mild-to-moderate OSA. However, in severe OSA, the treatment of choice remains to be CPAP.

Compliance with indications and contraindications to MAD treatment is indispensable for achieving the intended therapeutic effects, while protecting the patient from adverse effects. A simple construction of MAD devices, their availability, and the comfort of use encourage a widespread application among people with the symptoms of snoring or with milder forms of OSA, who do not tolerate CPAP treatment. After the implementation of therapy with an intraoral device, control visits at the dental office in order to assess the masticatory motor system are necessary. The effectiveness of OSA treatment should be objectively evaluated by repeat PSG examinations.

Conflict of Interest The authors declare no conflict of interest in relation to this article.

Ethical Consideration This review article does not contain any studies with human participants or animals performed by any of the authors.

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