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Research article

Maxillomandibular advancement in edentulous patients as a treatment option for obstructive sleep apnea: report of two cases and a proposed treatment protocol

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ABSTRACT

Obstructive sleep apnea (OSA) is a common disease that often causes debilitating symptoms. In its most severe form, OSA increases the risk of cardiovascular disease and mortality. OSA is characterized by repeated episodes of pharyngeal collapse leading to airway obstruction. The treatment options available in severe cases are limited to continuous positive airway pressure ventilation and maxillomandibular advancement (MMA). OSA is particularly difficult to treat successfully in edentulous patients. Two cases are presented here to illustrate use of MMA in edentulous patients with OSA. Our learning points based on these cases are shared, and a treatment and follow-up protocol is proposed for this specific patient group.

1. Introduction

Obstructive sleep apnea (OSA) is characterized by repeated episodes of obstruction of the upper airway during sleep [1]. In this disease, pharyngeal collapse causes airway obstruction that often produces symptoms, including snoring, daytime sleepiness, fatigue, lack of concentration, disturbed mood, and an increased risk of motor vehicle accidents [2, 3]. Furthermore, OSA is associated with hypertension, myocardial infarction, and stroke [4]. These associations result in a deterioration of quality of life and a decreased life expectancy. Therefore, treatment may be indicated even if symptoms are absent.

Symptoms of OSA are subjectively assessed using the Epworth Sleepiness Scale and Fatigue Severity Scale questionnaires. The severity of the disease is assessed objectively using polysomnography (PSG) and defined using the apnea-hypopnea index (AHI). The AHI represents the degree of disturbed breathing per hour during sleep. An AHI of 5–15/h represents mild OSA, an AHI of 15–30/h indicates moderate OSA, and an AHI >30/h represents severe OSA. Mild OSA is believed to be present in 25% of the adult population and moderate to severe OSA in 10% [5]. The mortality in patients with untreated severe OSA approaches 30% at 15 years [5].

The most commonly used non-surgical treatment options for OSA are a mandibular advancement device (MAD) and continuous positive airway pressure (CPAP). A MAD is an intra-oral appliance that moves the mandible forward, thereby increasing airway diameter and patency. CPAP involves wearing a mask that increases airway pressure, thereby preserving airway patency. However, these non-surgical treatment options are not always successful. For example, some patients do not

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tolerate CPAP because the treatment-related burden is too high [6]. Nonadherent patients have a 10% greater risk of mortality at 5 years than adherent patients [7].

Surgical treatment of severe OSA can thus be considered in patients who do not tolerate CPAP. In 1978, J.H. Priest introduced mandibular advancement as an alternative treatment for airway obstruction at the 60th Annual Meeting of the American Association of Oral and Maxillofacial Surgeons in Chicago. Subsequently, several studies reported improvement of PSG parameters in patients treated by bilateral sagittal split osteotomy (BSSO) advancement [8, 9]. Combination with MMA proved more successful than advancement with BSSO alone [10]. By advancing the maxilla (up to 10 mm), the velum and velopharyngeal muscles are moved forward [11]. Simultaneously advancing the mandible results in advancement of the tongue muscles/ligaments and suprahyoid muscles [12]. Movement of these structures expands the upper airway, thereby preventing collapse of the pharyngeal wall and enabling continued breathing during sleep [13, 14]. Therefore, MMA is preferred nowadays for the surgical treatment of OSA and has success (50% reduction of AHI) and cure (AHI <5/h) rates of 86% and 43%, respectively [15].

Treatment of OSA using MMA is more complex in edentulous patients than in their dentate counterparts. Nevertheless, MMA may be the best treatment option for an edentulous patient who has not tolerated CPAP and is not able to use a MAD. Findings of an absence of an occlusal reference and presence of thin atrophied bone with little space for fixation of bone segments (because of limited bony overlap) is challenging, even for experienced surgeons.

We have developed a well-defined protocol for the treatment of edentulous patients with OSA. Two cases are presented here to illustrate the benefits of MMA as a treatment option in edentulous patients.

