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A Review of the Use of Mandibular Advancement Appliances in Sleep-Disordered Breathing

Abstract: This paper sets out to provide a review of the provision of mandibular advancement appliances for patients with sleep-disordered breathing. A contemporary overview is provided in relation to: the rationale for their use; guidelines on patient selection; design features; clinical evidence of success; advantages; disadvantages; treatment objectives and follow-up and practical aspects to their provision.

Clinical Relevance: Mandibular advancement appliances are now increasingly being recognized by sleep specialists as playing a valuable role in the management of sleep-disordered breathing. The dentist is ideally positioned and, with the appropriate training, could provide this relatively simple form of treatment for patients who suffer what can be a socially-embarrassing condition, with high levels of morbidity.

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The term 'sleep-disordered breathing' (SDB) has been used to describe a spectrum of related conditions, which range from simple (non-apnoeic) snoring to obstructive sleep apnoea (OSA). An integral aspect of the diagnosis of the subject with SBD is an overnight sleep study, providing an objective measurement of severity. In view of the night-to-night variation which can be observed, it is unclear if it is the best measure of the disorder but it remains the one most commonly used.[1] Mandibular advancement appliances (MAA) are customized devices, designed to posture the mandible forwards during sleep, and are increasingly being recognized in the management of sleep-disordered breathing (SDB).[2]

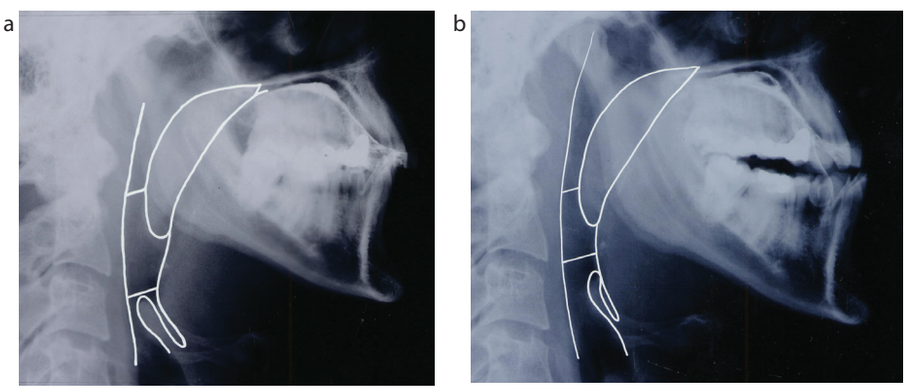

Figure 1. (a) Lateral videofluoroscopic image showing the antero-posterior dimension of the pharyngeal airway prior to placement of mandibular advancement appliance. **(b)** Lateral videofluoroscopic images showing the antero-posterior dimension of the pharyngeal airway opening following insertion of mandibular advancement appliance.

Rationale for the use of mandibular advancement appliances

It is postulated that the principle mechanism of action of these appliances is:

- Anatomical, which include increased upper airway calibre and decreased upper airway compliance[3-8] (Figure 1). Thus, forward and inferior displacement of the mandible not only acts to increase the size of the pharyngeal airway by drawing the tongue forward through its muscular attachments, but preserves the velopharyngeal airway by stretching the palatoglossal and palatopharyngeal arch, thereby reducing airway collapsibility of the airway.[5,9]
- Physiological. There is some evidence relating to the effect of MAA on upper airway dilatory muscle activity, which may serve to compensate for the reduction in tone, observed during SDB.[10-13]

Guidelines on patient selection

There are two principle sources of current guidelines relating to the use of

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MAA in SDB. The Scottish Intercollegiate Guidelines Network[14] published evidence-based recommendations on the management of obstructive sleep apnoea/hypopnoea syndrome (OSAHS) in adults. The guideline advises the following:

- Intra-oral devices are an appropriate therapy for snorers and for patients with mild OSAHS with normal daytime alertness;
- Intra-oral devices are an appropriate alternative therapy for patients who are unable to tolerate nasally-applied continuous positive airways pressure (n-CPAP).

