Interdisciplinary treatment of obstructive sleep apnoea: cooperation with orthodontist and maxillofacial surgeon

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Key words:
OSA; role of a dentist; orthodontist and maxillofacial surgeon

Received: 17. 6. 2016
Accepted: 18. 6. 2018

Abstract

Obstructive sleep apnoea, known as OSA, is a chronic disorder of breathing characterized by frequent episodes of partial or complete obstruction of upper airway during the non-REM phase of sleep. It can be graded as mild, moderate and severe. We know numerous morphological and functional predisposing factors as well as risk factors which contribute to OSA. Among many particularities of stomatognathic system are mandibular microgenia and rethrognatia, bigger base of tongue and longer soft palate and as a consequence the narrowing of the upper respiratory tract. The gold standard for the diagnosis is polysomnography. Its primary consequences hypoxemia and recurrent arousals from sleep can show numerous and harmful effects on health, neurophysiological development and quality of life. Today OSA is also recognized as a public health problem. Treatment of OSA is multidisciplinary and very diverse. The article presents the basic facts about the disease with the emphasis on the craniofacial morphology and the role of a dentist, orthodontist and maxillofacial surgeon in its prevention, recognition and treatment.

Cite as: Komljanec H, Ihan Hren N. [Interdisciplinary treatment of obstructive sleep apnoea: cooperation with orthodontist and maxillofacial surgeon]. Zdrav Vestn. 2018;87(7–8):353–64.

DOI: 10.6016/ZdravVestn.1670

1 Definition, clinical signs and epidemiology

Obstructive sleep apnoea, known as OSA, was first described already in 1837 by Charles Dickens as part of the Pickwickian syndrome. In 1956, Sidney Burwell documented in detail the signs and symptoms in a patient with OSA. An important advance in the knowledge of OSA was achieved by Guilleminault in late 70's of the past century (1). Due to the narrowing of the upper respiratory tract (URT), mostly involving the pharynx with soft palate, uvula and the tongue base, the patient often stops breathing during sleep. As a result, the patient wakes up for a moment, inhales, snores and again falls asleep. The patient is not aware of these brief episodes of wakefulness, although they may occur several times within an hour. The URT obstruction occurs in the nREM phase of sleep, so the patient has difficulty achieving the REM phase. Patients with OSA say that they do not dream during sleep.

Obstructive sleep apnoea is determined by the apnoea-hypopnoea index (AHI), i.e. the number of breathing di-

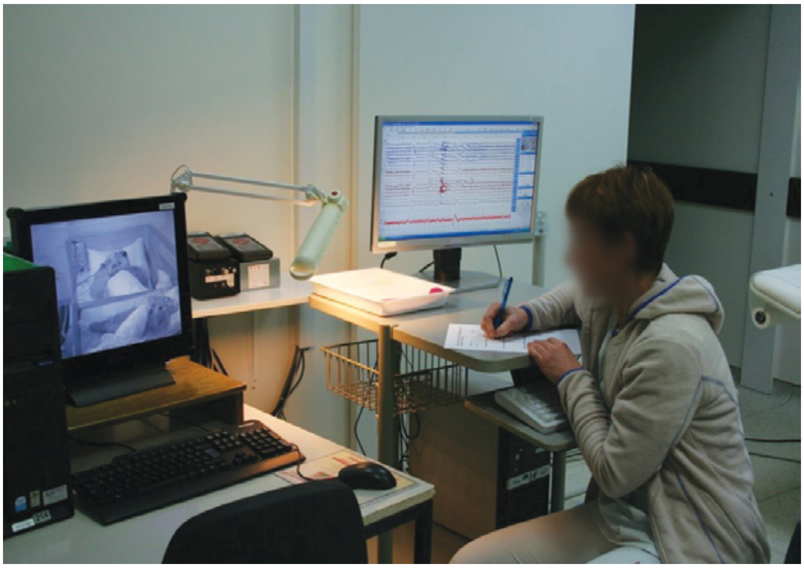

Figure 1: Monitoring of a patient during polysomnography at the Department of Neurology of the UMC Ljubljana.

sorders occurring per hour of sleep, which cause oxygen saturation decrease and thereby tissue hypoxaemia. Obstructive sleep apnoea is defined as AHI > 15/h in asymptomatic or AHI > 5/h in symptomatic individuals. OSA is classified as mild (AHI 5–14/h), moderate (AHI 15–30/h) and severe (AHI > 30/h) (2).