2. Case presentation

Consent was gathered from the patients investigated in this study.

2.1. Case 1

A 62-year-old man was referred to our Department of Oral and Maxillofacial Surgery with severe OSA (AHI 46/h, oxygen desaturation index [ODI] 45/h). He had a body mass index of 31.1 (height, 1.83 m; weight, 100.5 kg) and a medical history of high cholesterol, hypertension, and type 2 diabetes mellitus (including two episodes of ketoacidosis) that was difficult to control despite treatment with insulin.

The patient's main complaints were snoring, tiredness, and hypersomnolence for several years. His Epworth Sleepiness Scale score was 19 and his Fatigue Severity Scale score was 46. Dietary advice was provided but did not result in substantial weight loss. CPAP was proposed as the first line of treatment but was not tolerated by the patient.

Clinical examination revealed severe maxillary and mandibular hypoplasia. The patient had an edentulous upper jaw and an atrophic lower jaw with only four isolated front teeth remaining. A Class II relationship with a large overjet was present (Figure 1). Radiologic examination confirmed mandibular and maxillary hypoplasia and atrophy of both jaws.

Drug-induced sleep endoscopy (DISE) was performed in the ENT department to analyze the level of obstruction/collapse in the airway. Obstruction was observed at the level of the tongue base, the soft palate, and the lateral oropharynx. Chin-lift during DISE resulted in a wider and more patent airway.

After multidisciplinary deliberations between a somnologist/pulmonologist, ENT specialist, maxillofacial surgeon, and dentist, the following treatment plan was devised:

- Removal of the remaining isolated teeth
- Conventional prostheses in the upper and lower jaws
- Two interforaminal endo-osseous implants in the lower jaw

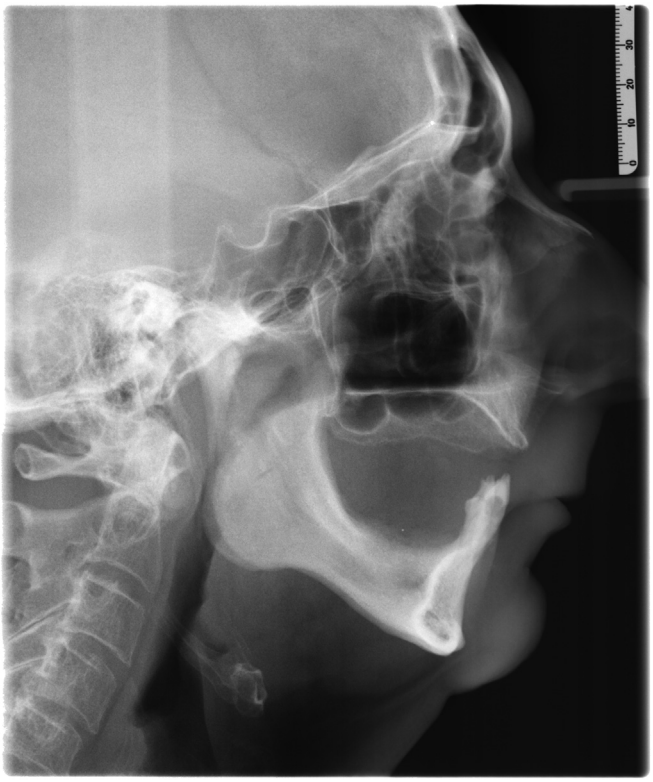

Figure 1. Preoperative lateral cephalogram from a retrognathic patient with obstructive sleep apnea showing a severely atrophied maxilla and mandible.

- MMA and genioplasty (chin advancement surgery)
- Removal of osteosynthesis material approximately 6 months later.

The patient consented to the treatment plan. First, the remaining isolated teeth were removed by a maxillofacial surgeon (GM). In collaboration with a specialized dentist (PM), two endo-osseous implants (standard regular neck, width 4.1 mm, length 12 mm; Straumann, Basel, Switzerland) were placed interforaminally for fixation of the prostheses. The prostheses were set in Class II occlusion (because of the severe mandibular hypoplasia) with the possibility of advancing the mandible to class I occlusion. The upper prosthesis and lower prosthesis each contained four small hooks that could be used for intermaxillary fixation during bimaxillary surgery.

