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Surgical Treatment of Obstructive Sleep Apnea by Maxillomandibular Advancement

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Summary: In recent years obstructive sleep apnea syndrome has gained increasing interest. Treatment of choice is nasal continuous positive airway pressure ventilation during sleep for upper airway patency, which does not cure sleep apnea and has to be applied throughout a patient's lifetime. In respect to various underlying pathomechanisms, in certain cases with craniofacial disorders, causal therapy by craniofacial osteotomies seems possible. A series of 21 consecutive patients with maxillary and mandibular deficiency were treated primarily with a 10-mm maxillomandibular advancement by retromolar sagittal split osteotomy and Le Fort-I osteotomy, respectively. Obstructive sleep apnea syndrome was considerably improved in all patients. In 20 of 21 patients, the postoperative respiratory disturbance index (RDI) was reduced clearly to under 10, oxygen saturation rose and sleep quality improved. This was achieved by a maxillomandibular advancement of 10 mm without secondary refinements. In one patient the RDI could only be reduced to 20, probably due to insufficient maxillary advancement; oxygen desaturations still existed despite secondary corrections. These results indicate that successful surgical treatment is possible in a high percentage of selected patients with certain craniofacial characteristics. In addition to cardiorespiratory polysomnography there should be routine cephalometric evaluation of all patients. Maxillomandibular advancement should be offered as an alternative therapy to all patients with maxillary and/or mandibular deficiency or dolichofacial type in combination with narrow posterior airway space. **Key Words:** Obstructive sleep apnea—Surgical treatment—Maxillomandibular advancement.

Various pathophysiological conditions may contribute to the etiopathology of obstructive sleep apnea syndrome (OSAS). Obesity must be considered first, as we have known since the description of the "Pickwick-syndrome" in the Pickwick papers by Charles Dickens. However, not all patients with OSAS show the classic features; many patients are not obese at all. Certain craniofacial characteristics (maxillary and especially mandibular deficiency) influencing pharyngeal obstruction seem to be much more frequent than previously expected (1). In patients with these craniofacial characteristics, surgical correction of the deformities appears to be an appropriate method to influence pharyngeal obstruction and cure obstructive sleep apnea. Surgical techniques for correction of maxillary and mandibular deficiency are well established and have been known for years in the treatment of patients with skeletal dysgnathias. Furthermore, it is well known that mandibular advancement leads to advancement of the suprahyoid and tongue muscles fixed to the mandible (2); in maxillary advancement the velum and velopharyngeal muscles are advanced (3).

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METHODS

Selection of patients

Before considering any treatment we confirmed the presence of OSAS not only by clinical symptoms, but also by complete polysomnographic control, according to the guidelines of Rechtschaffen and Kales (4). Initial treatment for all patients consisted of nasal continuous positive airway pressure (nCPAP) (5). After cephalometric evaluation (1), which is described later on, alternative surgical treatment by maxillomandibular advancement was offered to all patients with certain cephalometric characteristics (maxillary and/or mandibular deficiency in combination with narrow posterior airway space) (Table 1). In this paper 21 consecutive surgically treated patients have been evaluated, all of whom preferred surgical treatment over nCPAP, which they had used for a minimum of 3 months as initial therapy.

In addition to cephalometric evaluation, all patients had a careful clinical investigation for any anatomical or pathological abnormalities. If necessary, the clinical investigation was supplemented by further tests using various technologies, particularly fiberoptic evaluation, intrapharyngeal pressure recording, computerized tomographic scanning or acoustic reflexion technique. Nevertheless, no further abnormalities could be found.

