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One-Stage treatment for maxillofacial asymmetry with orthognathic and contouring surgery using virtual surgical planning and 3D-printed surgical templates

Zhifan Qin, Zhen Zhang, Xiang Li, Yu Wang, Peng Wang, Jihua Li*

State Key Laboratory of Oral Diseases and Department of Oral and Maxillofacial Surgery, Sichuan University, West China College of Stomatology, Chengdu 610041, China

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KEYWORDS
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Virtual surgery;
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Summary *Purpose:* Asymmetry is one of the most common maxillofacial deformities. One-stage treatment for maxillofacial asymmetry with orthognathic and contouring surgery has been rarely reported. This retrospective study aims to investigate the feasibility of simultaneous orthognathic and facial bone contouring surgery with the help of virtual surgical planning and 3D-printed navigation templates for facial asymmetry.

Patients and Methods: From January 2012 to December 2015, 51 patients diagnosed with maxillofacial asymmetry received treatment of combined orthognathic and contouring surgery under the guidance of virtual surgical planning and 3D-printed templates. Photographs and measurements were taken before and after operation to evaluate the effectiveness of the treatment.

Results: Photographs and cephalometric analysis showed the asymmetry was effectively corrected. All patients were satisfied with the aesthetic results.

Conclusion: This study suggested the clinical feasibility of simultaneous orthognathic and contouring surgery for the treatment of maxillofacial asymmetry. Virtual surgical planning and 3D-printed surgical templates enable the surgeons to plan and carry out the procedure more predictably and achieve satisfactory outcomes.

Introduction

Symmetry is an essential feature in human aesthetics, and an asymmetric face is usually considered as inharmonious and unattractive. For patients with maxillofacial

* Corresponding author.
E-mail address: leejimwa6698@sohu.com (J. Li).

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Table 1 Operative methods and appraisal of patient satisfaction of maxillofacial asymmetry of 51 patients.

Group	Patients (n)	Operative methods	Degree of satisfaction		
			Very satisfied	Satisfied	Not satisfied
I	12	A + E	11	1	0
II	29	A + C + E	27	2	0
III	10	A + B + D + E	8	2	0

Abbreviations: A, bilateral sagittal split ramus osteotomy; B, ipsilateral condylectomy and vertical ramus osteotomy and contralateral sagittal split ramus osteotomy; C, Le Fort I osteotomy; D, TMJ surgery; E, contouring surgery.

deformities, facial asymmetry, especially asymmetry of the lower face, is a common chief complaint. Currently, the etiology of facial asymmetry is not yet fully understood, but it is generally accepted that maxillofacial asymmetry is related to hereditary as well as environmental factors during the fetal, infant, or adolescent periods.[1]

Briefly, balance in facial symmetry is determined by the position, volume, and shape of both soft and hard tissues. Orthognathic surgery is a well-recognized treatment for facial asymmetry by repositioning the maxillofacial bones to a more satisfactory position. However, orthognathic surgery alone cannot remarkably change the shape and volume of jawbones, and additional contouring surgical procedures are usually required.[2] Since Legg's first report on masseteric hypertrophy in 1880, various surgical methods have been applied to correct an asymmetric face, and both orthognathic and contouring surgeries have been reported to correct facial asymmetry. However, one-stage treatment of simultaneous orthognathic and contouring surgery to correct facial asymmetry is rarely reported.[3] Moreover, for patients with additional aesthetic problems such as square face or malar prominence, surgeons need to formulate a plan not only to correct the patients' asymmetry but also to simultaneously solve patients' other aesthetic problems.[4-6] Therefore, the authors propose that a comprehensive treatment plan should be developed for patients with facial asymmetry to acquire satisfactory aesthetic outcomes.

Recently, advanced techniques such as computer-aided design/computer-aided manufacturing (CAD/CAM) and rapid prototyping (RP) are implemented to assist the treatment of such complex maxillofacial deformities.[7,8] This article highlights the use of such techniques complemented with virtual surgery and 3D surgical templates in the treatment of facial asymmetry.