Besides OSA, the group of respiratory disorders also includes snoring, obstructive sleep apnoea syndrome (OSAS), central sleep apnoea (CSA), periodic breathing of the Cheyne-Stokes type, and hypoventilation syndrome. All these are characterised by an excessive reduction in gas exchange during sleep (e.g. hypoventilation) or an abnormal breathing pattern (e.g. apnoea, hypopnoea, or awakening associated with respiratory strain) (3).

When normal sleeping pattern disturbances are combined with daytime symptoms, this is defined as obstructive sleep apnoea syndrome (OSAS).

OSA symptoms at night include loud snoring, restless and poor-quality sleep, frequent urination and feeling of strangulation (4,5). Daytime symptoms are excessive sleepiness, drowsiness already before noon, fatigue, headache, poor concentration and decision making, automatic behaviour, aggression, hyperactivity (6,7).

The prevalence of OSA in adult males is form 3 % (8) to 7 % (9), and in adult females from 1 % (10) to 4 % (9). In the paediatric population, the prevalence of OSA ranges from 1 % (11) to 4 % (12). The data do not vary greatly between the developed and developing countries (13). Researchers associate the increasing prevalence of OSA with an increase in obesity. OSA is a poorly recognised sleep disorder. Therefore many cases remain undetected and the actual occurrence of OSA is most probably higher than shown by the officially reported numbers. So far, data on the prevalence of OSA in Slovenia are not yet available.

2 Pathogenesis

We already know that the development of a disease in an individual may depend on one or more factors, which are divided into morphological (static) and functional (dynamic).

Morphological factors include obesity, soft tissue and bony anomalies of the URT.

The most relevant anomalies of the URT soft tissues are: hypertrophy of the tonsils (particularly in children), hypertrophy of the uvula, elongated uvula, elongated and thickened soft palate, macroglossia, oedema, fatty deposits. In patients with OSA, pharyngeal lumen – particularly in the post-palatal region – is narrow (14,15), the narrowing being more expressed in the lateral than in the sagittal plane (16). The latter finding should be considered when evaluating the lateral cephalometric image of the head and neck.

URT hard tissue irregularities include malformations in the size, shape and position of the upper and lower jaw, often in association with occlusal deviations, nasal septum deviation, URT length, and hyoid bone position (17).

Among the functional factors are reflexes that affect the URT lumen, coherent pharyngeal function and the activity of pharyngeal inspiratory muscles. Oedema of the pharyngeal tissue is both morphological and functional factor as it narrows the URT while also hindering normal function of the receptors responsible for triggering the protective reflexes (18).

The known risk factors for OSA include: obesity (19), male gender, age over 40 years (20), heart disease, thyroid disorders, ethnic and genetic factors (21), alcohol drinking (22), smoking (23), and tranquiliser use (5). A direct correlation between the level of obesity and the severity of OSA has been firmly demonstrated. During sleep, the pharyngeal muscle tone decreases, and as a result, the sub-mucosal fatty tissue exerts pressure on the URT (24). Compared to the control group, patients with OSA have a significantly increased body mass index (BMI) and neck circumference (25).