Sleep studies

All patients underwent standardized polysomnography before and 3 months after surgery. Within these studies, monitoring of electrophysiological parameters and scoring of sleep stages were performed according to conventional criteria (4). The following variables were recorded for the evaluation of respiration: airflow was semiqualitatively measured by oronasal thermistors, thoracic and abdominal respiratory movements were monitored by (uncalibrated) inductive plethysmography, snoring sounds were recorded by a neck microphone attached to the skin and oxygen saturation was measured by pulse oxymetry. All breathing disorders were manually scored. Apneas were defined as a complete cessation of airflow lasting 10 seconds or longer. Hypopneas were defined as a >50% decrease in oronasal airflow, lasting at least 10 seconds. The classification into obstructive, mixed or central types of breathing disorders resulted from an analysis of respiratory movements and snoring. The respiratory disturbance index (RDI) was determined by the number of apneas and hypopneas per hour of sleep. A computer-based analysis was used for quantitative evaluation of oxygen saturation and provided the mean saturation during sleep and the time spent with saturation values <90% in relation to the total sleep time. In addition, another study was conducted during the 2nd night of nCPAP therapy. However, no scoring of sleep stages was performed from these recordings.

For the assessment of subjective findings, a standardized questionnaire was used that has been proven to be valuable in other scientific or clinical settings (6). All patients were asked for complaints before and after surgery. Statistical analysis was performed using the Student's *t* test.

Cephalometric evaluation

Cephalometric evaluation of craniofacial characteristics was accomplished with cephalometric x-ray tracings of the viscerocranium in profile view for vertical, and especially sagittal, dimensions. Cephalometric x-ray means not just lateral head film, but a long distance between the x-ray source and the patient's head and a minimal distance between the patient's head and film to minimize magnification. In our series, patient to x-ray source distance was 4 m, which led to a magnification of 2–5%. For reproducibility the patient's head was fixed in a cephalostat in an upright position, with the central x-ray in the transmeatal axis. For precise determination of skeletal and soft tissue references, wedge filter screens are essential.

TABLE 1. *Selected cephalometric changes due to maxillomandibular advancement. [Cephalometric analysis cited according to (1)]*

	Preoperative (n = 21)	Postoperative (n = 21)
SNA (Sella–Nasion–A-point)	79.6 (3.4)°	85.2 (4.5)°[a]
SNB (Sella–Nasion–B-point)	75.2 (4.0)°	80.7 (3.8)°[a]
Facial axis	81.9 (4.5)°	86.3 (3.8)°[a]
Facial depth	84.4 (5.2)°	90.5 (3.1)°[a]
Maxillary depth	87.3 (4.6)°	93.9 (3.7)°[a]
PAS (Mandibular plane)	8.3 (2.0) mm	15.2 (3.9) mm[a]
PAS (Occlusal plane)	7.4 (2.6) mm	11.3 (3.9) mm[a]
PAS (Maxillary plane)	25.7 (4.1) mm	32.1 (4.4) mm[a]
PAS (Uvula tip)	7.0 (2.2) mm	11.8 (3.6) mm[a]
Basion—Posterior Nasal Spine	44.2 (2.8) mm	50.5 (3.8) mm[a]

All values are presented as means with SD in parentheses.
[a] Significant (Student's *t* test).

As we described previously (1), cephalometric evaluation is quite complex (1). More than 500 patients with polysomnographic evidence of OSAS were evaluated cephalometrically in comparison to 120 patients in whom obstructive sleep apnea could be excluded. In short, significant craniofacial changes in about 40% of these patients could be found. These craniofacial changes consisted of mandibular and/or maxillary deficiency; in most eases a dorsocaudal rotation of the mandibulo-maxillary complex could be stated as regularly accompanied by pharyngeal narrowing.

Surgical principles

Mandibular and maxillary deficiency in combination with pharyngeal narrowing were the basis for the consideration of surgical treatment by maxillomandibular advancement (Table 1). All patients had conservative nCPAP therapy for at least 3 months prior to surgery, not only to see whether subjective symptoms improved, but also to minimize intraoperative risks by normalizing cardiovascular changes caused by obstructive apneas.