Patients and methods

From January 2012 to December 2015, 51 patients (age range from 18 to 33 years) diagnosed with maxillofacial asymmetry were treated with simultaneous orthognathic and contouring surgery at the Department of Oral and Maxillofacial Surgery (West China Hospital of Stomatology, Sichuan University, Chengdu, China). The inclusion criteria were as follows: (1) Patients who had a chief complaint of facial asymmetry and were clinically diagnosed to have maxillofacial asymmetry; (2) patients for whom facial asymmetry was related to hyperplasia of maxillofacial bones and the affected side was considered unappealing by both patients and surgeons; (3) patients treated with simultaneous orthognathic and contouring surgery; and (4) patients who received complete orthodontic treatment. The exclusion criteria were as follows: (1) Patients treated with either orthognathic or contouring surgery alone; (2) patients for whom facial asymmetry was related to hypoplasia of maxillofacial bones; and (3) patients presenting with systemic diseases. The follow-up was 6–24 months with an average of 13 months. The present retrospective study was approved by the West China Hospital of Stomatology Institutional Review Board (WCSHIRB), and all patients provided informed consent.

Of 51 patients, 12 of them (Group I) presented with only mandibular asymmetry and one-jaw orthognathic surgery was performed along with genioplasty and contouring surgery and the remaining 39 patients presented with bimaxillary asymmetry and two-jaw orthognathic surgeries were performed combined with genioplasty and contouring surgery (Groups II and III). Among the 39 patients, 10 of them (Group III) were accompanied by severe mandibular condylar hyperplasia (eight patients) or condylar osteochondroma (two patients). Histopathological examinations including safranin O staining and safranin-fast green staining were used to differentiate the two pathological conditions.[9] Condylectomy and condylar reconstruction were performed by way of sliding vertical ramus osteotomy (VRO) with the medial pterygoid muscular pedicle to reconstruct the condyle. Information about the patients is listed in Table 1. The procedures were formulated according to clinical examinations, cephalometric measurements, and patients' subjective willing.

All patients were treated according to the following protocol: (1) Preoperative orthodontic treatment; (2) routine radiological examinations including panoramic, frontal, and lateral X-rays and spiral computed tomography (CT) with 1 mm thickness and more than 400 slices per scan; (3) virtual surgery planning; (4) combined orthognathic and contouring surgery; (5) postoperative orthodontic treatment; and (6) Postoperative evaluation.

Virtual surgery and 3D-printed surgical templates

Facial asymmetry is a type of complicated three-dimensional (3D) deformity in the field of maxillofacial surgery. Traditionally, the choice of surgical procedure depends mainly on surgeon's clinical experience and patients' subjective needs instead of quantitative analysis. Traditional 2D cephalometric radiographs are usually of limited use for understanding complicated jaw deformities because it lacks 3D analysis.[10] Moreover, the traditional model surgery is complex and time consuming, which also fails to accurately simulate surgical procedure for the complex asymmetric deformities. With the development of virtual surgery, we are offered with new methods to solve these problems. The cephalometric analysis based on 3D reconstruction provides us with a comprehensive view of maxillofacial tissues, and virtual surgery enables the surgeons to plan the procedures properly and accurately. Additionally, 3D-printed templates facilitate the transfer from virtual plan to actual surgery.[11]

All the patients underwent spiral CT examinations, and the images were obtained in the Digital Imaging and Communications in Medicine (DICOM) format. A surface scanning image of the dental arch was collected 1 month before the surgery and obtained in the STep ladder instruction (STL) format. Data were processed with Mimics software version 12.0. DICOM data from CT scan and STL data from dental arch scan were superimposed to construct a composite skull model with accurate dentition.