3 Characteristics of the face and oral cavity in patients with OSA

Craniofacial anomalies play an important role in the pathogenesis of OSA. Among OSA patients, certain facial types are more common than in normal population. The deviations are evident mainly in the sagittal as well as in the vertical planes, in particular in terms of dorso-caudal rotation of the lower jaw, with the rotation centre situated near the temporomandibular joint (TMJ) (26). It has been found that the correlation between skeletal abnormalities and the severity of OSA is higher in non-obese subjects (27). Study results are also consistent with the high incidence of OSA in patients with craniofacial anomalies such as the Pierre-Robin's sequence, Treacher-Collins and Down's syndrome (28). Micrognathia and retrognathia of the mandible constitute an important morphological factor for OSA (29). It has been found that in the population of OSA patients, rather than retrognathia, micrognathia of the mandible is statistically significant (30), while some researchers also attributed significance to retrognathia of the maxilla (31). In addition, a number of other anatomical features of the head and neck have been described in patients with OSA. Thus, a greater base of the tongue, larger soft palate and narrower lower dental arch were found (32). Two sites of the URT narrowing were established: above the tongue base, which is associated with a longer and thicker soft palate, and behind the tongue base, which is associated with retroposition of the mandible and an increased distance between the mandibular plane and the hyoid bone (33). In patients with OSA, the residual oropharynx, i.e. the area devoid of soft tissue, is reduced by 9 % (34), and according to some studies even by 50 % (15), due to the longer tongue and soft palate.

In patients with OSA, measurements revealed a longer contact area between the soft palate and the tongue, a smaller size of the nasopharynx and velopharynx in the sagittal plane (on a lateral cephalometric image of the head and neck), and a shorter distance between the tongue base and the posterior pharyngeal wall. A more upright position of

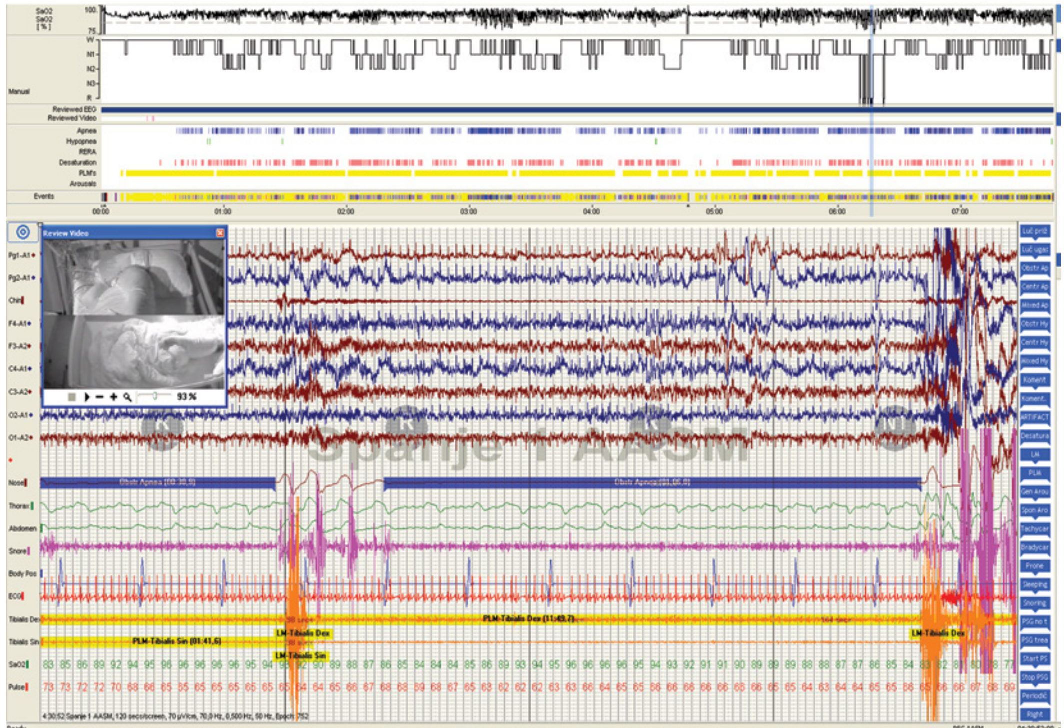

Figure 2: Polysomnography record taken at the Department of Neurology of the UMC Ljubljana.

the tongue was established along with a greater tongue length in the caudal direction (35). Furthermore, the measurements revealed a shorter distance between the posterior pharyngeal wall and the lower incisors, which results in a reduced space for the tongue (14). Patients with OSA were found to adopt a compensatory physiological posture with increased cranio-cervical angle, thereby increasing their airway patency in the standing position during waking state (15).

