Obstructive Sleep Apnea Treated with Maxillomandibular Advancement Surgery by Computer-Assisted Simulation

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Abstract
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Keywords
Class II malocclusion; Obstructive sleep apnea (OSA); Maxillomandibular advancement (MMA); Virtual surgical simulation.

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CASE REPORT

Obstructive Sleep Apnea Treated with Maxillomandibular Advancement Surgery by Computer-Assisted Simulation

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ABSTRACT

This 23-year-old female patient was diagnosed as a severe type of obstructive sleep apnea (OSA), skeletal Class II jaw relation with mandibular deficiency, hyper divergent facial pattern, dental Class II malocclusion, midline deviation and occlusal plane canting. By the assistance of virtual surgical simulation and maxillomandibular advancement (MMA) approaching, patient was satisfied the improvement of functional and esthetic changes after the 18-months treatment.

Keywords: Class II malocclusion; Obstructive sleep apnea (OSA); Maxillomandibular advancement (MMA); Virtual surgical simulation

1. INTRODUCTION

Obstructive sleep apnea (OSA) is a worldwide disorder, which indicates some part of the upper airway being obstructed during sleep. It might occur in the velopharynx (from the posterior nasal spine to the tip of the uvula), oropharynx (from the tip of the uvula to the tip of the epiglottis) or hypopharynx (from the tip of the epiglottis to the cricoid cartilage) individually or together [1]. The prevalence varies in the literature, with approximately 5–20% in the general adult population [2] and 2.6% in Taiwanese adult [3]. The risk factors of OSA development include obesity, menopause, male gender and aging. The correlations between OSA and craniofacial morphologies like retrognathia, long and narrow faces, narrow and deep palate, steep mandibular plane angle and lower hyoid position were not well established [4].

Several methods could be used to reflect patients’ symptoms in a more efficient way. Examples of screening questionnaires include the Epworth Sleepiness Scale (ESS), the Friedman classification that includes the modified Mallampati (MMP) score, the nasal obstruction symptom evaluation (NOSE) score, and the STOPBang questionnaire. Although the gold standard of diagnostic confirmation for OSA is polysomnography (PSG) by using the applicable result of the apnea-hypopnea index (AHI). According to the International Classification of Sleep Disorders, [5], there are two sets of OSA diagnostic criteria: the first set includes the presence of one clinical symptom and AHI ≥ 5 (events/hour) concurrently; the second set only contains AHI ≥ 15 (events/hour). Furthermore, the AHI can also be used for classifying OSA patients into different categories, including mild (5 ≤ AHI < n15), moderate (15 ≤ AHI < 30) and severe (30 ≤ nAHI). Different categories of the OSA indicates different treatment protocols. Furthermore, by using radiographic images and simulation software programs to calculate the dynamic airflow, determination of the most...
Constricted portion in the complex upper airway is enhanced.

Continuous positive airway pressure (CPAP) is the gold standard treatment for OSA in adults. Although some patients are unable to tolerate wearing the CPAP device, about 46%—83% of OSA patients did not adhere to this treatment [6]. Consequently, maxillomandibular advancement (MMA) could be an alternative and effective treatment option for treating moderately to severely affected OSA patients. Some research even recommends MMA as a gold standard treatment in surgical-orthodontic care for OSA [7]. It is not only beneficial on the function, but improves the facial esthetics as well. With the counterclockwise (CCW) rotation with MMA, more pharyngeal airway space could be created with the changes in airway muscle tension and maximize the anterior position of the hyoid bone [8,9]. However, the complicated surgical procedures have been very difficult to be precisely

Figure 1. A, the pretreatment extraoral and intraoral photographs showing skeletal Class II jaw relation and mandibular retrognathism. B, the pretreatment lateral cephalometric film showing constricted pharyngeal airway. The panoramic film showing the fixed retainer in the previous orthodontic treatment was still bonded, teeth 14, 24, 32, 43 were missing and teeth 18, 28, 38, 48 were impacted.
achieved previously. By recent developments in science and technology, cone-beam computed tomography (CBCT) and simulation software could be used to resolve this challenge more precisely.

The aim of this article is to present the treatment course of an adult severe OSA CASE treated with MMA surgery and orthodontics, where the post-treatment outcome of this patient was greatly improved in both PSG examination and fluid dynamic analysis.