Finally, any surgical procedure should be considered only in patients with obvious subjective symptoms as well as severe polysomnographic findings. In our series, only patients with an RDI over 20 were considered as candidates for surgery in consideration of the mortality

TABLE 2. *Patient demographics, surgical procedures, and pre- and postoperative body mass index*

Case no.	Gender	Age	Therapy	Body mass index Preoperative	Body mass index Postoperative
1	Male	40	Maxillary/mandibular advancement (10 mm)	29.4	30.9
2	Male	22	Maxillary/mandibular advancement (10 mm)	23.8	24.5
3	Male	21	Maxillary/mandibular advancement (10 mm)	27.1	28.5
4	Male	56	Maxillary/mandibular advancement (10 mm)	35.7	36.4
5	Female	32	Maxillary/mandibular advancement (10 mm)	30.9	29.9
6	Male	48	Maxillary/mandibular advancement (7/14 mm)	26.2	25.9
7	Male	55	Maxillary/mandibular advancement (9/10 mm)	29.4	31.1
8	Male	51	Maxillary/mandibular advancement (10 mm)	26.9	26.5
9	Male	43	Maxillary/mandibular advancement (10 mm)	27.4	26.8
10	Male	57	1. Maxillary/mandibular advancement (4/14 mm) 2. Uvulopalatoplasty 3. Palatal advancement (5 mm)	28.1	28.7
11	Male	54	Maxillary/mandibular advancement (10 mm)	28.4	27.4
12	Male	43	Maxillary/mandibular advancement (10 mm)	31.3	29.8
13	Male	40	Maxillary/mandibular advancement (10 mm)	24.5	23.0
14	Male	32	Maxillary/mandibular advancement (10 mm)	26.1	27.1
15	Male	35	Maxillary/mandibular advancement (8/10 mm)	25.0	25.3
16	Male	47	Maxillary/mandibular advancement (10 mm)	27.1	26.8
17	Male	57	Maxillary/mandibular advancement (10 mm)	23.1	23.5
18	Male	50	Maxillary/mandibular advancement (10 mm)	23.3	23.1
19	Male	50	Maxillary/mandibular advancement (10 mm)	25.4	26.0
20	Male	56	Maxillary/mandibular advancement (10 mm)	25.6	25.0
21	Male	47	Maxillary/mandibular advancement (10 mm)	22.6	21.9
Mean (SD)		44.6 (11.0)		27.0 (3.2)	27.1 (3.5)

rate in this group (7,8). Cephalometric abnormalities per se are no indication for any therapy at all. Contraindications were multiorgan disease, particularly in elderly people who could be sufficiently treated by nCPAP, chronic alcoholism and drug abuse. Subjects with marked obesity with a body mass index (BMI) over 30 should be excluded until a clear weight reduction can be observed. In our series, only one patient with a BMI clearly over 30 was surgically treated.

Surgical treatment principles consisted of mandibular advancement by bilateral retromolar sagittal osteotomy. The mandible was osteotomized and sagittally split in the region of the jaw angle on both sides. Temporomandibular joint segments were kept in place, the inferior alveolar nerve stayed intact and the distal toothbearing segment was advanced like side-scenes without any bone interpositioning. Maxillary advancement was done by osteotomy of the toothbearing part of the maxilla on the Le Fort-I level. Fixation in the new position was achieved by miniplates in the maxilla and bicortical miniscrews in the mandible. If necessary, correction of nasal septal deformity could easily be achieved during Le Fort-I osteotomy.

For proper enlargement of pharyngeal narrowing, the primary aim was a maxillomandibular advancement of 10 mm to secure success. In patients with correct bite and without dysgnathias, simultaneous maxillary and mandibular advancement was performed to preserve the preoperative bite situation. In patients with dysgnathias, the bite was corrected simultaneously.

Maxillomandibular advancement not only leads to enlargement of velo- and hypopharyngeal structures, but also—perhaps more importantly—to a straightening of the suprahyoid and velopharyngeal muscles and tendons by advancement of their skeletal attachments. If necessary, this effect can be supported by additional chin advancement by genioplasty or additional advancement of the palatal plate with the attached velum muscles. In some cases, a surgical reduction of excessive soft tissues has to be considered if they attribute to pharyngeal encroachment. Chin advancement was not necessary, but in one of our cases secondary refinements were tried by palatal advancement and velopharyngeal soft tissue corrections.

On these premises 21 consecutive patients have been treated so far. Table 2 gives an overview of the gender and age of the patients, the surgical procedures and the preoperative and 3 months postoperative BMI, as a possible additional influencing factor. Nineteen of the 21 patients had maxillomandibular advancement of approximately 10 mm. Two of the patients had marked dysgnathias, both mandibular deficiencies. One of them had maxillary advancement of 7 mm and mandibular advancement of 14 mm. The second patient had a mandibular deficiency worsened by widely destroyed temporomandibular joints and an atrophic, partly edentulous mandible, so mandibular advancement without bone interposition was possible only to 14 mm, which consequently meant a 4-mm maxillary advancement.