The most frequent cause of OSA in children is hypertrophy of the tonsils and adenoids. They were found to have a posteriorly inclined mandible, anteriorly inclined maxilla, a shorter anterior skull base, narrowed URT and a less pronounced nose (36). In children with OSA, the morphology of the dental arch and dental arch relations were studied. The typical findings were as follows: a large overjet, a small overbite or even anterior open bite, a narrower upper and a shorter lower dental arch. Often, distal or asymmetric relation of the molars and lower arch crowding are present (37).

Although the impact of morphology on the OSA is clearly evident, OSA in an individual can not be identified on the basis of anatomical irregularities. However, their recognition is of significant importance in determining the ideal therapy for an individual patient (38).

4 Diagnosis

OSA diagnosis is established by measuring respiratory parameters during sleep. The method of choice is polysomnography (PSG) (39,40). In Slovenia, PSG is performed in laboratories for respiratory disorders during sleep at the Golnik Hospital, as well as at the Department of Neurology of the UMC Ljubljana, the Department of Hypertension of the Peter Držaj Hospital, and at the UMC Maribor. A patient with suspicion of OSA must sleep in the laboratory.

PSG measures the frequency and duration of respiratory arrests, blood oxygenation, airflow through the respiratory tract, pulse, activation of the intercostal muscles (inhalation attempt), eye movement measurments (EOG), electrical activity of the heart (ECG), the brain (EEG), on the chin and in the legs (EMG).

A somewhat less complex method for OSA diagnosing is polygraphy, which measures the same parameters as PSG, except for brain activity, muscle activity and electrocardiography. It allows testing with portable monitors at home.

Among the diagnostic methods, drug-induced sleep endoscopy (DISE) is increasingly gaining ground (41).

It is highly recommended that patients with OSA have the lateral cephalogram of the head and neck analysed (33). Two parameters of the lateral cephalogram analysis of the head and neck were pointed out as deserving particular attention of physicians who are dealing with the craniofacial area. It was found that a distance between the tongue base and the posterior airway space (PAS) of 5 mm or less, and a distance of the mandibular plane to the hyoid (MP-H) of 24 mm or more should be regarded as statistically significant factors for a higher index of respiratory disorders (42).

5 Untreated OSA may be associated with the following conditions

Night hypoxia and hypercapnia result in an increased risk for hypertension, arrhythmia, cardio-vascular disorders including brain stroke, ischaemic cardiac disease including myocardial infarction, neurological complications including an exacerbation of epilepsy. Chronic intermittent hypoxia is a severe risk factor for death (43).

An indirect adverse consequence of snoring is a lower quality of sleep of the person sleeping in the same room.

The consequences of excessive daytime sleepiness are traffic accidents, reduced work productivity, worse memory and concentration, difficulty in coping with daily tasks, depression, decreased libido or impotence, weight gain (positive feedback loop).

OSA imposes a financial burden on the whole society. It is estimated that the healthcare related costs due to untreated OSA in the United States (USA) amount to 3.4 billion US dollars annually, not including the indirect costs associated with the absenteeism from work and the increased risk of causing accidents in traffic and in the workplace (17).

6 Treatment

OSA should be treated as a chronic disease using a multidisciplinary approach, where the active role of the patient is equally important. The treatment objective is to reduce the consequences of the disease, improve the quality of live and increase life expectancy. The least invasive treatment methods should be chosen whenever possible (5). The ultimate treatment plan depends on the severity of the disease as well as on the