Measurements were taken using "measurement and analyze" function in Mimics to evaluate the severity of facial asymmetry. The measurement was performed on spiral CT to analyze the maxillofacial asymmetry based on the methods promoted by Grummons in 1987. Frankfort horizontal plane (the plane passing the bilateral porion and left inferior orbitale), midfacial plane (the plane perpendicular to the FHP through the nasion), and coronal plane (the plane perpendicular to the FHP through the sella point) were selected as base planes. Mx-mid represents differences in the distance from bilateral Mx points (Maxillare points, intersection of tuber maxilla and zygomatic arch on the jugular process) to the midfacial plane. Ag-mid represented the difference in the distance from bilateral Ag points (Antegonion points, the deepest point of antegonial notch of the mandible) to the midfacial plane. Ag-Me represented difference in the distance from bilateral Ag points to the Me point (Menton point, most inferior point on mandibular symphysis). Ag-FH represented the difference in the distance from bilateral Ag points to the FH plane. Me-Mid represented the distance from the Me point to the midfacial plane. SOZ-mid represented the difference in the distance from bilateral summit of zygoma points (SOZ points) to the midfacial plane. SOZ-FH represented the difference in the distance from bilateral summit of zygoma points to the FH plane. U1-mid/L1-mid represents the distance from the upper/lower central point of central incisors to the midfacial plane. U3-mid/L3-mid represented the difference in the distance from bilateral upper/lower cuspids to the midfacial plane. U6-mid/L6-mid represented the difference in the distance from bilateral upper/lower mesio-buccal cusps of first molar to the midfacial plane. Data of the oblique side were recorded as a positive number, and the contralateral side was recorded as a negative number. Statistics of patients performed with one-jaw orthognathic surgery (Group I, 12 patients) and two-jaw orthognathic surgery (Group II + III, 39 patients) were processed separately (Figure 1).

The data were processed in SPSS software version 22.0 (Chicago, IL, USA). The mean differences in different groups were compared using the independent samples *t*-test, and the mean differences of pre- and postoperation in the same group were compared with the paired *t*-test. A P-value less than 0.05 was considered to be statistically significant.

Virtual surgery was simulated on the software program after the measurements (Figure 2). In two-jaw orthognathic surgery, two sets of nylon-guiding templates, namely, intermediate templates and final templates, were designed and fabricated using an SLS 3D printer (Stratasys Co. Ltd, US). The design and fabrication of navigation templates were provided by Shenzhen PTY Medtech Co., Ltd (Figure 3). These kinds of templates directly repositioned the maxilla in the virtual position independent of the mandible, as well as determined the final occlusion and the position of the mandible.[11-12] After the simulation of orthognathic surgery, the mirror reverse function was used to evaluate the asymmetry of the facial contour. Orthognathic surgery only corrected the positions of the jawbones. Facial asymmetry still existed, especially in the inferior border of the mandible, chin, and zygoma. Different procedures of contouring surgery were selected on the basis of patients' facial characteristics. Zygoma and zygomatic arch reduction were performed on patients with unilateral malar prominence. Mandibular outer cortex splitting ostectomy was performed to correct lateral prominent mandibular angle, and mandibular "V-line" ostectomy formed by two lines of osteotomy on both sides of the mandible was performed to correct inharmonious mandibular inferior border. Similarly,