The surgical procedure was performed 6 months after placement of the implants. First, the edge of the prosthesis was trimmed to create access for the incision and sutures. The upper prosthesis was not fixed to the maxilla at this time because it was anticipated that a Rowe disimpaction forceps would be used and that there would be a possibility of fracture of the prosthesis. A Le Fort I osteotomy was performed as previously described [16]. During mobilization and advancement of the maxilla, the patient developed bradycardia that resolved after administration of intravenous atropine and reduction of the maxillary advancement. Bradycardia occurred repeatedly as a result of the trigeminocardiac reflex (TCR) during advancement of the maxilla. The maximum possible maxillary advancement with normal cardiac rhythm was 6 mm. Fixation was performed using four 2.0-mm plates (KLS Martin, Huizen, The Netherlands). Some difficulties were experienced when fixing the maxilla because of the thin atrophied bone, but rigid fixation was eventually achieved.

Subsequently, the upper prosthesis was fixed on both sides of the hard palate using two 2.0-mm screws. BSSO was performed using the splitter-separator technique [17, 18]. After successful splitting of the mandibular ramus on both sides, the medial pterygoid muscles at the inferior border of the mandible were released to allow mandibular advancement.

However, difficulties in mobilization and advancement of the mandible were encountered. Therefore, a single hook was inserted in the chin region to stretch the soft tissues. The lower prosthesis was placed on the implant construction and fixed with perimandibular wires. Mandibulomaxillary fixation (MMF) was performed for Class I occlusion and the mandible was placed within the planned occlusion. Rigid fixation was performed on both sides using two monocortical plates and two bicortical screws (KLS Martin). During fixation, the prosthesis in the upper jaw became loose, so was refixed with four screws in the palatal bone (two laterally, one in the middle of the pre-maxilla, and one dorsally). The surgeon decided not to perform genioplasty in the same session because of the compromised vascularity of the atrophic mandible and the difficulty of plate fixation in a patient with such fragile maxillary bone.

Postoperatively, the patient was admitted to the intensive care unit (ICU) for observation overnight and transferred to the day care unit on the following day. The patient experienced some feeding difficulties immediately following his surgery, so a dietician was consulted to optimize food intake. Four days after surgery, the patient developed tachypnea with an elevated glucose level of 25 mmol/L. Diabetic ketoacidosis with respiratory insufficiency was diagnosed, so the patient was transferred back to the ICU for infusion of sodium chloride (0.9%), intravenous insulin, and sodium bicarbonate. The patient's condition stabilized rapidly and his blood glucose levels normalized. The patient was admitted for a total of 6 days and was discharged in good condition.

During follow-up, the patient showed a 2-mm midline shift of the maxilla to the right. Occlusion with the prosthesis showed a small residual overjet and a small vertical open bite. Four weeks postoperatively, the screws in the maxillary prosthesis and the perimandibular wires were removed. Sensation in the lower lip on both sides was compromised directly after surgery but had returned to normal by 3 months postoperatively. A minor retrognathic mandibular appearance was noticed after surgery.

PSG performed 4 months after surgery revealed an AHI of 20/h and an ODI of 19/h. The patient's complaints of daily fatigue and sleepiness decreased during the postoperative months. This outcome was defined as surgical success, albeit characterized by an incomplete remission of OSA.

Chin advancement was considered in view of the incomplete remission of OSA and the patient's persistent retrognathic appearance. Furthermore, the patient had developed a fistula in response to infected osteosynthesis material in the lower jaw. Therefore, genioplasty and removal of the miniplates was performed 5 months after MMA. The chin osteotomy was performed intra-orally. After a submucosal and periosteal incision, the planned osteotomy was marked with a bur and finished bicortically with a saw. Special care was taken to saw the implants caudally whilst still including the mental spina. Dorsally in the inferior border of the mandible, the osteotomy ended under the mental foramen. A chin advancement of 10 mm was achieved. Fixation was performed using a chin plate and two additional plates (KLS Martin; Figure 2).

