



The inverted-L ramus osteotomy versus sagittal split ramus osteotomy in maxillomandibular advancement for the treatment of obstructive sleep apnea patients: A retrospective study

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ABSTRACT

This study aimed to compare the effectiveness and feasibility of inverted-L osteotomy (ILO) and sagittal split ramus osteotomy (SSRO) on obstructive sleep apnea (OSA) treatment. According to different surgery procedures, 28 OSA patients who underwent maxillomandibular advancement (MMA) were divided into 2 groups (group A: ILO, n = 9; group B: SSRO, n = 19). Polysomnography (PSG) and Epworth sleepiness scale (ESS) on T0, T1 and T2 were used to evaluate the effectiveness of OSA treatments. Patients' airway structures and facial appearances were also evaluated. From T0 to T1, the mean apnea-hypopnea index (AHI, /per hour) dropped from 69.2 ± 8.4 to 11.2 ± 2.4 ($P < 0.01$) in group A and from 54.6 ± 14.6 to 9.4 ± 5.4 ($P < 0.01$) in group B; LSpO2 (lowest pulse oxygen saturation, %) increased from $66.5 \pm 7.7\%$ to 88.2 ± 4.6 ($P < 0.01$) and from $76.6 \pm 10.7\%$ to $89.4 \pm 2.4\%$ ($P < 0.01$) while the mean ESS score decreased by 51% in group A and 44% in group B. Most patients (group A: 88.9%; group B: 84.3%) were satisfied with their postoperative appearance. Mild relapse was observed in both groups on T2. This study concluded that MMA containing ILO and MMA containing SSRO are both feasible and effective for selected OSA patients.

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1. Introduction

OSA, affecting approximately 2–4% of the world population, is a common disorder of repetitive upper airway collapse during sleep, leading to disrupted sleep and oxygen desaturation (Jordan et al., 2014). It is relevant to significant cardiovascular morbidity (Levy et al., 2011). Continuous positive airway pressure (CPAP) ventilation is the standard treatment, but compliance with and tolerance of it are always relatively poor (Heinzer et al., 2015). Procedures like Uvulo-palato-pharyngoplasty (UPPP), nasal reconstruction and radiofrequency ablation of upper airway structures generally lack a curative effect for OSA, and they are more used as supplementary therapy (Boyaci et al., 2013). With definite curative effect on OSA in many studies, nowadays, maxillomandibular advancement (MMA)

is recommended as the initial surgical treatment by an increasing numbers of surgeons for OSA patients (Prinsell, 2000; Düzlülü et al., 2018). MMA is the most effective surgical intervention except for tracheostomy (Zaghi et al., 2016). It reshapes the pharynx and enhances soft-tissue tension, reducing the collapsibility and obstruction of the airway (Faria et al., 2017). In almost all studies, common MMA (traditional MMA and counterclockwise MMA) consists of Le Fort I osteotomy of the maxilla and bilateral sagittal split ramus osteotomies (SSROs) (Pirklbauer et al., 2011; Ronchi et al., 2013). SSRO is the most common technique used to correct mandibular deformities for its versatility and amenability to rigid fixation, and it is also the workhorse of OSA treatment (Greaney et al., 2015). ILO is an orthognathic surgical technique with some special advantages in correcting mandible malformation (Franco et al., 2016). According to our experience, ILO could correct OSA apparently by lengthening and extending the mandible deformities. However, we found that this approach was scarcely applied in the OSA treatment, and there were no previous studies in the literature that have investigated the effect of ILO on OSA

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patients. By comparing and contrasting objective and subjective outcomes of a series of OSA patients, the purpose of this study was to examine the feasibility and effectiveness of two different MMAs on OSA treatment.

2. Material and methods

All medical practice followed the Declaration of Helsinki on medical protocol. This study was approved by the ethics committee of West China College of Stomatology and the institutional review board of Sichuan University. Informed consent was obtained from all individual participants included in the study.

2.1. Participants

The inclusion criteria for subject selection were as follows: (1) Patients underwent MMA for the treatment of OSA (diagnosed by overnight polysomnography (PSG), $AHI \geq 5$ (defined as the sum of apnea and hypopnea events per hour); apnea was defined as a >90% reduction in airflow with respiratory effort for at least 10s; hypopnea was defined as a >50% reduction in airflow accompanied by oxygen desaturation of more than 3% or arousal from sleep) in a stomatology hospital of West China by the same surgeon between December, 2014 and May, 2017; (2) Radiographs and PSG data were available on T0: no more than 1 week pre-surgically, T1: right after surgery (no more than 3 months), and T2: more than 12 months after surgery; (3) Pre and postsurgical orthodontic treatment were completed; (4) Genioplasty was also performed; (5) Patients had already undergone other non-invasive treatments that had been unsuccessful, had rejected the long-term treatment (CPAP) or suffered maxillofacial deformities. Exclusion criteria included incomplete information on PSG and radiographs, unstable psychological status, loss to follow-up, poor compliance and excessive asymmetric preoperative countenance. According to different procedures, in the analysis, the participants were assigned to group A or group B:

- Group A: patients accepted MMA consisting of Le Fort I osteotomy and bilateral ILOs, and genioplasty and iliac bone grafting were also adopted.
- Group B: patients accepted MMA consisting of Le Fort I osteotomy, bilateral SSROs and genioplasty.