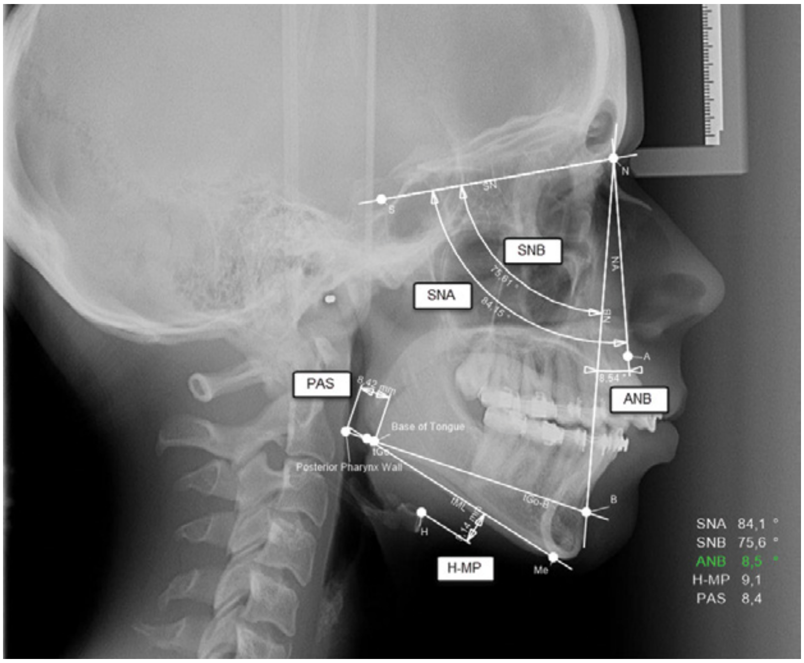

Figure 3: Lateral cephalometric image of the head and neck with specific parameters for the diagnosis of OSA (SNA, SNB and ANB angles, and PAS and MP-H distance).

symptoms in each individual patient. The results of the research support a multidisciplinary search for the specific cause of the disease and therapy in an individual, thus determining the most appropriate treatment for the patient, and thereby ensuring greater safety for their health.

- Lifestyle change: Normalisation of body weight is a necessary measure for all OSA patients with excessive body weight. The same measure is also indispensable in children (44). In addition, the patients should quit smoking and drinking alcohol.
- Prevention of snoring: sleeping on the side, avoiding the use of tranquilisers at least 3 hours before bedtime (5).
- Surgical elimination of obstructions in the URT: Removal of the tonsils and adenoids, reduction of soft palate length.
- Therapy with continuous positive airway pressure (CPAP): CPAP is the method of choice in moderate and severe OSA. An air compressor supplies air under pressure to the patient's respiratory system through a nasal or naso-oral mask, and by maintaining positive airway pressure expands the collapsed respiratory system. CPAP is a symptomatic therapy and the patients are expected to use it for the rest of their lives. CPAP use during sleep is the most effective OSA therapy, provided that the patients use it every night. Unfortunately, patients often find it difficult to comply with CPAP. The patients' main complaints are the pressure exerted by the mask and the noise generated by the compressor. Even those patients who initially comply with this therapy, may later on refuse it as a long-term treatment option. In young patients in particular the use of mask may entail psychological and social adverse effects (26). Thus, due to poor patient compliance, the CPAP success can only be 50 % (45).
- The use of individual orthodontic devices that move the lower jaw forward, and tongue holders.
- Orthognathic surgery: Maxillomandibular advancement (MMA).

A study has shown that as many as 40 % of tests assessed the success of OSA treatment according to the AHI and the lowest oxygen saturation (Lsat). For reliable estimates, it is also necessary to include the quality of life (QOL) parameter, as it has been proven that AHI alone is not in correlation with changes in the quality of life (46). Given that patients are seeking help primarily because of daytime sleepiness and poor quality of life, it has been often suggested that

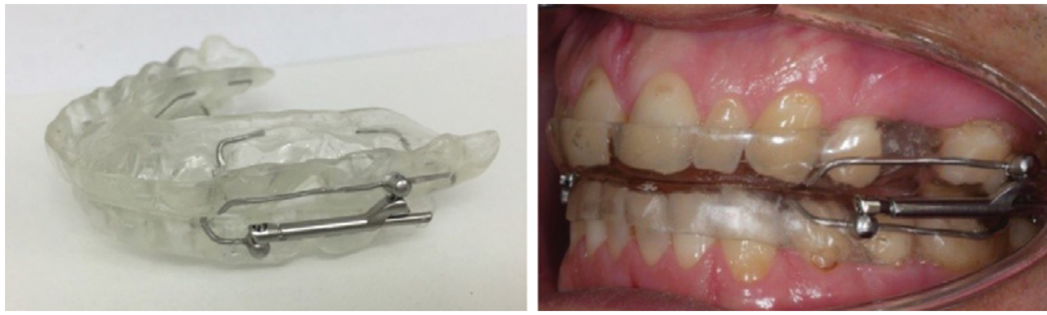

Figure 4: Orthodontic appliance for holding the mandible forward using metal and acrylate guides (a derivative of the Herbst appliance) – view of the appliance (left) and the appliance in site (right) (Helena Komljanec, MD dent.med., orthodontist).

when evaluating treatment success, greater importance should be attributed to the subjective symptoms of the patient.