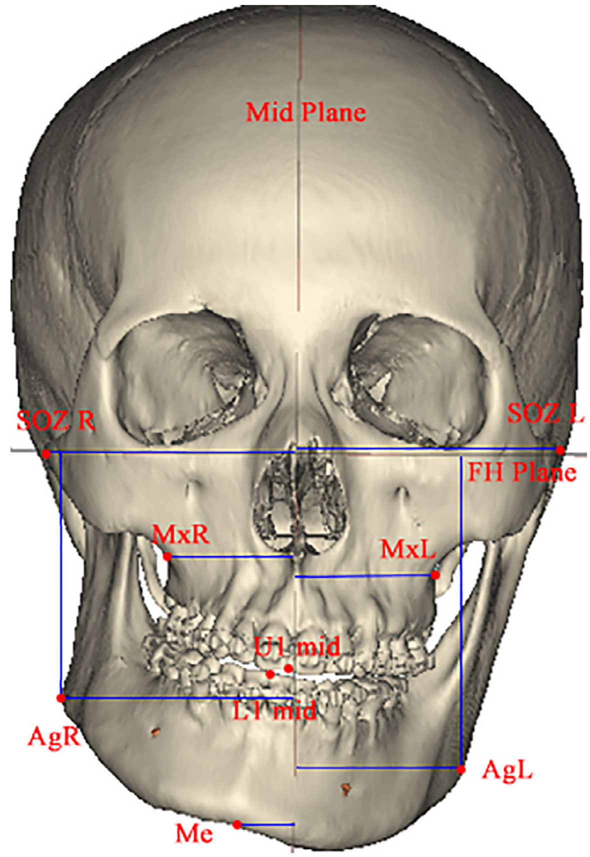

Figure 1 Measurements based on CT scans in patients with facial asymmetry. Mx (Maxillare): intersection of tuber maxilla and zygomatic arch on the jugular process; mid: midfacial plane; Ag (Antegonion): the deepest point of antegonial notch of the mandible; Me (Menton): most inferior point on mandibular symphysis; FH: Frankfurt horizontal plane; SOZ: summit of zygoma; U1/L1: upper/lower central point of central incisors.

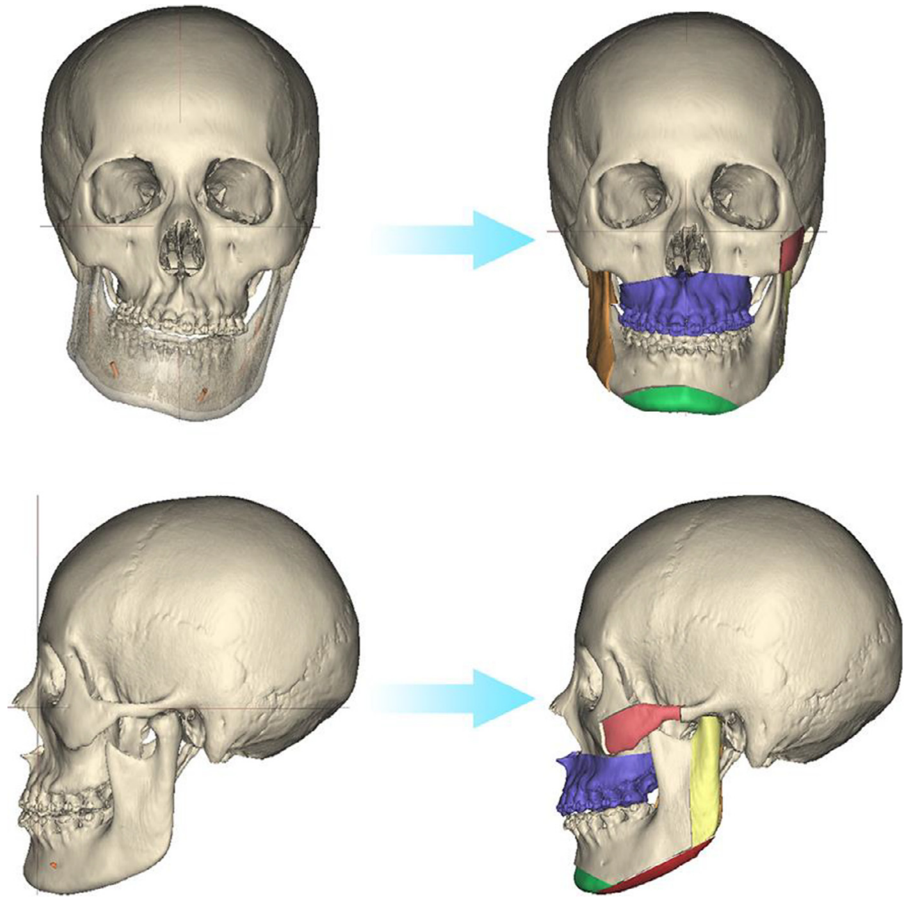

Figure 2 Illustrations of virtual surgery planning for a patient who underwent Le Fort I osteotomy, TMJ surgery, vertical ramus osteotomy, SSRO, combined with genioplasty, contouring surgery including V-line osteotomy, and zygoma and zygomatic arch reduction.

a series of templates were fabricated to assist the contouring surgery.[6,13]

Surgical procedures

All procedures were performed under general anesthesia using nasotracheal intubation. Negative pressure drainage was applied and removed 3–4 days postoperation.