2. CASE REPORT

This is a CASE of a 23 years-old female suffering from an OSA problem. Her body mass index (BMI) was 25.3, a little higher than the average range (18.5–24). Based on the patient’s statement, she had received uvulo-palato-pharyngoplasty (UPPP), nasal laser surgery and orthodontic treatment previously. In the previous orthodontic treatment course, she had had teeth number 14 and 24 extracted to correct large overjet and OSA problems, but unfortunately, her symptoms persisted and were reflected on ESS (13/24) and NOSE (11/20) scores. The polysomnography showed that AHI was 73.1 events/hour and the minimum SpO2 was only 73.1%. Drug-induced sleep endoscopy (DISE) showed lateral pharyngeal wall and tongue base were totally collapsed during sleeping.

By using the cone-beam computerized tomography (CBCT) and computerized fluid dynamic analysis (Soteria DcmRecons, version Alpha v0.7.0; Soteria Biotech Ltd., New Taipei City, Taiwan), the most constricted and highest air pressure in the velopharynx were determined (Figure 6A).

2.1. Clinical examination

The extraoral examination showed that this patient had skeletal Class II jaw relation combined with retrognathic mandible, with lip and occlusal plane canting also observed. The intraoral examination showed bilateral canine and molar were Class II relationship, four 3rd molars were impacted, with overbite and overjet being 1.4 mm and 3.4 mm. Teeth #14, 24, 32 and 42 were missing, impacted, with overbite and overjet being 1.4 mm and 3.4 mm. Teeth #12 and 22 were microdontia and the Bolton ratio in anterior teeth was 86%, which was higher than normal range (Figure 1).

The lateral cephalometric analysis showed a Class II jaw relationship with the ANB angle of 6°. According to McNamara’s analysis, her maxilla and mandible were both retrusive, the A-Nv was −6 mm and B-Nv was −21 mm. In the vertical aspect, the SN-MP was 48.1° and accordingly defined as hyperdivergent facial pattern.

In the dental analyses, both angles of U1-SN and L1-MP were less than normal level, indicating the retrusion of upper and lower incisors. The distance of U1 to NA and L1 to NB were also lower than normal range, indicating the retracted positions of upper and lower incisors.

According to McNamara’s airway analysis, [10], the lower pharyngeal space was 3.5 mm, which is narrower than the average level in adult females of 11–14 mm. This corresponding result of the PSG examination and an obstructive airway was observed (Table 1).

2.2. Diagnosis

1. Skeletal: Class II jaw relation, both jaws are deficient in the anteroposterior aspect, with hyperdivergent facial pattern in the vertical aspect.
2. Dental: Angle’s Class II malocclusion, occlusal plane canting, retroclined and retruded incisors in both arches, higher Bolton’s ratio in anterior teeth.
4. Function: Severe OSA.

2.3. Treatment plan

1. Pre-surgical orthodontic treatment: level the occlusal plane and prepare for surgery.

| Table 1. The cephalometric analysis in pretreatment and post-treatment. |
|---------------------------------|----------------|----------------|
| Skeletal analysis               | Norm           | Initial Finish |
| SNA                             | 79.9–86.3      | 78.5           | 81 |
| SNB                             | 76.6–83.6      | 72.3           | 75 |
| ANB                             | 0.8–5.2        | 6.2            | 6  |
| NAPog                           | −0.6–10        | 10.5           | 12 |
| A-Nv mm                         | −3.8–4.8       | −5.5           | −2.5 |
| B-Nv mm                         | −10.7–3.1      | −20.5          | −15 |
| Pog-Nv mm                       | −10.7–4.3      | −25            | −17 |
| SN-MP                           | 23.8–35        | 48             | 46  |
| PP-MP                           | 16.3–25.9      | 34             | 32  |

| Dental analysis                 |                |                |
| U1 to NA mm                     | 4–8            | 1.8            | 2   |
| U1 to SN                        | 101.9–117.9    | 83             | 83.5|
| L1 to NB mm                     | 4.3–8.9        | 5              | 6   |
| L1 to MP                        | 88.4–102.4     | 86             | 92  |

| Facial analysis                 |                |                |
| U lip to E-line mm              | −3.7–0.1       | −3             | −3.5|
| L lip to E-line mm              | −2.4–1.6       | −2.5           | −4  |
2. **MMA surgery**: By the assistance of virtual simulation, we planned to correct occlusal plane cant with maxilla superior repositioning in varying amounts of anterior impaction. Then, the maxilla would be advanced by 4.5 mm and counterclockwisely rotated, while the mandible was be treated with bilateral sagittal split osteotomy along the occlusal plane of maxillary arch to achieve an ideal interdigitation. In the final step, genioplasty was to be performed to maintain lower facial height, which could be also maintained by CCW rotation of both jaw bones. Lastly, the airway volume must be increased to improve the obstructive condition. All predicted amounts of movements are documented in Figure 2.