7 The role of dentist, orthodontist and maxillofacial surgeon in the prevention and treatment of OSA

Many patients with OSA remain undiagnosed. Anamnestic records in dental offices should be updated with additional questions: 1. Do you snore while sleeping? 2. Do you feel that you do not dream at night? 3. Do you feel sleepy in the daytime?

Epstein et al. have proposed five questions relating to OSA that should be routinely answered by physicians and dentists for each patient: 1. Is the patient overweight/obese? 2. Is the patient retrognathic? 3. Does the patient complain of daytime sleepiness? 4. Does the patient snore? 5. Does the patient have hypertension (47)? Positive answers to the above questions require of dentists, orthodontists and maxillofacial surgeons to pay particular attention to the diagnosis of skeletal and dental deviations associated with OSA. The role of dentists is important as they can easily recognise mandibular retrognathia and micrognathia, a large overjet, clas II dental relationship and excessive mechanical wear and tear of the biting surface of the teeth. Namely, it has been proven that OSA is the most relevant risk factor for nighttime bruxism (48). When treating a patient who requires surgical elimination of obstructions in the URT, the maxillofacial surgeon should always suspect the presence of OSA.

OSA in children adversely affects the growth and development of orofacial area. The dentists who suspect OSA in children should refer their patients as soon as possible to an otorhinolaringologist, to a specialist outpatient clinic for sleep disorders, as well as to a orthodontist. It has been proven that early diagnosis and treatment of OSA results in almost full normalisation of the growth and development of the orofacial region (36). In the time-span from birth to adulthood, the human face increases by 2.5-fold in size. The face growth is influenced by genetic and functional factors. OSA-related open-mouth posture in children contributes to the development of long-face syndrome. On the other hand, the very morphology of the long face increases the risk for the

Figure 5: Orthodontic appliance for holding the mandible forward using acrylate guides – view of the appliance (left) and the appliance in site (right) (Prof. Nataša Ihan Hren, DSc, MD dent. med., maxillofacial surgeon)

onset of OSA (49). Therefore, the role of paediatricians and dentists to encourage parents and children to abandon the habitual open-mouth posture is very important.

The dentists who suspect OSA in adults should refer their patients to a specialist outpatient clinic for sleep disorders, as well as to a maxillofacial surgeon and a orthodontist.

Studies have confirmed the need that orthodontists be included in both the diagnosis and treatment of OSA (14,50). Besides the standard parameters of the lateral cephalogram analysis of the head and neck, orthodontists should also perform measurements of the PAS and MP-H distance. In comparison with computed tomography (CT), cephalography is cheaper and the patient's exposure to radiation is lower. But on the other hand, CT scan has a major advantage over the lateral head and neck cephalography. Namely, CT can also image changed dimensions of the pharynx in the lateral plane, and, as regards OSA, pharyngeal changes in the lateral view are more important than changes in the sagittal view. Moreover, cephalography is performed with the patient in upright position and CT in supine position, which affects the size of the URT (51). As a result of lower radiation doses, the number of investigations is increasing, so that the diagnosis and treatment of OSA is also possible by means of cone beam CT (CBCT) (52,53).

Orthodontic treatment of OSA comprises treatment with non-removable and removable orthodontic devices (alone or in combination with CPAP) and the treatment of a patient with non-removable and removable orthodontic devices before and after the orthognathic jaw surgery. Orthodontic devices for the treatment of OSA are designed to pull the mandible and the surrounding tissues forward (mandibular advancement appliance – MAA), or to pull only the tongue forward without changing the position of the mandible (tongue retaining device – TRD). Prior to the beginning of treatment, orthodontists should subject their patients to a complete orthodontic examination, including examination of the soft and skeletal tissues of the oral cavity and face, TMJ, function analysis, in particular seek evidence of possible sleep bruxism, record and analyse local dental X-rays, orthopantomography and cephalography of the head and neck (an example of the analysis of OSA-specific parameters is presented in Figure 3). Candidates for MAA are patients with healthy dental and periodontal tissues, without significant changes in the TMJ, with adequate flexibility of the mandible and appropriate manual skills, and motivated to use the device according to the instructions of the orthodontists. Patients who do not fulfil the mentioned requirements shall receive a TRD instead of MAA (47).