During the surgery, a series of surgical templates were utilized to transfer the virtual plan to actual surgery (Figure 4). In two-jaw orthognathic surgery, the templates often consisted of the intermediate occlusal splint, the final occlusal splint, two pairs of 3D arms, and a series of bone attachments. First, bone attachments with a guiding line were fixed on the surface of the maxilla using mini-screws with the help of the intermediate occlusal splint and the 3D arms. Osteotomy was performed by a marked guiding line. After fracture of the maxilla, the final splint was positioned with the help of the second pair of 3D arms. Rigid internal fixation was done following repositioning of the maxilla, and all the templates were removed. All these procedures mentioned above were independent of the mandible. Next, SSRO or VRO of the mandible was performed with the help of a final occlusal splint, intermaxillary fixation was done, and normal occlusal relationship was achieved. To achieve a harmonious facial contour, genioplasty and contouring surgery were performed. The osteotomy line of the mandibular inferior border was guided by surgical templates attached to the final occlusion splint. With the help of the indication line, resection of the excessive mandibular inferior border was performed. Similarly, the osteotomy line of genioplasty was ensured under the guidance of surgical templates. The 3D arms were then removed, and repositioning of the chin was performed. The chin was fixed with internal fixation plates and screws.

Results

All patients showed uneventful postoperative recovery. No major complications such as infection, jaw displacement, and osteonecrosis were observed. Minor postoperative complications occurred, such as transient lip numbness caused by dissection of the mental nerve (5.9% (3/51)), transient numbness in the infraorbital area caused by dissection and exposure of infraorbital nerve (3.9% (2/51)) and transient disability of frowning caused by dissection and stretching of the frontal branch of the facial nerve (3.9% (2/51)). Spiral CT was performed 1 week and 6 months after surgery, and 3D measurements were taken again as described above to evaluate improvements in facial deviation.

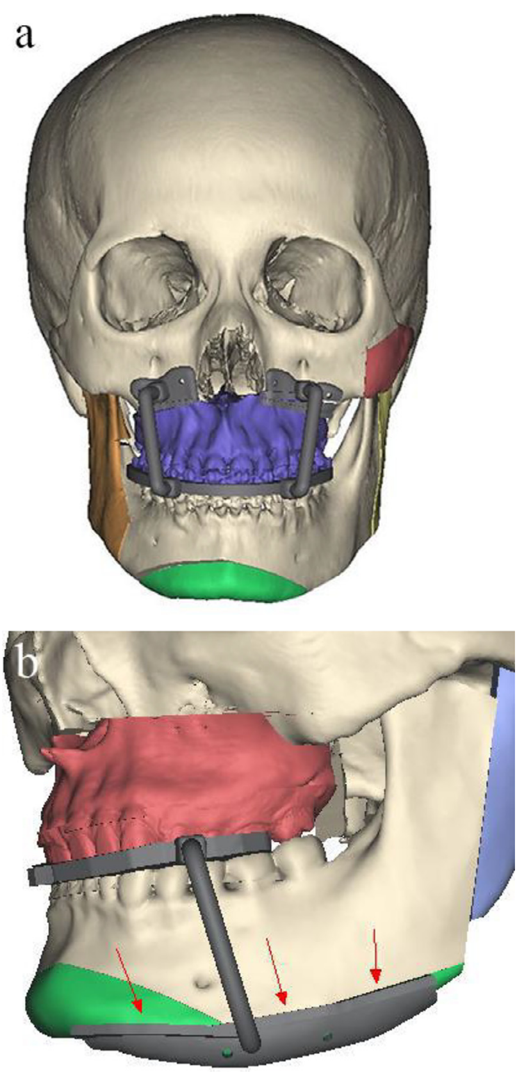

Figure 3 Pictures illustrating the design of typical guiding templates. Guiding templates of Le Fort I osteotomy (a) and V-line osteotomy (b).