The patient recovered well and was discharged on the day following surgery. One month postoperatively, he had almost normal sensation in his lower lip with uneventful healing of the chin and plate removal sites.

Four months after the second surgical procedure, PSG revealed an AHI of 16/h and an ODI of 12/h, mostly in the supine position (63% with an AHI of 23/h) and in the side position with an AHI of 6/h.

2.2. Case 2

The patient was a 31-year old man diagnosed with severe OSA (AHI 90/h, ODI 88/h). He had a body mass index of 29.1 (height, 1.89 m; weight, 104 kg) and a medical history of 15 pack-years of smoking, asthma, tonsillectomy, and turbinectomy, but was not on medication. His main complaints were daily sleepiness and fatigue. His Epworth Sleepiness Scale score was 17 and his Fatigue Severity Scale score was 53. He was a truck driver and had been required to stop driving because of his severe OSA. CPAP was proposed as the treatment of first choice but was not tolerated.

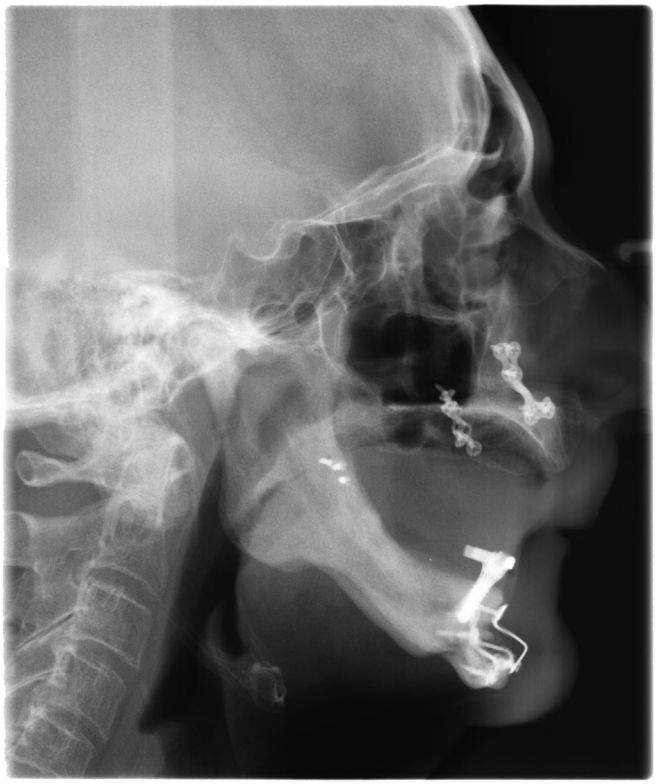

Figure 2. Postoperative lateral cephalogram of an edentulous patient with obstructive sleep apnea after maxillomandibular advancement and secondary chin advancement combined with removal of the mandibular miniplate osteosynthesis material.

Maxillofacial examination revealed severe maxillary and mandibular hypoplasia. The patient had an atrophic edentulous mandible in a Class II relationship with the edentulous maxilla (and a Class II occlusion of his prosthesis). Radiologic examination showed an edentulous mildly atrophic maxilla and mandible.

DISE performed in the ENT department showed an obstruction at the level of the hypopharynx and mild tongue-tonsil hypertrophy. Chin-lift during DISE resulted in a wider airway.

Given that the patient was a truck driver and unable to work because of his severe OSA, work-up for surgical treatment was planned immediately. After multidisciplinary deliberations, the treatment plan consisted of the following:

- MMA surgery
- Two interforaminal endo-osseous implants in the lower jaw after MMA
- A new mandibular prosthesis.