2.2. Polysomnography

All patients in the study were monitored by PSG (Embletta X100, Embla, Broomfield, CO) in the sleep medicine center of West China Hospital of Sichuan University on T0, T1 and T2. PSG recordings were scored by an experienced technician. The PSG data were scored according to the AASM manual, 2007 version (Berry et al., 2012). All PSG studies were specialist-attended, in-laboratory examinations using a digital polygraph. The following parameters were recorded: electroencephalography; electrocardiography; electromyography; anterior tibialis; snoring; pulse oximetry; respiratory effort; sleep position.

In our study, the following data on T0, T1, T2 of PSG parameters were collected and analyzed: 1) AHI; 2) lowest pulse oxygen saturation (LSpO₂).

Surgery success was defined by an AHI <20 with at least a 50% reduction, and surgical cure was defined as AHI <5.

2.3. Subjective sleepiness

Pre- and postoperative subjective sleepiness were assessed via the Epworth Sleepiness Scale (ESS) (Johns, 1991). Patients rated

their ease of falling asleep in 8 potentially sleep-permissive scenarios ranking 0 (no chance of dozing) to 3 (high chance of dozing) in this questionnaire. All module scores were added to obtain total points. Higher score represents higher likelihood of OSA to some extent.

2.4. Upper airway analysis

All radiographs were taken by the same technician in a West China stomatology hospital medical imaging department, with participants undertaking lateral cephalograms in the natural head position and spiral CT scan (MX16-Slice, Philips and Neusoft Medical Systems Co., Ltd.) in the supine position. Image was saved as DICOM to import into Dolphin 3D imaging software, version 11.7 (Dolphin Imaging and Management Solutions, Chatsworth, CA) for 3D reconstruction and analysis.

The airway morphology and position of hyoid bone were the main subjects (Fig. 1.1). The orientation was adjusted with the Frankfort horizontal (FH) plane as the horizontal reference plane, and the anteroposterior plane was adjusted through the ANS and nasion (N) perpendicular to the horizontal plane. In this study, we focused on the nasopharyngeal and oropharyngeal regions, and the boundaries of region of interest (ROI) were defined as posterior nasal spine superiorly, nadir of epiglottis, lateral pharyngeal walls, posterior pharyngeal wall, and the posterior border of the tongue. The length and volume of the upper airway were measured, and the minimum cross-section area (min CSA) was also found in airway 3D reconstruction of CT scan.

Posterior airway space (PAS) and position of hyoid bone were analyzed in lateral cephalograms. The position of the hyoid bone is established in several ways as referred to in previous literature, both in the vertical direction (distance from the hyoid bone to the mandibular plane (MP-H), to the Frankfort plane (H-Frankfort), to the anterior base plane (Ba-N)), and in the anteroposterior direction (distance between projection of point H and point N on the Frankfort plane (H'-N')) (Paoli et al., 2001).

2.5. Skeletal structure analysis

Lateral cephalograms were standardized and traced using the Tweed technique (Fig. 1.2). The maxillary advancement was measured with the subspinal point (A), mandibular advancement with subchin point (B) on a parallel to S-N (sella-nasion) line. Skeletal structure was evaluated by measuring the SNA, SNB and ANB. Ramus height was defined as the distance of Co (condylar position) to Go (gonion). The 3D reconstructed CT scan of the maxillofacial region and anthropometric photographs were performed to assess the appearance.

2.6. Surgical procedure

All the cases adopted virtual surgical simulation by PTY Medtech Co., Ltd. Shenzhen (Fig. 2). Patients were operated on under general anesthesia using nasotracheal intubation. All surgical procedures were performed by the same surgeon using standard technique. Maxillary surgeries were first done under the guidance of the intermediate template, and then mandibular surgeries were executed in all patients. Iliac bone graft harvesting was performed simultaneously with maxillary surgery, and then bone graft was applied in ILO (Fig. 3). ILO was performed by extraoral incision while SSRO, Le Fort I and genioplasty were performed intraorally in our study. Moderate antibiotics and corticosteroid medications were used pre, intra and postoperatively. The nasotracheal tube of anesthetic intubation was not removed until monitored physiological states of