3. **Post-surgery orthodontic treatment**: Align the teeth and achieve proper overbite and overjet, then finish the treatment in stable occlusion.

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**Figure 2.** These are the prediction of MMA surgery on the computerized simulating software. A, the amount of superior Le Fort I osteotomy in maxilla, combined with roll-rotation to correct maxillary canting. B, the amount of bilateral sagittal split osteotomy advancement in each side, combined with genioplasty to modify facial profile. C, The difference between the initial and final prediction.
2.4. Treatment progress

The pre-surgery orthodontic treatment was commenced with full-mouth 0.022-inch OPA-K fixed edgewise appliances and .016” NiTi wire to level and align the dentition. In the 3rd month of treatment, wire was changed to .016 x .022” stainless steel in both arches and this patient was ready to receive MMA surgery. After 2 weeks following discharge, she came back to our OPD for post-surgery orthodontic treatment adjustment. Both her jaw bones were advanced and improvement of the facial profile was observed, but her overjet had increased from 3 mm to 5 mm. This could be the result of surgical relapse caused by malposition of the condyle heads during rigid fixation at time of MMA surgery.

Two interdental mini-screws were placed between teeth #12, 13 and 22, 23 in the 9th month of treatment. Class II elastics (1/4”, 3.5oz) between interdental screws and lower first molars were used to pull the lower dentition forward to reduce the overjet via dental compensation. In comparing the mechanics of pulling elastics from the upper canines to the lower 1st molars, the side effects could be reduced that had occurred in the maxillary dentition (Figure 3). PSG examination was also arranged to compare the difference between the pretreatment and the 6-months later recall after MMA surgery. At the 18th month of treatment, the entire treatment course was completed with stable occlusion and acceptable teeth alignment. Both radiographs and photographs showed significant changes (Figure 4). A lingual fixed retainer was bonded in the lower anterior region, and an upper Hawley retainer was delivered for retention.

3. RESULTS

The facial profile of this patient was dramatically improved, and both retrusive jaws were corrected to within normal range. By superimposition of pretreatment and post-treatment cephalometric films, it was obvious that both jaws moved anteriorly and the hyoid bone moved anteriorly and superiorly as well (Figure 5 and Table 1). In the regional superimposition, the lower 1st molars extruded 1 mm because of prescription of Class II elastics on this tooth position and placement of upper interdental mini-screws to achieve better occlusion; accordingly, both lower incisors and 1st molars were proclined and mesial-shifting.

Figure 3. The intraoral and extraoral photographs in 9 months of treatment, we placed two interdental screws between upper lateral incisors and canines to pull the lower dentition anteriorly by elastics. We used these biomechanics to close the overjet caused by surgical relapse.
In the 6-months post-surgical PSG exam following, the AHI (11.3 events/hour) was greatly reduced and minimum SpO2 (77%) was increased. The patient's BMI was 27.4, which was still much higher than the normal range. Clinical symptoms such as daytime sleepiness and snoring were improved, which were also reflected on NOSE (1/20) and ESS (4/24) scores. The change of airway volume at different timepoints are also documented in Table 2. The air pressure during inspiration (Figure 6B) or velocity magnitude (Figure 6D) in the computerized fluid dynamic analysis, both showed significant changes between pre-treatment and 6 months post-operation. General life quality appeared significantly better than before.

4. DISCUSSION

There are many different treatment options in treating OSA, including CPAP, weight loss, positional therapy, oral appliances, maxillary expansion, tongue suspension, UPPP, nasal surgery and MMA [4]. These treatment options depend on the severity of OSA and the collapsed position in the airway.
Compared to other treatment options in OSA patients, MMA is a reliable and stable choice for moderate to severe OSA patients in long-term studies [9]. Especially in the lateral pharyngeal wall and concentric velum collapse CASE, MMA is particularly effective [8]. Significant changes in the pharyngeal airway volume show 80.43% increase and a mean 83% AHI decrease, [11], reflecting a strong correlation between changes in the above variables [12,13]. The mean final AHI is 12.4 events/hour and the overall success rate is about 87.5%, [14], which is very close to the 89.8% success rate of CPAP [15]. In our case, the initial AHI was 73.1 events/hour and 6 months post-operation was 11.3 events/hour. The total change was 84.5% decreased in the AHI, which coincides with results of research previously mentioned [11]. Significant changes in cross-section area in the velopharynx was also observed both in CBCT and 2D lateral cephalometric radiographs.