More recently, The American Academy of Sleep Medicine issued the following recommendations on the use of MAA in SDB:[2]

- Non-apnoeic snoring – fail to respond to OR not appropriate for weight loss or positional changes;
- Mild to moderate OSA – in which patients express preference for MAA; intolerant of OR, refuse n-CPAP;
- Severe OSA – these patients must always undergo a n-CPAP trial and, only if they are found to be intolerant of OR or refuse it, should they be offered a MAA. Furthermore, MAA should be offered to patients who are not suitable candidates for surgery.

Thus, it would appear that the MAA plays a very central role in the management of SDB, either as a primary or secondary treatment choice.

Design features

There is considerable variation in the design of MAA, but all posture the mandible forwards, to a varying extent, with a degree of vertical opening. They may be prefabricated or custom-made using a soft or hard plastic and as a one- or two-piece design. Despite the wide variety of appliances described in the literature, most study groups have been small and, as such, there are limited guidelines available in relation to the optimal design features important to their success.[15] The author, based on the available literature, recommended adhering to the following considerations.

Good retention

It is vitally important to ensure that any MAA is retained well by the dentition, in order to prevent disengagement during sleep and consequent loss of the forward mandibular posture. Millman *et al*,[16] reported that a minimum of six teeth were required in each arch, with at least one posterior tooth in each quadrant, in order to provide adequate retention for a MAA.

Sufficient protrusion to maintain airway patency

There is controversy in the literature with respect to the degree of advancement needed to open the airway effectively. Advancement has been reported in absolute millimetre terms[16] and as a percentage of the patient's maximum protrusion.[17,18] Ferguson *et* al,[19] reported that subjects posturing 50% of their maximal protrusion increased the cross-sectional area of the upper airway by 33%, whilst maximum protrusion resulted in almost a doubling of the cross-sectional area. However, it must be noted that the degree of mandibular protrusion attainable will inevitably vary from individual to individual and, as such, one should aim to achieve the maximum comfortable protrusion.[15] In this regard, a MAA that allows incremental advancement offers clear advantages, for example the Medical Dental Sleep Appliance.[20] Gao *et al*[7] and Tsuiki *et al*[8] have demonstrated the benefit of progressive advancement of the mandible in order to determine the most effective position to treat SDB.

Minimal vertical opening

A MAA which promotes mandibular opening results in a downward and backward rotation of the mandible with concomitant posterior movement of the tongue and soft palate (Figure 2). In turn, this can lead to further narrowing of the pharyngeal airway, thus negating any benefits from protrusion.[21,22].

Full occlusal coverage

This is desirable in order to minimize unwanted tooth movements occurring, as a direct consequence of MAA treatment, such as changes in the occlusion resulting from over-eruption of unopposed teeth and potential occlusal disharmony.

The use of a MAA

This is not appropriate in subjects with epilepsy, as it could potentially obstruct the airway if it were to become dislodged during a nocturnal seizure.

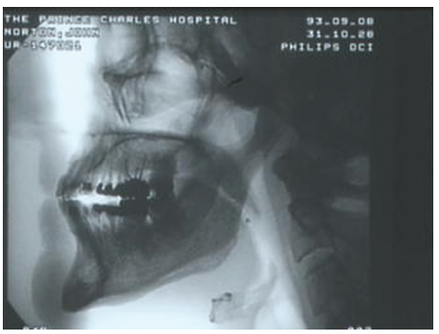

Figure 2. Lateral cephalometric images demonstrating the potentially adverse effect on the pharyngeal airway as a result of excessive vertical opening. The yellow lines demarcating retro-palatal and –lingual airway dimension can be seen to reduce when mouth opening is excessive.

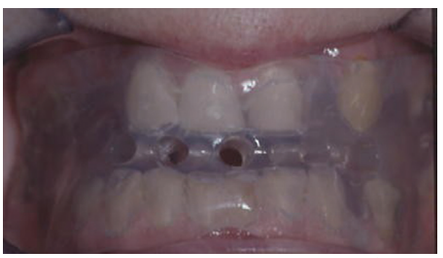

Figure 3. First generation vacuum-formed mandibular advancement appliance.

Currently available appliances

The currently available appliances could be broadly classified in to three types, based on a succession of design modifications, which importantly permit incremental advancement of the mandible.