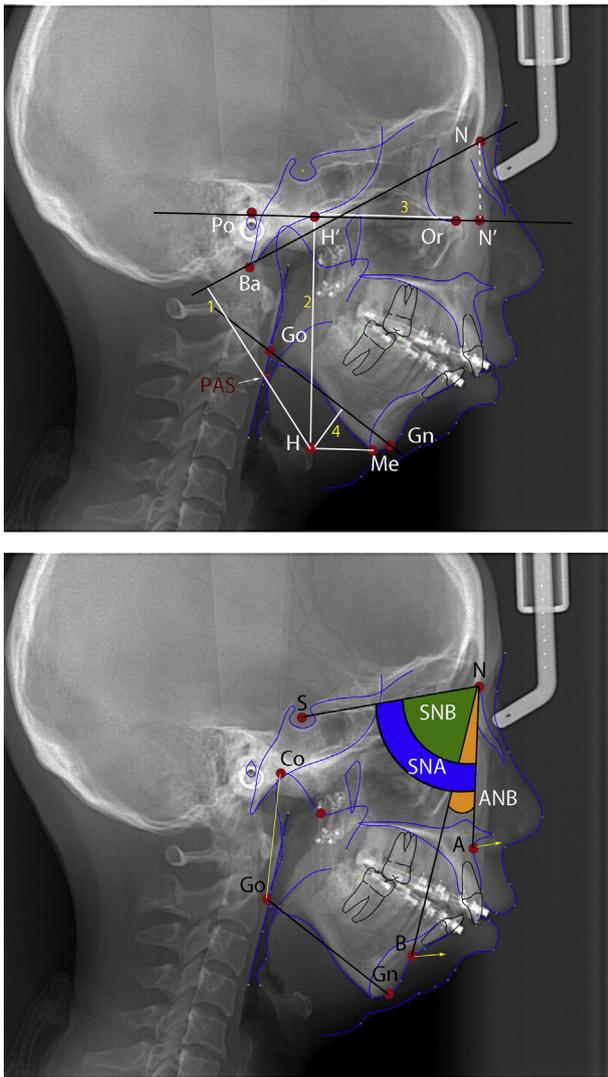


Fig. 1. Cephalometric analysis. 1.1. Airway parameters. PAS: posterior airway space, represented by minimal distance between the base of the tongue and the posterior pharyngeal wall. Position of Hyoid bone in vertical direction, 1), H–BaN: distance from H to line between N and Ba (anterior base plane); 2), H–Frankfort: distance from H to Frankfort plane (orthogonal projection); 3), MP–H: distance from the projection of the anterior upper edge of the hyoid bone on the perpendicular to the mandibular plane (gonion-pogonion); Position of Hyoid bone in vertical direction, 4), N'–H' distance between N' (orthogonal projection of the Na on the Frankfort plane) and H' (orthogonal projection of the point h on the Frankfort plane). 1.2. Skeleton parameters. S: sella; N: nasion; A: sub-spinal point; B: sub-chin point; SNA angle: the maxillary prognathism; SNB angle: the mandibular prognathism; ANB angle, the relative prognathism; Go: gonion point; Co: Condylar position. The yellow line shows the distance of Co–Go and represents ramus height. The yellow line shows the advancement of maxilla parallel to S–N plane; the yellow arrow shows the advancement of mandible parallel to S–N plane.

the patient stabilized for at least 24 h. Patients were required to bite the final splint for 2 weeks with intermaxillary fixation.

2.7. Intraoperative situations, complications and patient satisfaction on appearance

Operation duration and intraoperative blood loss of all patients were noted. Information on all complications after surgery was collected during the postoperative consultation. Light touch (by Semmes-Weinstein monofilament tester), sense of direction, terminal point discrimination, and temperature sensation were measured in four quadrants of the chin and lip on both sides. A

questionnaire was used to determine change in subjective sensation compared with that before surgery. The degree of inferior alveolar nerve injury was judged as light or heavy by comprehensive measurement and questionnaire results. Temporomandibular joint or muscle pain were evaluated by patients themselves subjectively, and level of pain was recorded. The dental occlusal outcome was assessed with dental study casts taken at baseline, and posttreatment by a specific orthodontist, abnormal occlusion was recorded. Facial nerve damage was measured by whether there were abnormal muscle cramps while making the relevant facial expressions. Spiral CT scans were used to identify bone nonunion and fracture during the follow-up. After surgery, patients were scheduled to score their satisfaction with their facial appearance on a 5-point Likert scale (1 = very dissatisfied; 5 = very satisfied).

2.8. Data statistics

All statistical analyses were performed using SPSS, version 17 (SPSS Inc., Chicago, IL, USA). Data were expressed as the mean \pm standard deviation. Continuous variables were tested by Shapiro–Wilk Test, Stem-and-Leaf display, and P–P test for normality. Signed-Rank Test was used to compare preoperative and postoperative data, as well as relapse. Wilcoxon Rank Sum Test was used to compare difference between two groups, with $P < 0.01$ indicating a statistical significance.

3. Results

3.1. Basic information

This retrospective monocentric study analyzed 28 Chinese adult patients from an initial pool of 35 patients. 9 participants (3 male and 6 female, mean age: 22.3 ± 3.2 years) were assigned to group A, and 19 participants (12 male and 7 female, mean age: 43.3 ± 3.2 years) to group B (Table 1). In group A, all cases had refused CPAP treatment; 5 participants had suffered from ankylosis of the temporal mandibular joint (TMJ), and bilateral TMJ arthroplasty had been performed. In group B, 9 cases experienced CPAP treatment but could not tolerate it; 2 cases underwent nasal or pharyngeal surgeries without effective correction; 2 cases remained invalid with oral positioner.

3.2. OSA treatment effectiveness

Postoperative mean BMIs were 21.2 ± 3.4 in group A and 24.2 ± 3.1 in group B, contrasting with 20.9 ± 2.7 and 25.8 ± 5.2 respectively before treatment. After MMA, mean AHI dropped by 84.1% from 69.2 ± 8.4 to 11.2 ± 2.4 per hour ($P < 0.01$) in group A for a mean AHI reduction of 90.2% and by 80.9% from 54.6 ± 14.6 to 10.4 ± 5.4 per hour ($P < 0.01$) in group B for a mean AHI reduction of 85.6%; LSpO₂ increased from $66.5 \pm 7.7\%$ to $88.2 \pm 4.6\%$ ($P < 0.01$) and from $76.6\% \pm 10.7$ to $89.4 \pm 2.4\%$ ($P < 0.01$) while ESS decreased from 14.2 ± 1.2 to 6.9 ± 1.9 ($P < 0.01$) and from 12.1 ± 3.1 to 6.7 ± 1.4 ($P < 0.01$) in group A and group B respectively. In group A, success rate and cure rate were 88.8% and 44.4%; in group B, success rate was 89.4% and cure rate was 46.1% (Table 2).