The mechanism of MMA advance both jaw bones, which would protract the soft palate, tongue base, the hyoid bone anteriorly and lead to decrease in AHI. This movement would increase velopharyngeal (82%), oropharyngeal (54%) and hypopharyngeal (30%) spaces at the same time [16]. Nevertheless, the combination of MMA and CCW rotation has proven to be the movement with the strongest impact on the pharyngeal airway [15–17]. Furthermore, adjunctive surgical procedures such as UPPP, septoplasty, turbinectomy, adenoidectomy or genial tubercle advancement are occasionally combined with MMA to enhance treatment results. In our CASE, not only both maxilla and mandible were advanced by CCW rotation, but also more pharyngeal space was gained as well. In addition to these movements, septoplasty was also applied to correct the asymmetric morphology of the nostril and to prevent the nasal septum deviation or space shrinkage caused by impacted movement of the anterior maxilla. Even though this additional surgical procedure is not effective for increasing pharyngeal space, it is still necessary to avoid the adverse effects during this surgery.

In concerning long-term stability of MMA, the success rate of MMA is about 90% at the immediate post-operative period. Although the success rate would decrease and post-surgical mean AHI may increase back to the level of moderate OSA over very long-term follow-up (>8 years). This outcome

<table>
<thead>
<tr>
<th>Airway volume</th>
<th>Velopharynx</th>
<th>Oropharynx</th>
<th>Hypopharynx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretreatment</td>
<td>3937 mm³</td>
<td>4435 mm³</td>
<td>5183 mm³</td>
</tr>
<tr>
<td>6-months</td>
<td>4829 mm³</td>
<td>4581 mm³</td>
<td>6045 mm³</td>
</tr>
<tr>
<td>Post-operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-treatment</td>
<td>6606 mm³</td>
<td>4897 mm³</td>
<td>6795 mm³</td>
</tr>
</tbody>
</table>

Figure 5. Superimposition of cephalometric tracing from pretreatment (black) and post-treatment (red). A, the overall superimposition shows that both her maxilla and mandible are moved anteriorly and the obvious enlargement in pharyngeal airway is observed. The position of hyoid bone is also more superior and anterior. B, Maxillary superimposition (Upper), and mandibular superimposition (Lower).
could be explained with different possible reasons, like the soft tissue in the upper airway becoming lax with time, skeletal relapse, increasing in BMI or merely aging [18,19]. However, few studies have discussed this topic and additional research with long-term follow-up is required, although it could still be assumed that patients receiving MMA surgery will have gradual worsening of OSA over time.

Tooth agenesis is very common in daily clinical patients for orthodontists. The reported prevalence in the permanent dentition range is from 1.6 to 9.6%, [20–22], which varied in different ethnic groups. Mandibular second premolars are reported as the most common missing tooth position, followed by maxillary second premolars, maxillary lateral incisors and mandibular lateral incisors in Mongoloid populations [23]. Many articles have also reported treatment guidelines for tooth agenesis, including tooth substitution, restorative therapy or single implant [24,25]. Furthermore, interproximal reduction (IPR) or restorative treatments are usually necessary for adjusting the Bolton's ratio. In our CASE, this patient's teeth #32 and 42 were missing and had been substituted with teeth #33 and 43; besides, teeth #12 and 22 were microdontia. All the above clinical findings led to a higher Bolton's ratio of 86% in the anterior region. To achieve ideal tooth alignment, it was recommended that teeth restoration of #12 and 22 and IPR in lower arch to decrease the Bolton's ratio. However, the patient's chief complaint was OSA and she felt that her occlusion was acceptable, so the orthodontic treatment was completed in an acceptable and stable occlusion.

5. CONCLUSION

MMA provides an effective and reliable treatment option in patients with moderate to severe OSA and craniofacial deformity. By the aid of computer-assisted simulation software, the difficulty of double jaw surgery can be predicted and any potential interference can be determined during surgical planning in the software. Even though postoperative AHI appears to increase back to a moderate level in
very long-term studies, it actually decreases the AHI and improves esthetics significantly. More attention on airway changes in the retention phase of such patients should be considered, and further studies are required to resolve the unsolved questions.

Conflicts of interest statement

The authors declare that there is no conflict of interest.

REFERENCES