The patient consented to the treatment plan. Two days before surgery, the patient's prostheses were sent to a technician who created four hooks in the prosthesis for intraoperative MMF (Figure 3). During surgery, the upper and lower prostheses were first trimmed to ensure adequate access for the incisions. The upper prosthesis was fixed with four palatal screws immediately (Figure 4). A Le Fort I procedure was performed as previously described [16]. A maxillary advancement of 10 mm was planned and achieved. Subsequently, the lower prosthesis was fixed with perimandibular wires and four screws. Placement of screws was possible in the relatively high mandible with a low position of the mandibular canal. Next, BSSO was performed as described previously [17, 18]. After BSSO, MMF was performed using the hooks in the fixed prostheses. Difficulties were expected with MMF, so an extra screw was placed in the mandibular

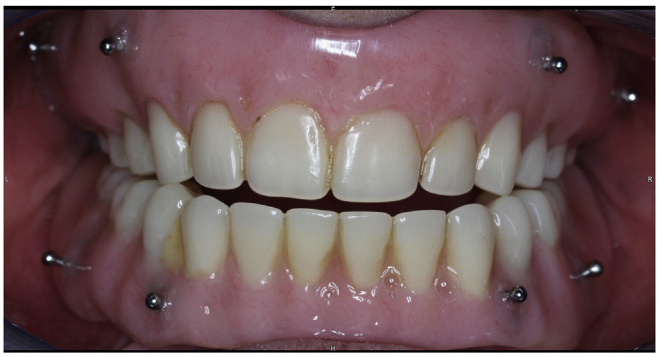

Figure 3. Photograph of upper and lower prostheses with hooks to allow for maxillomandibular fixation.

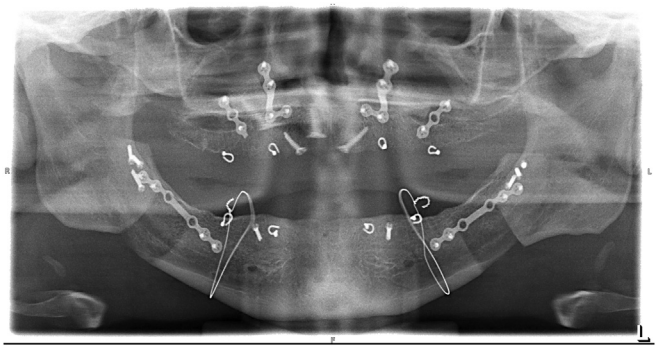

Figure 5. Panoramic radiograph of an edentulous patient with obstructive sleep apnea after maxillomandibular advancement surgery.

symphysis and paranasal wires were placed to allow sufficient MMF with the prosthesis. The mandible was fixed with one monocortical plate and two transbuccally positioned bicortical screws on each side (Figure 5).

Postoperatively, the patient was admitted to the ICU for overnight observation and was transferred to the day care unit on the following day. No postoperative complications were noted and the patient was discharged from hospital after 5 days.

Follow-up showed an absence of snoring and apneas (reported by the patient's partner). The patient reported no daytime sleepiness or fatigue. A Class I profile with stable Class I occlusion was achieved with the new prosthesis. Mild deviation of the nasal septum was observed but without any clinical complaints. Sensation of the lower lip on both sides was compromised directly after surgery but was normal 2 months post-operatively. After 3 months, the perimandibular wires and fixation screws were removed from the prostheses in the maxilla and mandible.

PSG performed 3 months after surgery showed mild apneas and hypopneas with an AHI of 7/h and an ODI of 17/h. This outcome was defined as surgical success.

2.3. Treatment protocol

Based on our clinical experience, we have established the following protocol for MMA in edentulous patients with severe OSA:

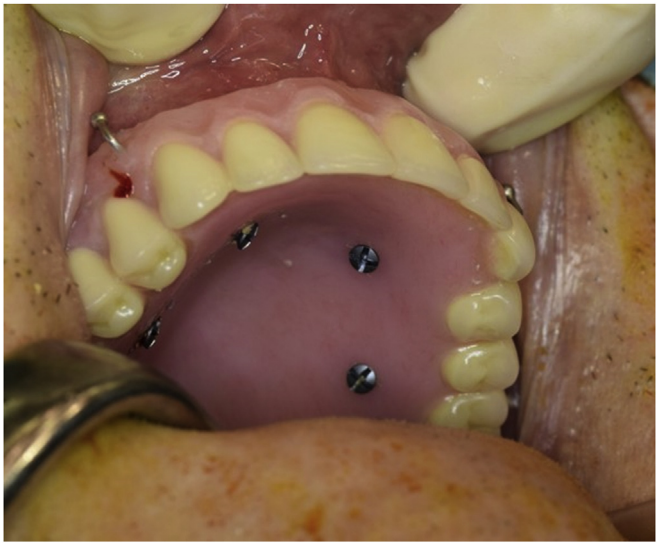

Figure 4. Intraoperative photograph of de upper prosthesis with the fixation with 4 titanium screws into the maxilla.