3.3. Upper airway changes

Table 3 provides data of upper airway parameters at T0 and T1. The mean upper airway volume (AV), the mean min CSA and the mean PAS were all increased in both of groups ($P < 0.01$) after surgery. A greater airway change of AV ($61.5 \pm 11.2\%$), min CSA ($147.2 \pm 52.1\%$), PAS ($81.3 \pm 21.2\%$) was seen in group A compared with AV ($42.3 \pm 9.6\%$), min CSA ($39.2 \pm 32.2\%$), PAS ($43.8 \pm 11.8\%$) in group B.

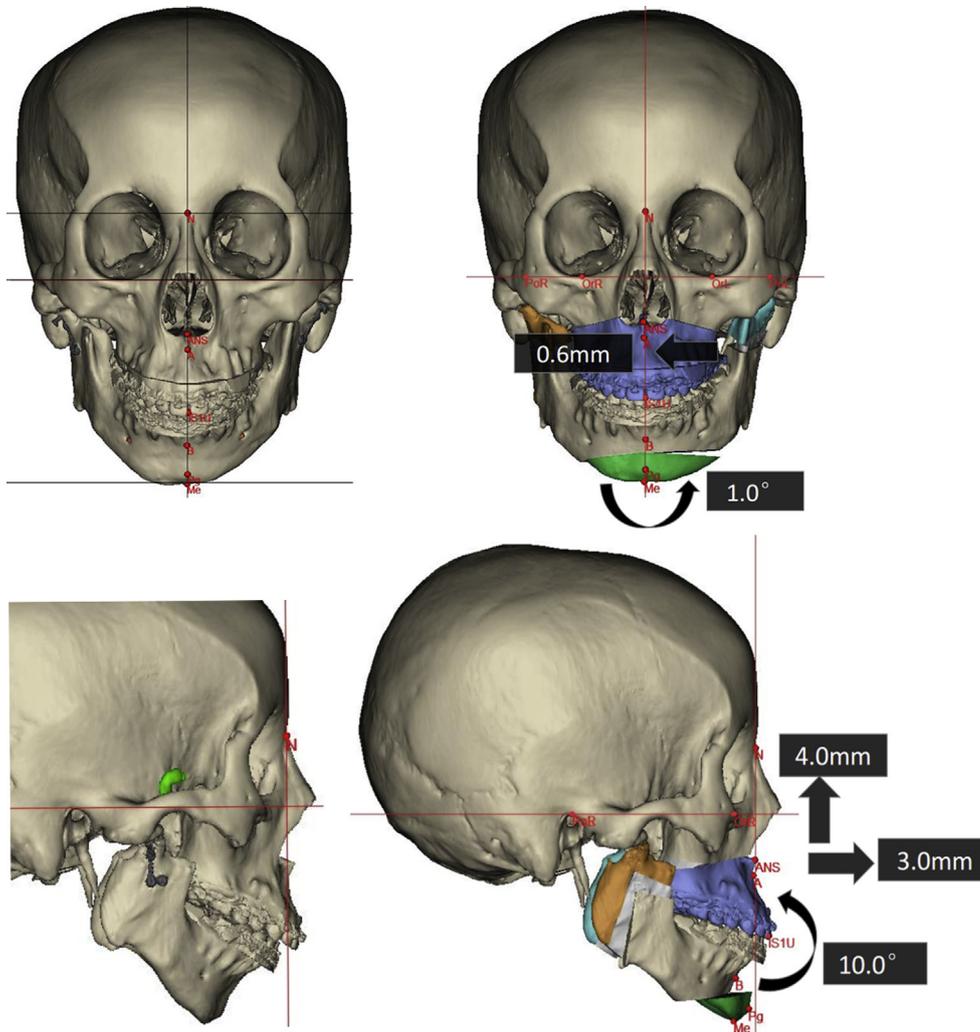


Fig. 2. The virtual surgical planning and simulation and 3D printed surgical templates. The same participant in group A who had suffered from TMJ ankylosis, and Arthroplasty had been complete adopted Le Fort I osteotomy, bilateral inverted L ramus osteotomy, genioplasty and iliac bone grafting.

Notice, however, that there were significant differences of the upper airway length (AL) between the two groups. The mean AL of group B ($P < 0.01$) decreased significantly, while little change was observed in group A ($p > 0.01$). The airway even became longer in 6 patients in group A. From the reconstruction image, we observed that the upper airway became plump after two kinds of MMAs (Fig. 4.1, 4.2). Hyoid hardly moved in group A in the vertical direction, while there was a little upward and forward change in group B (Table 3).