The MAA group includes the Herbst device and its derivatives, activator, monoblock, twinblock and a number of commercially available products (Figure 4–7). MAA treatment is indicated in snoring, mild to moderate OSA, in patients with unsuccessful CPAP treatment and in those who decline CPAP or orthognathic surgery. In a study comparing different MAA types, the PSG indexes improved when the study subjects used any type of MAA. The degree of effectiveness depends on the severity of OSA, the material and method of device manufacturing, and the extent of jaw displacement (in the sagittal and vertical planes) (54). By shifting the mandible and the tongue onwards, MAA significantly increases the URT, and additionally increases the activation of URT dilator muscles, thereby reducing the possibility of URT collapse (55). Several authors have proven that none of the devices can effectively treat OSA in all patients. Therefore, orthodontists, who treat patients with OSA, should have a profound knowledge of respiratory disorders and ample experience in the use of a wide range of orthodontic devices (56). The patient should have PSG measurements performed before treatment, and generally also with the device already in place immediately after its placement. Only in this way can the therapeutic effect of the device be determined. The first two checks must be carried out at half-year intervals and afterwards once yearly. The follow-up checks are intended to assess the effects of the device, the patient's compliance and potential adverse effects, and to adjust the device as necessary (56). All the time the patient should be subject to monitoring by other specialists dealing with sleep disorders (47). The objective of MAA treatment is to achieve AHI < 5/h, oxygen saturation > 85 % and an improvement of clinical signs and symptoms. Inadequate removable appliances may significantly impair the bite and TMJ function. Therefore, a patient with indication for MAA use should be treated by an orthodontists. The most common problem that patients report when using MAA is increased salivation (57). Dental and skeletal changes due to MAA were studied. After 6 months of MAA use, the findings revealed increased facial height and decreased overbite and overjet. After 24 months, the growth of the first upper and lower permanent molars and an increase in the inclination of the lower incisors were established. Further findings included an increase in the SNA and SNB cephalometric parameters, a decrease in the inclination of the upper incisors and a reduced upper dental arch length (58). Studies have established various mechanisms of MAA action in patients with OSA. Adachi et al. have proven the importance of increased activity of the genioglossus muscle due to the forward shift of the mandible (59). Some studies prove the importance of increased retropalatinal and retroglossal pharyngeal space, most of all in the lateral plane (60). Tan et al. have reported that patients tolerate MAA better than nCPAP (61). However, the therapists should always be aware of the fact that the exact pathophysiological mechanism of OSA has not yet been fully explained. Therefore, an increase in the URT volume and muscle tone alone may not necessarily lead to condition improvement. It is recommended that patients treated with MAA should have their condition checked by PSG, since it has been found that in exceptional cases MAA may even aggravate the condition.