1. Multidisciplinary assessment of OSA, including PSG and DISE with chin-lift
2. Maxillofacial analysis, consisting of evaluation of the remaining teeth/prostheses, maxillomandibular relationship, patient profile, and possible relationship with the upper airway
3. Radiologic examination for treatment planning, diagnosis of possible pathology, and assessment of the feasibility of implant placement
4. Placement of two interforaminal mandibular endo-osseous dental implants at least 6 months before MMA (if possible)
5. Placement of four hooks in the upper and lower prostheses several days before surgery to allow intraoperative MMF
6. MMA surgery as follows:
   - Preoperative consultation with the anesthesiologist regarding possible TCR.
   - Trimming of the prostheses to allow space for the incisions and sutures.
   - Fixation of the maxillary prosthesis with four bicortical screws in the palatal bone (Figure 4), and if necessary, paranasal wires.
   - Le Fort I osteotomy with advancement of the maxilla up to 10 mm (depending on the patient's profile).
   - Rigid fixation of the maxilla with four 2.0-mm monocortical titanium plates and screws.
   - BSSO with a vertical bur-cut that allows for sufficient horizontal bony overlap.
   - Fixation of the mandibular prosthesis with perimandibular wires or bicortical screws, and if necessary, an additional screw in the mandibular symphysis.
   - Advancement of the mandible by at least 10 mm (depending on the position of the maxilla), including release of the pterygoid muscle at the inferior border of the mandible.
   - Intermaxillary fixation using the hooks in the prostheses and/or screw in the mandibular symphysis and para-nasal wires.
   - Rigid fixation of the mandible with one 2.0-mm monocortical plate and two bicortical screws on each side.
7. Chin advancement concomitant with MMA surgery (in cases with less severe atrophy and if esthetically desirable)
8. Postoperative admission to the ICU for observation for at least one night, and subsequent admission to the day care unit for several days
9. Removal of the prosthesis with removal of perimandibular/para-nasal wires and mandibular/maxillary screws after 6–12 weeks
10. Postoperative PSG not earlier than 3 months after MMA
11. If not performed preoperatively, consider postoperative implant placement 3–4 months after MMA
12. If not performed during surgery, consider a secondary chin osteotomy 3–6 months after MMA (in cases with incomplete remission)
13. New full prosthesis 6 months after the final surgery.

3. Discussion

Here we have proposed a treatment protocol to help surgeons facing the challenging task of treating CPAP-resistant OSA in edentulous patients. The two cases described in this report show that MMA combined with implant placement and prosthetic rehabilitation can successfully treat OSA in this specific patient group. However because of the small sample size and the nature of a case report one should be careful to interpret these conclusions.

Patients must be motivated to pursue conservative treatment, including weight loss, before surgery is considered. CPAP is the gold standard treatment for severe OSA, given that it is predictable and non-invasive. However, patient compliance with CPAP can be low, leading to limited clinical effectiveness. Furthermore, some patients are genuinely intolerant of CPAP and need alternative treatment.