In two patients postoperative orthodontic refinements were advised, which the patients refused, having

TABLE 3. *Polysomnographic results*

	Preoperative values [Mean (SD)]	Postoperative values [Mean (SD)]	p	nCPAP [Mean (SD)]
AI	29.5 (19.3)	1.7 (3.4)	<0.001	1.0 (1.7)
HI	15.4 (15.0)	1.9 (2.0)	<0.001	1.5 (2.1)
RDI	44.9 (17.5)	3.6 (4.7)	<0.001	2.5 (2.3)
Mean saturation	93.2 (1.6)	95.1 (1.3)	<0.01	95.4 (1.1)
Time spent in SaO_2 <90%/TST (%)	11.5 (12.5)	1.0 (1.1)	<0.001	0.7 (0.8)
SWS/TST (%)	8.4 (5.9)	15.1 (5.3)	<0.01	–

Abbreviations: AI = apnea index; HI = hypopnea index; RDI = respiratory disturbance index; TST = total sleep time; SWS = time spent in slow-wave sleep.

no occlusal and functional problems. Seven patients had postoperative prosthetic rehabilitation.

RESULTS

The postoperative results are summarized in Table 3 as average values for apnea index, hypopnea index, RDI, mean oxygen saturation, percentage of total sleep time spent in oxygen saturation <90% and percentage of slow-wave sleep. These postoperative results are compared to the preoperative situation as well as the results under nCPAP therapy. Table 1 shows some of the cephalometric changes. Figures 1–4 give a graphic overview of polysomnographic changes for all patients by RDI, time spent in oxygen saturation <90%, percentage of slow-wave sleep and minimal oxygen desaturation.

Postoperative RDIs (Fig. 1) could be reduced clearly to below 10 in all patients except the one with a maxillary advancement of only 4 mm. In this patient the RDI was about 40, compared to a preoperative RDI of 67. After the primary procedure, the remaining apneas in this patient were due to persistent pharyngeal obstruction at the velopharyngeal level, which could be confirmed by intrapharyngeal pressure measurements at different levels. Therefore, as a secondary procedure, excision of soft tissue hyperplasias at the velum and palatal folds (uvulopalatoplasty) was performed, which further reduced the apneas. An additional advancement of the bony palatal plate with the attached velar muscles as a third step finally led to an RDI of 20 in this patient.

Mean oxygen saturation rose from preoperative 93.2% to postoperative 95.1% (Table 3). The time spent in oxygen saturation below 90% was reduced from preoperative 11.5% to postoperative 1.0% of total sleep time (Table 3). Postoperatively, the patients showed no desaturations below 90%, except the one patient with maxillary advancement of only 4 mm, who had single desaturations between 80 and 90%, contributing to the mean 1.0% (Table 3, Fig. 4).

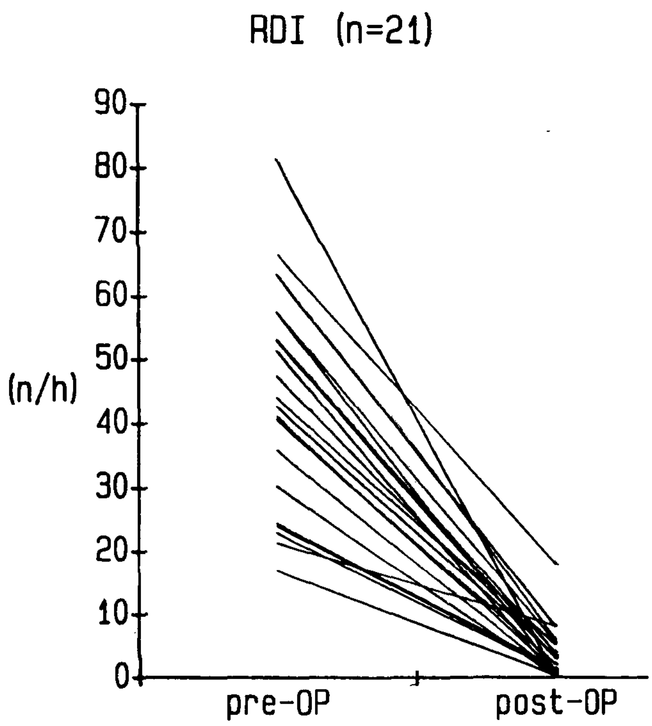

FIG. 1. Presentation of the pre- and postoperative respiratory disturbance indexes (RDI) for all patients.