3.4. Skeletal structure changes

Patients in group A had a shorter ramus ($p < 0.01$) and more severe deformities before MMA compared with participants in group B. Both groups adopted counterclockwise rotation, and the mandibular advancement was far greater than that of the maxilla. From T0 to T1, SNA ($P < 0.01$) and SNB ($P < 0.01$) were all increased in two groups while ANB decreased ($P < 0.01$). Postoperative SNA, SNB and ANB were almost within the normal range. Larger changes of SNB ($P < 0.01$) were seen in group A (Table 3).

3.5. Esthetic satisfaction

Facial aesthetics are more subjective than objective, so the main basis of this study is the result of the 5-Likert rating table. No

patient was dissatisfied with his/her facial appearance. 88.9% of the patients in group A compared with 84.3% of patients in group B were satisfied or very satisfied with their facial changes (Table 4).

3.6. Complications

Mean operation duration was 6.5 ± 2.2 h in group A and 3.64 ± 0.5 h in group B, and the mean intraoperative blood loss was 553.4 ± 120.2 ml in group A and 363.8 ± 50.2 ml in group B. Severe intraoperative and postoperative complications were not recorded. None of the cases suffered from asphyxia. No obvious bony nonunion, fracture or loosening of internal fixation was observed. 1 patient in group A had temporal unilateral angulus oris deviation, which may have resulted from numbness of the mandibular marginal branch of facial nerve. The patient recovered after 3–6 months. Infection of wound was found in 1 case in group A and 1 case in group B, and they were treated in a timely manner. 2 patients in group B had a slight open bite, but no chewing problems. 1 patient in group B complained about clicking of the mandibular joint. 6 participants in group B were determined to have mild inferior alveolar nerve injury, and the symptoms disappeared soon after the surgery, within 3 months. 3 subjects in group B were diagnosed with severe inferior alveolar nerve damage, and almost returned to normal on T2 (Table 5). Owing to the extraoral access,

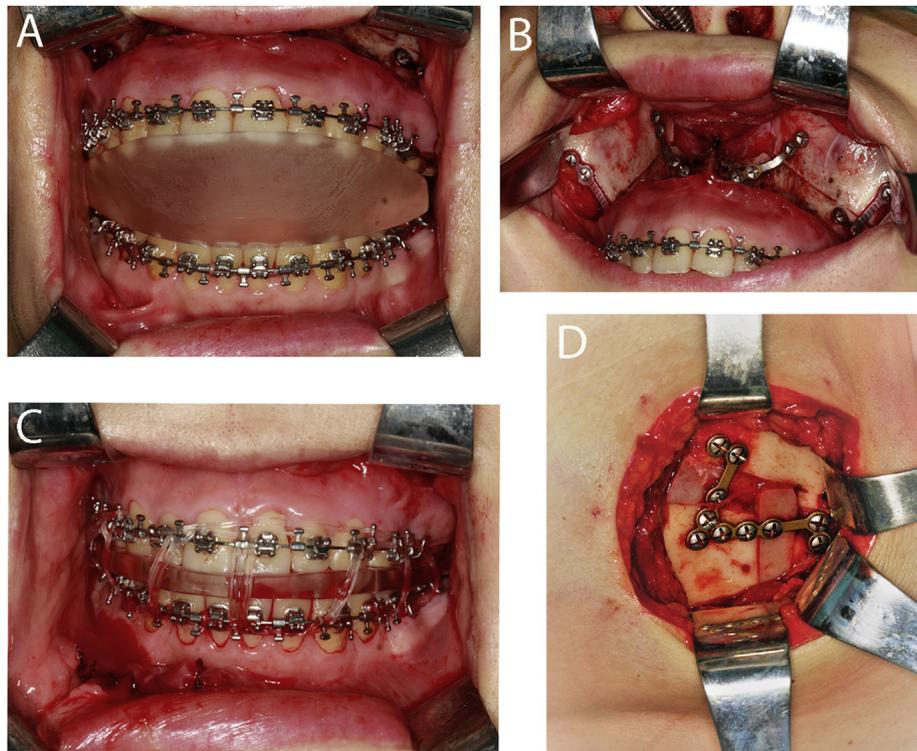


Fig. 3. Maxillary surgery was performed first under the guidance of the intermediate template(A) and fixed by titanium plate and screw(B). Mandibular surgery then performed under the guidance of the terminal template(C) and iliac bone graft filled the osteotomy space.

Table 1
Participant characteristics (N = 28).

Group	Procedures	Number	Gender		Age, years M(SD)	BMI M(SD)	Advancement, mm		Uplift, mm	
			Male	Female			MAX, M (SD)	MAN, M (SD)	MAX, M (SD)	MAN, M (SD)
A	I + Bi IIs + IV + V	9	3	6	22.3 (3.2)	20.9 (2.7)	1.4 (2.2)	13.1 (2.4)	3.2 (2.3)	
B	I + Bi IIIs + IV	19	12	7	44.3 (6.3)	25.8 (5.2)	2.3 (3.5)	6.7 (2.1)	4.3 (2.1)	

M(SD), mean (standard deviation); BMI, body mass index; MAX, maxillary; MAN, mandibular; Bi, bilateral. Procedures: I, Le Fort I osteotomy; II, the inverted L ramus osteotomy; III, the sagittal split ramus osteotomy; IV: genioplasty, V: iliac bone grafting.

Table 2
OSA related data.