The preoperative and postoperative CT revealed that discrepancy in bilateral facial widths was corrected significantly, and the facial contour became more harmonious ($P(T2 \text{ vs. } T1) < 0.05$; Table 2). Hard tissue changes in Group I patients were presented mainly on the mandible, whereas the maxilla remained relatively stable ($P(\text{Mx-mid}, T2 \text{ vs. } T1) > 0.05$). Chin deviation was the most evidently corrected asymmetry (5.85 ± 2.49 mm of Me-mid preoperation and 1.08 ± 0.47 mm of Me-mid postoperation). Hard tissue changes in Groups II and III patients were presented on both the maxilla and the mandible. Mandibular ramus height was the most evidently corrected asymmetry (8.30 ± 3.47 mm of Ag-FH preoperation and 1.36 ± 0.90 mm of Ag-FH postoperation). Patients performed with zygoma and zygomatic arch reduction showed significant improvement in zygomatic asymmetry (2.24 ± 0.78 mm of SOZ-mid preoperation and 0.32 ± 0.30 mm of SOZ-mid postoperation in Group I as well as 2.73 ± 1.03 mm of SOZ-mid preoperation and 0.35 ± 0.33 mm of SOZ-mid postoperation in Groups II + III).

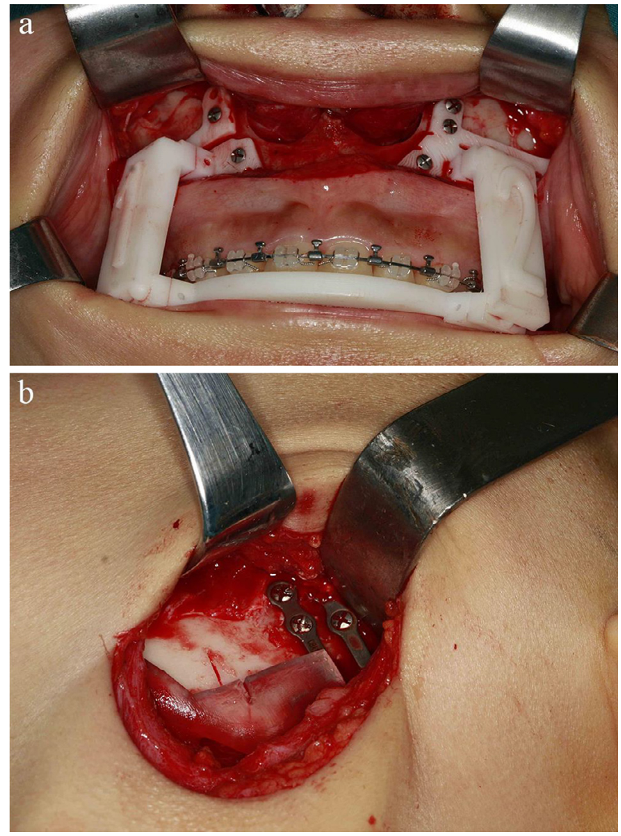

Figure 4 Photograph of the procedures of Le Fort I osteotomy (a). The maxilla was repositioned with the help of guiding templates. Photograph of vertical ramus osteotomy and V-line osteotomy (b). The osteotomy line of mandibular inferior border was indicated by guiding templates.

Facial frontal photos and occlusion were taken 6 months and 1 year after surgery, which also showed satisfactory aesthetic outcomes. The combination of orthognathic surgery, temporomandibular joint (TMJ) surgery, and contouring surgery showed expected clinical outcomes. All the patients remained in a stable Class I skeletal and occlusal relationship with no condylar recurrence confirmed by a CT scan. A questionnaire was sent to all patients to evaluate the degree of the satisfaction of the treatment, and all patients were satisfied with the aesthetic results (Table 1).

Clinical report

Patient 1

A 21 year old woman was referred to our center with a complaint of progressive facial asymmetry for more than 5 years. This patient experienced slow but progressive rightward facial deviation for several years. Extraoral examination showed left facial elongation and chin deviation 20 mm to the right. Moreover, her mandibular angles as well as cheekbones were prominent at the longer side. The difference between the bilateral mandibular ramus was obvious. Intraoral examinations showed Angle Class III malocclusion on the left side and a posterior cross bite on the right side with severe canting of the occlusal plane. Spiral CT showed

Table 2 Comparison of hard tissue index in patients with facial asymmetry by CT scans (mm).