Sleep quality improved in all patients. Slow-wave sleep improved from 8.4% to 15.1% of total sleep time on average (Table 3). The patients were quite content, because subjective symptoms like fatigue and daytime sleepiness disappeared (Table 4).

CONCLUSIONS

These results indicate that successful surgical treatment is possible in a high percentage of certain cephalometrically selected patients. In addition to cardiorespiratory polysomnography, there should be routine cephalometric evaluation of all patients. Maxillomandibular advancement should be offered as an alternative therapy to all patients with maxillary and/or mandibular deficiency or dolichofacial type in combination with narrow posterior airway space.

Obstructive sleep apnea syndrome could clearly be improved as is indicated by the postoperative RDI of less than 10 in 20 of 21 patients. This was achieved by maxillomandibular advancement of only 10 mm. The one case with an insufficient result was probably due to an insufficient maxillary advancement of only 4 mm in extreme velopharyngeal obstruction. In retrospect, the maxillary advancement should have been supplemented primarily by an additional advancement of the palatal plate, with its insertions of velopharyngeal muscles. We expect that this would have meant one single operation and could have saved velopharyn-

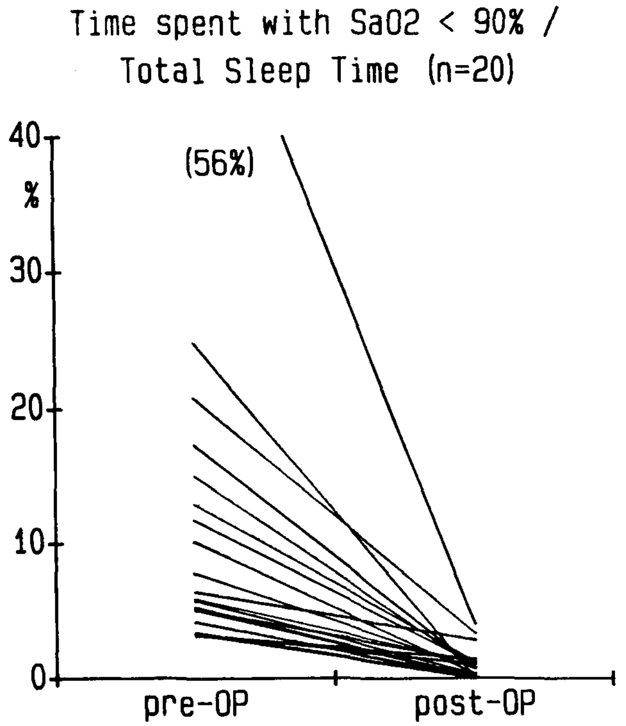

FIG. 2. Presentation of the pre- and postoperative percentages of total sleep time spent with an oxygen saturation <90% for all patients.