	Group A			Group B		
	T0	T1	T2	T0	T1	T2
AHI	69.2 (8.4)	11.2 (2.4)	12.4 (1.9)	54.6 (14.6)	9.4 (5.4)	10.2 (3.6)
LSpO2	66.5 (7.7)	88.2 (4.6)	87.1 (4.1)	76.6 (10.7)	89.4 (2.4)	88.3 (3.5)
ESS	14.2 (1.2)	6.9 (1.9)	7.6 (2.6)	12.1 (3.1)	6.7 (1.4)	6.5 (2.4)
Success rate		88.8%	88.8%		89.4%	84.2%
Cure rate		44.4%	44.4%		46.1%	46.1%

Data are given as the mean (standard deviation). AHI, apnea and hypopnea index; LSpO2, lowest pulse oxygen saturation; ESS, Epworth Sleepiness Scale. Bold signifies surgery success was defined by an AHI <20 with at least a 50% reduction compared with baseline data on T0, and surgery cure was defined as AHI5.

an inconspicuous scar in the submandibular area was inevitable in all patients in group A.

3.7. Relapse

In fact, both groups had mild relapses in terms of sleep breathing and facial bones. Compared with T1, the parameter data on T2 all declined to a certain extent. The mean AHI relapse in two groups were 10.7 ± 2.1 % and 8.9 ± 9.2 %, and mean SpO2 were 1.3 ± 0.9 % and 1.2 ± 0.9 %, while mean ESS changed little ($P > 0.01$).

Compared with PSG data changing, more obvious skeleton and airway relapse could be observed. Relapse of AV and SNB were pronounced. Using the Wisconsin Rank test to compare the recurrence of two groups after T1, except for SNB and AL, no significant difference could be seen in relapse of other parameters.

4. Discussion

OSA is a kind of potentially fatal disease, and MMA has proved its efficacy in the treatment of OSA (Varghese et al., 2012). MMA

Table 3
Data of radiographic changes.

		Group A			Group B		
		T0	T1	T2	T0	T1	T2
Airway	AV (mm ³)	12911.3 (2931.2)	20857.1 (1796.9)	18781.4 (2313.5)	14015.8 (2011.2)	19971.5 (1435.1)	17945.9 (1942.4)
	AL (mm)	47.2 (2.1)	47.5 (3.3)	47.4 (1.3)	48.1 (4.5)	46.5 (4.3)	46.9 (2.3)
	min CSA, (mm ²)	69.1 (27.4)	171.2 (15.3)	170.1 (9.4)	128.2 (21.8)	178.2 (19.1)	175.2 (18.1)
	PAS (mm)	5.9 (2.3)	10.7 (2.2)	10.1 (2.7)	7.3 (2.4)	10.5 (1.4)	10.1 (4.3)
Hyoid	H-Frankfort (mm)	107.3 (3.6)	107.0 (2.4)	107.1 (3.4)	108.2 (6.1)	104.1 (5.2)	105.2 (7.1)
	H-BaN(mm)	89.3 (4.1)	91.2 (6.3)	90.4 (5.7)	88.6 (5.2)	94.1 (3.4)	92.9 (4.7)
	H-MP(mm)	24.7 (4.2)	23.9 (3.6)	24.1 (3.6)	26.3 (4.7)	24.1 (3.4)	22.1 (3.2)
	H'-N'	63.2 (11.2)	59.4 (7.9)	60.7 (8.9)	60.2 (6.6)	57.1 (4.9)	58.1 (8.2)
Maxillofacial	SNA (°)	80.7 (2.1)	82.1 (2.8)	81.9 (1.9)	80.3 (2.4)	85.4 (2.0)	84.7 (1.2)
	SNB (°)	68.3 (1.6)	77.0 (1.4)	74.4 (2.8)	73.1 (2.4)	78.7 (2.3)	76.6 (3.1)
	ANB (°)	12.4 (2.7)	5.1 (3.4)	7.5 (2.6)	7.3 (2.4)	6.9 (1.5)	7.1 (1.7)
	Ramus height(mm)	46.2 (8.1)	60.2 (10.1)	59.6 (7.9)	61.8 (3.4)	62.1 (4.1)	61.9 (2.9)

Data are given as the mean (standard deviation).

T0:1 week before surgery; T1: less than 3 months after surgery; T2: more than 12 months after surgery.

AV, airway volume; AL, airway length; min CSA, the minimum cross-section area; PAS, the minimal distance between the base of the tongue and the posterior pharyngeal wall.

Height of hyoid: Vertical direction: H-Frankfort, H-BaN, H-MP; Anterior-Posterior direction: H'-N'.

SNA, the maxillary prognathism; SNB, the mandibular prognathism; ANB, the relative prognathism.

commonly consists of a Le Fort I osteotomy and bilateral SSRO (Pirklbauer et al., 2011; Ronchi et al., 2013). SSRO is used mostly in MMA because of its versatility and its amenability to rigid fixation (Baek and Lee, 2010; Zhu et al., 2012). First introduced by Trauner and Obwegeser et al., in 1957, ILO was considered an effective alternative for the treatment of mandibular deficiency (Collantes et al., 2015). ILO could supply a large increment in mandible height and length, which advanced both the mandible and the relevant soft tissue. According to this mechanism, we take it for granted that ILO was an effective method for OSA, however no study confirmed the efficacy and feasibility.