	Group I							Group II + III						
	Preoperation (T1)		Postoperation (T2)		D-value(T2-T1)		P (T2 vs. T1)	Preoperation (T1)		Postoperation (T2)		D-value (T2-T1)		P (T2 vs. T1)
	Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	Mean	SD	
Mx-mid	0.84	0.53	0.75	0.50	−0.09	0.05	>0.05	2.73	1.24	0.65	0.55	−2.08	1.02	<0.001
Ag-mid	5.46	2.45	0.98	0.56	−4.48	1.68	<0.001	8.04	3.90	1.34	0.92	−6.70	3.24	<0.001
Ag-Me	2.17	1.08	0.64	0.42	−1.53	0.68	<0.001	2.92	1.05	0.85	0.89	−2.07	0.62	<0.001
Ag-FH	4.28	1.89	0.82	0.66	−3.46	1.41	<0.001	8.30	3.47	1.36	0.90	−6.94	3.34	<0.001
Me-mid	5.85	2.49	1.08	0.47	−4.77	1.42	<0.001	7.48	3.06	1.23	0.85	−6.25	1.91	<0.001
SOZ-mid*	2.24	0.78	0.32	0.30	−1.92	0.52	<0.001	2.73	1.03	0.35	0.33	−2.38	0.68	<0.001
SOZ-FH*	0.46	0.28	0.30	0.24	−0.16	0.27	>0.05	0.78	0.36	0.20	0.14	−0.58	0.21	<0.001
U1-mid	0.36	0.24	0.28	0.22	−0.08	0.05	>0.05	1.21	0.71	0.48	0.23	−0.73	0.57	<0.001
L1-mid	1.85	0.95	0.40	0.24	−1.45	0.60	<0.001	2.07	1.02	0.47	0.26	−1.60	0.92	<0.001
U3-mid	1.12	0.68	0.55	0.34	−0.57	0.20	<0.01	1.54	1.08	0.56	0.25	−0.98	0.82	<0.001
L3-mid	2.07	1.08	0.52	0.24	−1.55	0.82	<0.001	2.34	1.21	0.62	0.30	−1.72	1.08	<0.001
U6-mid	1.66	0.96	0.56	0.35	−1.10	0.68	<0.001	2.46	1.40	0.60	0.32	−1.86	1.16	<0.001
L6-mid	2.52	1.24	0.61	0.38	−1.91	1.09	<0.001	2.81	1.36	0.76	0.29	−2.05	1.21	<0.001

Mean differences of two-side facial measured distances. Group I: patients performed with one-jaw orthognathic surgery; Group II and III: patients performed with bimaxillary orthognathic surgery. Mx (Maxillare): intersection of tuber maxilla and zygomatic arch on the jugular process; mid: midfacial plane; Ag (Antegonion): the deepest point of antegonial notch of the mandible; Me (Menton): most inferior point on mandibular symphysis; FH: Frankfurt horizontal plane; SOZ: summit of zygoma; U1/L1: upper/lower central point of central incisors; U3/L3: upper/lower cuspid; U6/L6: upper/lower mesio-buccal cusp of first molar. *Only patients performed with zygoma and zygomatic arch reduction were recorded, including two patients in group I, 13 patients in group II, and seven patients in group III.