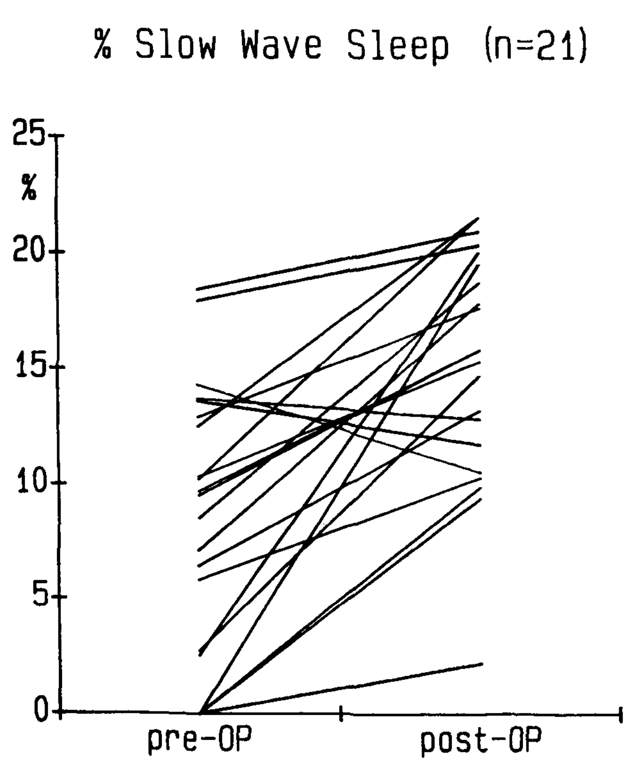

FIG. 3. Presentation of the pre- and postoperative percentages of slow-wave sleep for all patients.

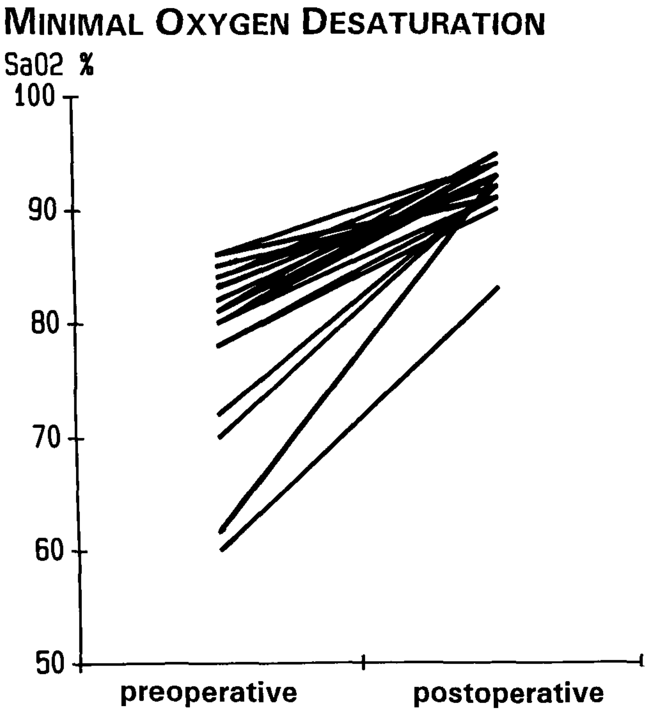

FIG. 4. Presentation of the pre- and postoperative minimal oxygen desaturations for all patients (n = 21).

geal soft tissue reduction in this patient. In all other patients, no additional soft tissue corrections were needed.

Under these conditions, in patients with maxillary and especially mandibular deficiency or dolichofacial type in combination with cephalometrically perceptible pharyngeal narrowing we advocate a surgical treatment by maxillomandibular advancement as an alternative to conservative nCPAP ventilation. A stepwise procedure, as is sometimes advocated (9–12) (e.g. first uvulopalatopharyngoplasty and, if unsuccessful, then maxillomandibular advancement as a second stage procedure), is not justified in our opinion in these cephalometrically selected patients.

TABLE 4. *Subjective findings from a self-report questionnaire (n = 21)*

	Preoperative	Postoperative
Fatigue?		
Yes	21	3
No	0	18
Daytime sleepiness?		
Yes	13	0
No	8	21
Reported apneas?		
Yes	19	3
No	2	18
Reported loud and irregular snoring?		
Yes	21	5
No	5	16

It must be kept in mind that our results are from selected patients with the abovementioned criteria. Uncritical overall application of these surgical possibilities must be avoided. In the past, uncritical application of uvulopalatopharyngoplasty in many unselected patients without any specific indication discredited all surgical methods.

Under the assumption that the effectiveness of maxillomandibular advancement is caused by straightening of the suprahyoid and velopharyngeal muscles and tendons by advancement of their skeletal attachments, worsening over the years might occur. Despite initial 1- and 2-year results, which remained stable, we do not know what will happen after 10 or 20 years. Therefore long-term follow-up is absolutely essential.

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