The tongue retaining device (TRD) is a removable appliance custom made

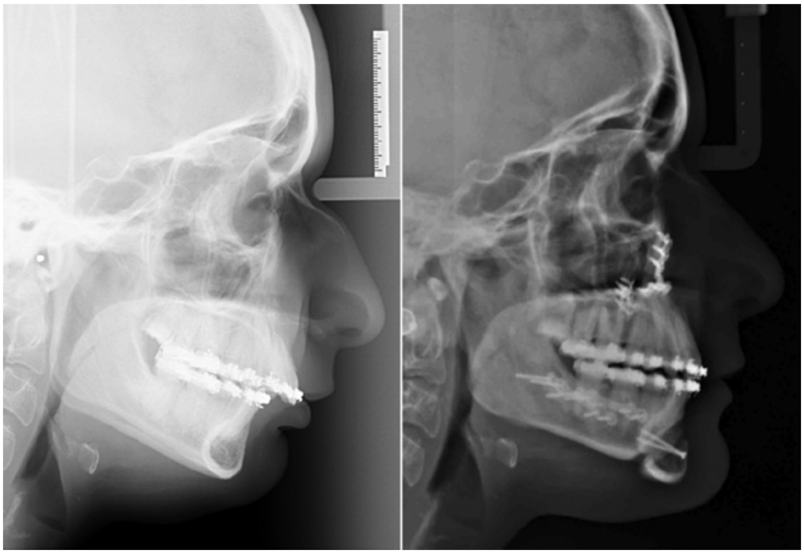

Figure 6: Cephalometric images of bimaxillary retrognathism before and after orthognathic advancement of the maxilla and mandible (Prof. Nataša Ihan Hren, MD dent. Med., DSc, spec. in maxillofacial surgery) in a 21-year old patient with a BMI of 20.3 and history of snoring, fatigue and disrupted sleep.

from casts of the patient's teeth and tongue. It covers the upper and lower dental arch, pulls the tongue forward and lifts the soft palate. A TRD is tolerated best by patients with class I malocclusion of the first permanent molars. Lower number of teeth in the oral cavity is associated with lower stability of the TRD. However, a TRD can even be used in toothless patients. Indications for the use of TRD are mild OSA, moderate OSA without daytime sleepiness, and cases of failure or refusal of CPAP or MMA treatment. Congested nasal passage is a contraindication for the use of TRD. TRD is effective in as many as 71 % of patients (62). However, even during the use of TRD, the AHI index may deteriorate, and therefore PSG control is indispensable. Adverse effects of TRD use include discomfort, painful tongue, increased salivation, aversion because of the unappealing outlook, displacement of the incisors and aggravation of the periodontal tissue condition.

Among the surgical treatment methods is by far the most effective surgical shift of the maxilla and mandible forward, i.e. maxillomandibular advancement (MMA). MMA includes maxilla advancement by Le Fort I osteotomy, and mandibular advancement by bilateral sagittal split osteotomy. MMA has become the method of choice in patients who refuse CPAP. MMA is suitable for patients with retrognathia of the maxilla and mandible as well as for those without dentofacial anomalies but presenting with severe or moderate OSA (63).

MMA expands the pharyngeal airway and increases tissue tension. Increased tissue tension reduces the risk of collapse of the velopharyngeal and suprahyoid muscles and of the lateral pharyngeal wall (64). CT scans have shown that following MMA, the URT length increases in the sagittal and transversal planes and decreases in the vertical plane (65). These changes reduce the air flow resistance, as described by the Poiseuill's law. The success rate of MMA method is as high as 86 % (66). Younger age, lower BMI and sufficient jaw advancement ensure greater MMA success. Obese patients with white fat accumulation and inadequate adipocyte activity, as well as patients with long-lasting OSA and thus at a higher risk of persistent neurological deficits in the pharynx are less favourable candidates for MMA. Maxillofacial surgeons can perform MMA even without a prior orthodontic preparation, while trying to maintain the patient's occlusion as it was before surgery. In cases where bite after MMA deteriorates (in particular, the occurrence of an open bite), its postoperative orthodontic correction is necessary (67). Ideally however, the patient should undergo orthodontic preparation prior to MMA. In the skeletal abnormalities of class II, an orthodontists must decrease inclination of the lower incisors and increase that of the upper incisors in the bucco-oral direction. In this way, surgeon is enabled to achieve greater advancement of the mandible.

8 Conclusion

OSA is an important health disorder, which has also been recognised – apart from other physicians – by dentists, orthodontists and by maxillofacial surgeons. Unfortunately, many patients with sleep dyspnoea remain undiagnosed. Therefore, physicians should pay more attention to anamnesis and clinical examination for the detection of OSA. It is also necessary to raise patients' awareness, as untreated OSA may have serious consequences for the patients as well as for their immediate and wider vicinity. OSA being a very complex and chronic disease, its treatment is long-term and requires an interdisciplinary approach with the participation of orthodontists as well as of maxillofacial surgeons.

The nurse gave her consent to the publication of the Figure 3.

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