First generation

These were primarily one-piece in design, with no ability to advance the mandible incrementally without a new appliance being fabricated (Figure 3).

Second generation.

This type of appliance was principally two-piece in design and offered the potential for incremental advancement (Figure 4). However, this would often necessitate laboratory support and was potentially more time-consuming at the chair-side.

Third generation

These appliances may be regarded as the 'gold standard' in design. They not only

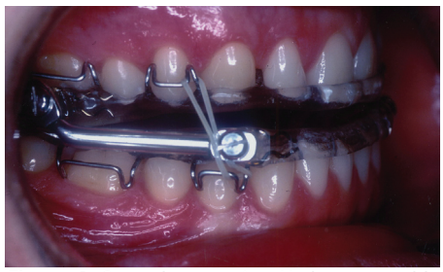

Figure 4. Second generation Herbst removable mandibular advancement appliance.

permit incremental advancement, which is self-adjustable, but also lateral movement of the mandible and ensure that the mandible is retained in its postured state during sleep (Figure 5).

Clinical evidence of success

The majority of investigations have been designed to evaluate the role of MAA in the management of OSA, rather than non-apnoeic snoring. This may be explained by the fact that OSA is potentially associated with high morbidity, in which treatment outcome can be assessed objectively using an overnight sleep study. Johnston *et al*[23] is the only randomized, placebo-controlled trial designed to assess clinical effectiveness in non-apnoeic snorers. They demonstrated the mandibular advancement appliance to be significantly more effective than a single arch placebo in reducing the frequency and loudness of snoring.

A recent Cochrane review evaluated randomized trials comparing oral appliances with control appliances or other treatments in adults with OSA.[24] A total of 13 trials involving 553 subjects were included. The review found that, whilst there was some evidence that these appliances improved subjective sleepiness and SDB compared with a placebo, they were less effective when compared with n-CPAP. The authors concluded that, based on the lack of definite evidence on their effectiveness, the use of oral appliances should be restricted to OSA subjects unwilling or unable to cope with n-CPAP. However, the review found shortcomings in all the studies evaluated, such as small sample size, a lack of blinding and under-reporting of methods and data. In a subsequent randomized crossover trial involving 80 patients with mild to moderate OSA, undertaken by Barnes *et al*[20], MAA were found to be subjectively as effective as n-CPAP. However, objectively n-CPAP performed superiorly.

Thus, based on the available literature, The American Academy of Sleep Medicine (AASM) issued the most recent recommendations on the use of MAA,[2] supporting their use primarily in patients with non-apnoeic snoring and mild to moderate OSA. There still, however, remains a need for larger studies as well as data on the long-term efficacy of MAA therapy.

Treatment objectives and follow-up

The overall treatment objectives, as described in the American Sleep Disorders Association[25] report on practice parameters for the treatment of snoring and OSA with oral appliances include:

- To reduce the snoring to a subjectively acceptable level for patients with primary snoring without features of OSA or upper-airway resistance syndrome (respiratory effort-related arousals).
- The resolution of clinical signs and symptoms, with normalization of the apnoea-hypopnoea index (AHI; number of abnormal respiratory breathing events per hour of sleep) and oxyhaemoglobin saturation in patients with OSA.

A number of subjective scales of measurement are available to measure changes in daytime sleepiness[26] and partner-recorded snoring levels,[23,27,28] in order to monitor treatment effect. It is important that OSA patients treated with MAA undergo a follow-up overnight sleep study with their appliance *in situ*, to ensure that normalization of the AHI and oxyhaemoglobin saturation takes place.

Disadvantages of treatment

It is important to note that MAA, like n-CPAP, does not provide a cure for SDB conditions and, as such, will need to be used long term, requiring periodic adjustment, repair or replacement. Little is known about long term compliance but short term reports on compliance range from 50–100%.[29] Menn *et* al,[30] reported 70% compliance after 3.4 years of use.

Short-term side-effects are common and include discomfort in the muscles of mastication, excessive salivation, dry mouth and abnormalities of the bite on awakening.[3,4,17] These effects appear to be transient and tend to resolve with regular wear.[3] Millman *et al*[16] found that careful adjustment and avoiding over protrusion of the mandible minimized these side-effects.