Treatment with an oral device, such as a MAD, can be successful in patients with mild OSA but seem to be less effective in patients with moderate to severe OSA and impossible for edentoulous patients without implants [19]. If DISE and/or maxillofacial analysis indicate a possible beneficial effect of MMA, bimaxillary advancement surgery may be indicated. DISE provides important information about the level of obstruction and the possibility of counterclockwise rotation of the maxillomandibular complex; however, it could be very difficult to proceed without wafers in cases with atrophy. If there is sufficient time available, implant placement in the lower jaw should be performed 6 months before surgery to enhance fixation of the mandibular prosthesis, because of missing forward retention. If direct treatment is necessary and correct fixation of the prosthesis is possible with screws, implant placement can be performed postoperatively. Additional chin advancement during MMA should be considered in mildly atrophied jaws. However, in patients with severe jaw atrophy, chin advancement (when indicated) can be performed 3–6 months after MMA, possible combined with removal of the osteosynthesis material. Additional OSA therapies, including a MAD or sleep position trainer, can be considered if necessary.

MMA is a very effective treatment for OSA and was reported in a systematic review to have a surgical success rate of 86% and an overall cure rate of 43.2% [15]. The cure rate increased to 66.7% in patients with a preoperative AHI <30/h. Success was defined as a 50% reduction of AHI, resulting in an AHI <20/h, and cure was defined as an AHI <5/h. A low major surgical complication rate of 1.0% was documented, along with a minor complication rate of 3.1%, no deaths, persistent paresthesias in 14.2% of cases, and a (mild) malocclusion rate of 44%. Most patients were satisfied with the surgical outcome, although some did have esthetic complaints [15].

The degree of maxillary advancement is a clear predictor of successful surgical treatment of OSA by MMA. Maxillary advancement increases nasopharyngeal and hypopharyngeal spaces by forward tension of the velum and velopharyngeal muscles [11]. The recommended advancement of the maxillomandibular complex for treatment of OSA is 10 mm [15]. In the first case presented here, the maximum maxillary advancement was 6 mm because of perioperative bradycardia. This could explain the incomplete remission and AHI of 16/h in this patient.

The general medical condition of patients with OSA undergoing MMA is different from that in their counterparts without OSA. Patients with OSA are a high-risk group for surgery and require multidisciplinary collaboration. This high risk is attributable to not only OSA but also potential comorbidities. Many patients with OSA are obese and have associated conditions, e.g., diabetes mellitus, hypertension, cardiac pathology, and pulmonary pathology, for which they are on polypharmacy. Therefore, specific perioperative care is required. In our opinion, these patients should be monitored postoperatively in an ICU setting for at least one day and remain under close clinical follow-up after transfer to the day care unit. The first patient described in this report underscores the need for close clinical follow-up. Dietary advice may be necessary in hospital and should be reiterated during follow-up.

MMA surgery may be less straightforward in edentulous patients. Reduced vascularization and atrophy of the maxilla and mandible could increase the risk of complications, e.g., unfavorable splits in the mandible or a complicated down-fracture of the maxilla. Fixation can be particularly complicated in the maxilla because of thin atrophic bone. Gregg et al. described poor bone healing and more foreign body reactions in patients with OSA undergoing MMA [20]. This higher risk of infection and malunion may reflect the generally older age of the patients and the relatively large amount of advancement.

The bradycardia that occurred in case 1 was a result of a TCR. This intraoperative complication may be more common in patients with OSA because of major advancement of the maxilla. Surgery near the cranial nerves, especially the trigeminal nerve, might stimulate the vagal nerve, which could lead to activation of the parasympathetic system, resulting in various types of dysrhythmia [21]. Manipulation of the nerve, or even the adjacent tissue, could trigger this reflex [22]. One should be aware of this intraoperative complication and collaborate closely with the anesthesiologist during the procedure. In case 1, a TCR prevented the planned maxillary advancement of 10 mm and resulted in a maximum possible advancement of 6 mm. However, a TCR is depending on the advancement of the maxilla, it is not possible to predict this reflex in advance. So during surgery, the surgeon should be able the adjust the plan if needed, and possible reduce the amount of advancement by titration, in close collaboration with the anesthesiologist.

The preoperative planning in complex cases of OSA should be patient-specific. The absence of occluding teeth results in the need for an adjusted prosthesis instead of wafers to secure correct intraoperative occlusion. Subsequent steps need to be taken to obtain stable preoperative occlusion (before MMA) that can be adjusted to favorable postoperative occlusion (after MMA) with the help of a specialized dentist.