In this study, we obtained positive results in both of the two groups. After MMA, sleep breathing conditions of patients in the two groups both significantly improved according to PSG. Additionally, patients in the two groups felt more energetic during the daytime after treatment according to ESS. In the two groups, the data of the upper airway changed significantly. Correspondingly, the airway became wider and more voluminous (Fig. 3) as previous studies indicated (Butterfield et al., 2015; Mattos et al., 2011). Accompanied by Le Fort I osteotomy and genioplasty, SSRO and ILO expanding the airway may benefit by some mechanism that creates a bigger space to accommodate the tongue body so that the tongue base moves forward with it and strains the soft tissue. In addition to relief from OSA, patients also benefited from improved facial appearance after MMA (Fig. 5). The mandibular retrusion was corrected in two groups; the unsatisfactory appearance was corrected. Adopting counterclockwise rotation MMA, there was no excess protruding maxilla occurring in the two groups. Almost all participants in the two groups were satisfied with their post-operative appearance in this study. It is obvious that ILO and SSRO are both feasible and effective as treatments for OSA.

There actually existed some differences between the results of the two groups. From pre-operative photos and cephalometric data, a shorter ramus ($p < 0.01$) and more severe micrognathia (smaller SNB) ($p < 0.01$) could be seen in patients in group A. In comparison with group B, patients in group A were younger ($p < 0.01$) and more emaciated (smaller BMI) ($p < 0.01$), and they suffered more severe OSA before operation according to PSG. Consistent with higher pre-operative AHI ($p < 0.01$), airway conditions (smaller AV, min CSA and PAS) were also worse in group A ($p < 0.01$).

With a higher baseline, a little larger reduction in mean AHI of 84.1% in group A than that of 80.9% in group B was observed ($P < 0.01$). A greater increase of mean SpO₂ ($p < 0.01$) and greater decrease of mean ESS ($p < 0.01$) were also observed in group A. ILO could provide a greater amount of improvement, but in fact, it

shared a similar success rate and cure rate with SSRO, and these results were close to those in other series (Düzlü et al., 2018; Pirklbauer et al., 2011; Ronchi et al., 2013).

ILO could be a more feasible method for selected OSA patients with severe mandible deformities according to the results. Larger mandibular and ramus height advancement was needed for participants in group A to correct severe deformities, and ILO could just meet the requirement. Larger airway improvements could be also seen in group A. Patients with more severe pre-operative deformities may have lower psychological thresholds, and serious breathing problems made them focus more on OSA, thus they were relatively easy to satisfy regarding the change in their countenance. Therefore, it is not surprising that group A had a higher satisfaction rate although still some flaws in their postoperative appearance. ILO could correct mandibular defects by increasing the height and length of mandible simultaneously, and it has the advantage in large advancements (>12 mm) (Medeiros and Ritto, 2009). The deficient ramus makes it hard to split and fix by SSRO and undesirable fracture might occur, while ILO is able to handle the problem (Zhu et al., 2012). It is also more suited for the 5 patients who accepted TMJ arthroplasties rather than SSRO in this study. Without exposing the inferior alveolar nerve (IAN), ILO showed a lesser incidence of neurosensory disturbance as other literature mentioned (Kobayashi et al., 2006), and none of the participants accepting ILO had IAN damage.

On the contrary, ILO took a longer time and resulted in more bleeding than SSRO, and an extra surgical site was needed to harvest bone graft in the ILO operation. To some extent, ILO may be more difficult and riskier than SSRO. Additionally, through an external entrance, submaxillary scar remained after ILO, and facial nerve branch injury may occur. However, possibly related to lengthening of the ramus, it is worth noting that ILO did not correct AL as SSRO did in this study. Regarded as an adverse factor for OSA, longer AL may be detrimental to decreasing upper airway resistance. On the other hand, changes of hyoid bone position differed in the two groups. Excluding the genioplasty factor, SSRO could provide an additional upward movement trend for hyoid compared with ILO. At present, we are not sure whether it is an absolute advantage for expanding the airway and maintaining stability. Furthermore, small fragments of bone may get less blood supply and tend to be absorbed. At the same time, greater muscle strength may be generated after larger advancement. Therefore, if SSRO could solve the OSA, there is no need to use ILO to undertake unnecessary risks.