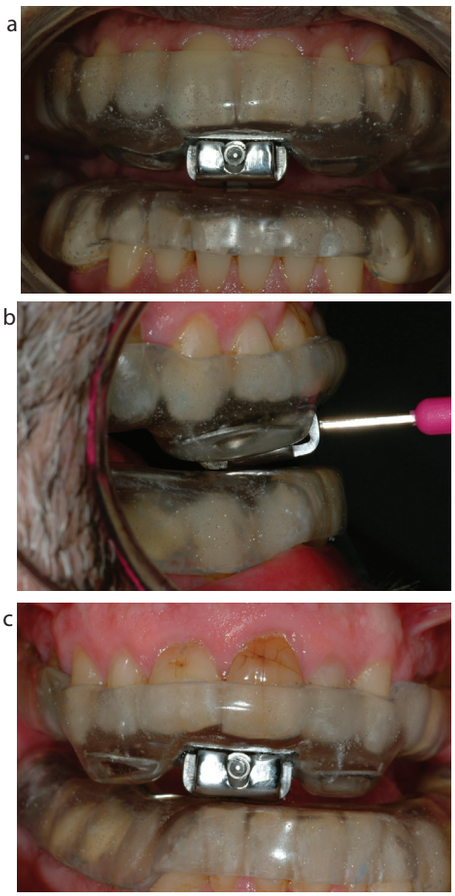

Figure 5. **(a)** Third generation Medical Dental Sleep Appliance. **(b)** Self-adjustment antero-posteriorly in an incremental manner and **(c)** Right and left lateral movement.

Later complications, which may preclude the use of a MAA, include temporomandibular joint (TMJ) discomfort and the risk of skeletal and dentoalveolar changes. Clark *et al,*[31] reported 3 out of 24 OSA subjects treated with a MAS developed TMJ problems, which resolved following appliance withdrawal. The literature is conclusive in reporting that MAA wear does not produce changes in the craniofacial skeleton or TMJ.[32-34] However, de Almeida *et al*,[35] in their cephalometric follow-up (mean period 7.3 ± 2.1 years) of 71 patients with SBD, reported the following tooth movements to be induced:

- Retroclination of the upper incisors (3.5 degrees);
- Proclination of lower incisors (6.6 degrees);

Tipping of the maxillary (2 degrees) and mandibular (3.4 degrees) molars.

These authors also reported the following occlusal changes:

- Reduction of overjet (up to 2.5 mm) and overbite (up to 3mm);
- Downward rotation of the mandible (1 degree);
- Increase in lower face height (1.8 mm);

No significant difference in chin position, relative to the cranium or mandibular length.

de Almeida *et al*[34] also noted an increase in vertical airway length (1.8 mm) and tongue cross-sectional area. Furthermore, both de Almeida *et al*[35] and Marklund[36] have reported on long term study model analysis (mean 7.4 ± 2.2 and 5.4 ± 0.8 years, respectively). Marklund,[36] in her prospective and longitudinal study of 155 patients treated for snoring and OSA, reported median reductions of 0.6 mm in both overjet and overbite only. However, de Almeida *et al*,[35] reported more significant change: overjet and overbite reduced by ≤ 1.2 mm and ≤ 2 mm, respectively. They further demonstrated the maxilla to be stable, whilst the mandible showed reductions in arch width and length. In view of the long term nature of this form of treatment and the potential for undesirable tooth movements to take place, patients should be followed-up long term. It should, however, be noted that, whilst informed consent is ascertained, highlighting the potential of tooth movement, the benefits of providing this relatively simple form of treatment for a potentially life-threatening condition, such as OSA, may well outweigh the 'risks'.

Conclusion

Mandibular advancement appliances offer a clinically effective treatment to patients with simple (non-apnoeic) snoring and mild to moderate obstructive sleep apnoea. Dentists therefore have a vital role to play in management. Accurate diagnosis of the sleep-disordered breathing condition is required prior to treatment. Patients with obstructive sleep apnoea should undergo a follow-up sleep study with their appliance in position and also require long term follow-up.

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