In case 1, The use of dental implants in combination with perimandibular wires created more stability for the lower prosthesis, which improves the stability of the intermaxillary fixation. In this case implant placement was performed before MMA surgery. This method is predictable but time-consuming because the implants need to be placed 6 months before surgery.

In case 2, a short preoperative procedure was chosen because the patient was a truck driver who was not able to perform his job because of OSA. The existing conventional prostheses were fixed in the atrophic maxilla with screws and in the less atrophic mandible with perimandibular wires combined with screw fixation. Sencimen et al. described the use of arch bars bonded to the acrylic resin denture in their publication. They described the management of obstructive sleep apnea by MMA surgery in a patient with total edentulism of the upper and partial edentulism of the lower arches [23]. The stability of intermaxillary fixation during surgery might be improved by using the described arch bars instead of the 4 hooks used in the present study. Although the fixation could be labeled as sufficient, because during fixation in the first case, the prosthesis in the upper jaw became loose, and had to be refixed with four extra screws in the palatal bone.

During MMA surgery, the wall of the prosthesis needs to be trimmed thoroughly to allow for the incisions and to provide enough visibility during surgery. This (and possible implant placement afterwards) necessitates a new prosthesis postoperatively. Concomitant with these new prostheses, the occlusion and a possible midline shift or open bite could be easily resolved. Good cooperation with a specialized dentist is important for achievement of optimal occlusion. The actual timing of implant placement, manufacturing a new prosthesis, and removal of osteosynthesis material is somewhat arbitrary. However, an adequate amount of time should be allowed for healing of the bony segments and implants (i.e., at least 6 months).

Removal of osteosynthesis material could be necessary, given that the plates often interfere with a correct fit of the prosthesis in severely atrophic cases. As described in case 1, chin advancement concomitant with removal of osteosynthesis material can be planned. If the profile permits an extra advancement of the chin and the AHI remains >5/h,

Table 1. Learning points for maxillomandibular advancement surgery in edentulous patients with obstructive sleep apnea.

Learning points
General
- Patients with OSA are not 'regular' orthognathic patients; orthognathic treatment is often more difficult in these typically older patients, who are more likely to have comorbidities and large advancements
Preoperatively
- Make four hooks in each prosthesis for maxillomandibular fixation
- Include flexible occlusion in the prostheses to allow maxillomandibular advancement
- Plan one night of observation in the intensive care unit and a 5-day admission
Intraoperatively
- Ensure sufficient trimming of the prostheses to allow access for the incisions and sutures
- Fix the upper prosthesis with at least four screws in the hard palate before Le Fort I surgery to ensure correct positioning in the midline; care is needed using the Rowe disimpaction forceps with the prosthesis fixed on the maxilla
- Fix the lower prosthesis with perimandibular wires
- Consult the anesthesiologist before mobilizing and advancing the maxilla, and be aware of the possibility of a trigeminocardiac reflex
- Consider extra screws and paranasal wires for adequate stabilization of maxillomandibular fixation
- Be aware of thin atrophied maxillary bone and possible difficulties regarding fixation of the maxilla
- Apply rigid fixation in the mandible with 2.0-mm plates combined with bicortical screws
- Plan removal of osteosynthesis material in severely atrophied jaws
Postoperatively
- Ensure adequate dietary intake, pain control, and treat specific risks associated with comorbidity (e.g., diabetes)
- Be aware of more severe eating difficulties because of a large advancement of the jaws

additional chin osteotomy with genioglossal advancement should be considered. PSG is necessary to assess the need for this additional procedure. When in doubt during surgery, the authors advise delayed chin advancement over direct chin advancement.

In conclusion, CPAP-resistant severe OSA is a challenge in edentulous patients but can be successfully treated with MMA. Special care is advised when deciding on the MMA treatment plan preoperatively along with careful attention to the patient's general medical condition and comorbidities. Here, we have proposed a treatment protocol for MMA as the treatment of choice for OSA in edentulous patients, our learning points are presented in Table 1.

Declarations

Author contribution statement

All authors listed have significantly contributed to the investigation, development and writing of this article.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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