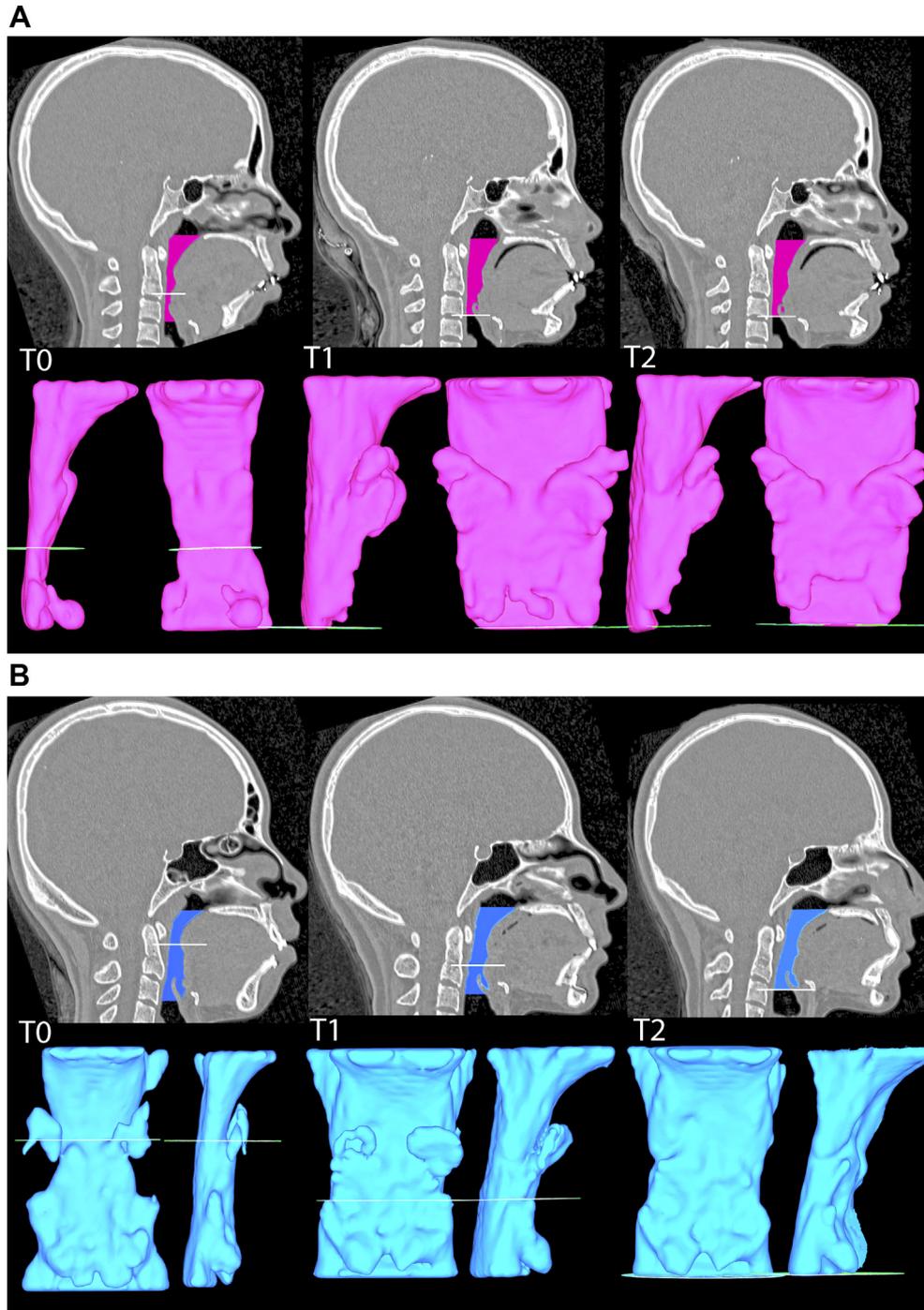


Fig. 4. Spiral CT 3D reconstruction of upper airway on T0, T1 and T2. Boundaries are palatal plane, nadir of epiglottis and lateral walls, posterior wall, anterior wall of upper airway. Green lines represent the min CSA. 4.1. A 27-year-old female participant in group A. 4.2. A 35-year-old male participant in group B.

Table 4
Facial appearance scoring.

	Group A	Group B
Very dissatisfied	0 (0%)	0 (0%)
Dissatisfied	0 (0%)	0 (0%)
Neutral	1 (11.1%)	3 (15.7%)
Satisfied	4 (44.4%)	9 (47.4%)
Very satisfied	3 (33.3%)	7 (36.9%)

In fact, due to a variety of reasons, only 1 participant in group A and 3 participants in group B in our current study have been involved in the long-term study for 5 years, while other participants have been involved for 2 years at least and are still being followed up. In our study, there existed a mild relapse in both groups in the follow-up, and no significant difference could be detected in participants two groups. Absolutely, the long-term stability of ILO and SSRO need more long-term evaluation. Our studies dealt with a highly selective population, and more cases are

Table 5
Postoperative complications.

	asphyxia	Open bite	infection	nerve injury		Bone non-union or fracture	Temporomandibular joint abnormalities	
				facial nerve	inferior alveolar nerve		pain	clicking
Group A	0	0	1	1 ^a	0	0	0	0
Group B	0	2	1	0	9 ^b	0	0	1

^a Facial nerve mandibular margin branch was affected.

^b The lower alveolar nerve was slightly injured of 6 participants, recovered within six months, and obvious injured of 3 participants improved gradually.



Fig. 5. Face and profile anthropometric photographs on T0, T1 and T2. Patients obtained much better appearances, and retrognathias were corrected. Faint scar behind the angle of the mandible could be seen in the case of group A.

needed to identify the precise characteristics of the OSA patients who will benefit from ILO and SSRO.

5. Conclusions

From the results above, MMA containing ILO and MMA containing SSRO are both effective for treatment of OSA. For OSA patients with severe micrognathia, insufficient ramus, and aberrant TMJ, ILO maybe more feasible. On the other hand, SSRO should be first choice for OSA patients with mild deformities.

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Ethical approval

All procedures involving human participants were approved by the Institutional Board of Ethics of the hospital.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Declaration of Competing Interest

Neither of the authors has any conflicts of interest. Each of authors has nothing to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jcms.2019.10.003>.

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