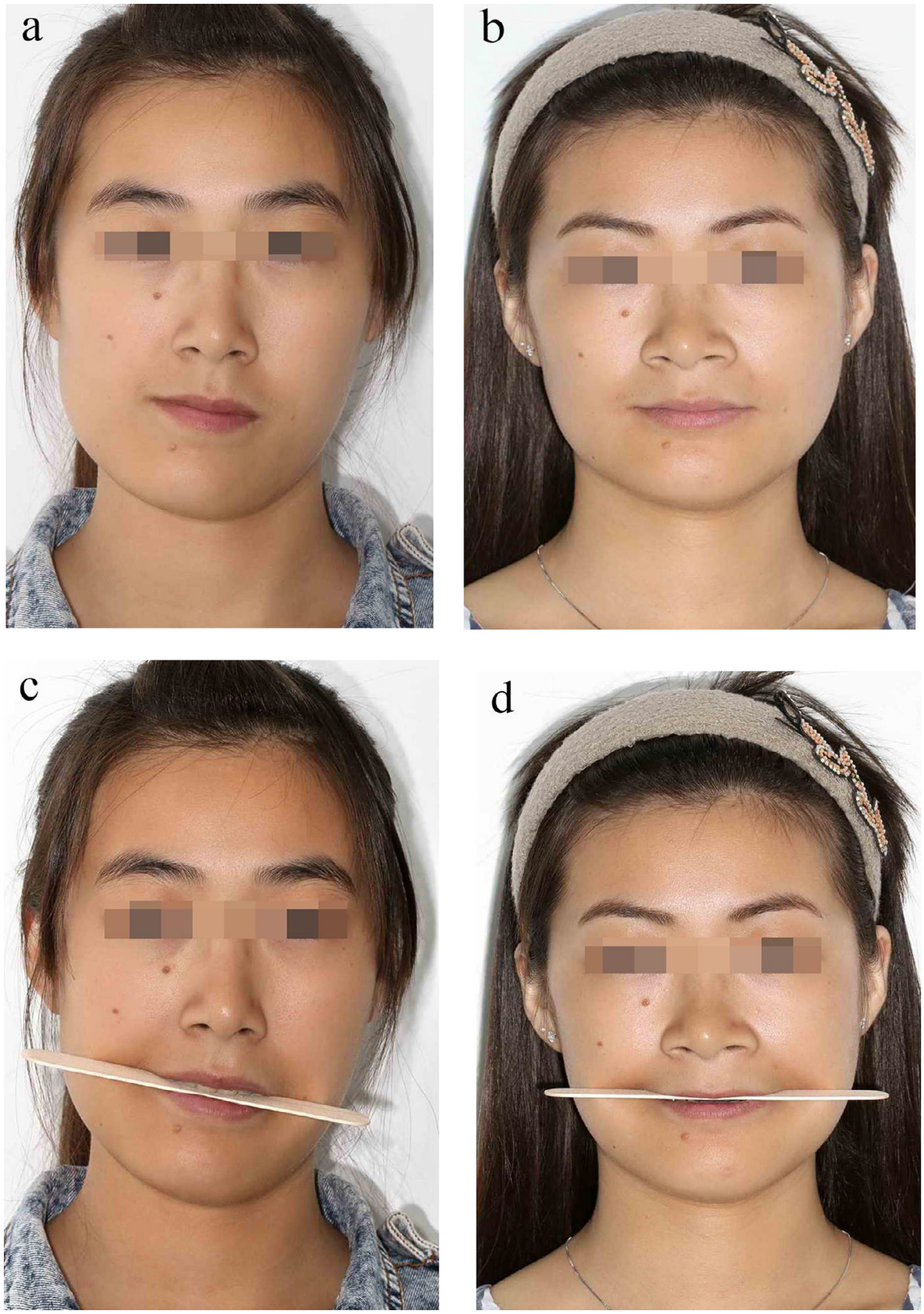

Figure 5 Preoperative views of a 21 year old woman in Case 1 (a, c). Postoperative views (b,d) after Le Fort I osteotomy, left condylectomy, left VRO, right SSRO, genioplasty, mandibular "V-line" ostectomy, and left zygoma and zygomatic arch reduction. Six month postoperative views show that the facial asymmetry is effectively corrected and the facial outline becomes slender and harmonious.

a large bony tumor of the left mandibular condyle, with an irregularly shaped structure extending medially and superiorly (Figure 2). Her clinical diagnosis was left condylar osteochondroma, left maxillary and mandibular vertical hyperplasia, severe mandibular asymmetry, left prominent mandibular angle, and cheekbone and chin deviation. A virtual surgical plan was made, and 3D-surgical templates were fabricated after 3D evaluation by spiral CT. The virtual surgical plan was discussed with the patient to ensure understanding and agreement. Le Fort I osteotomy and ipsilateral wedge ostectomy were performed on this patient with 3D-printed guiding templates to correct the right maxillary vertical hyperplasia. Condylectomy accompanied by condylar reconstruction with VRO from the retromandibular approach and contralateral SSRO from intraoral approach was performed to reposition the mandible. Then,

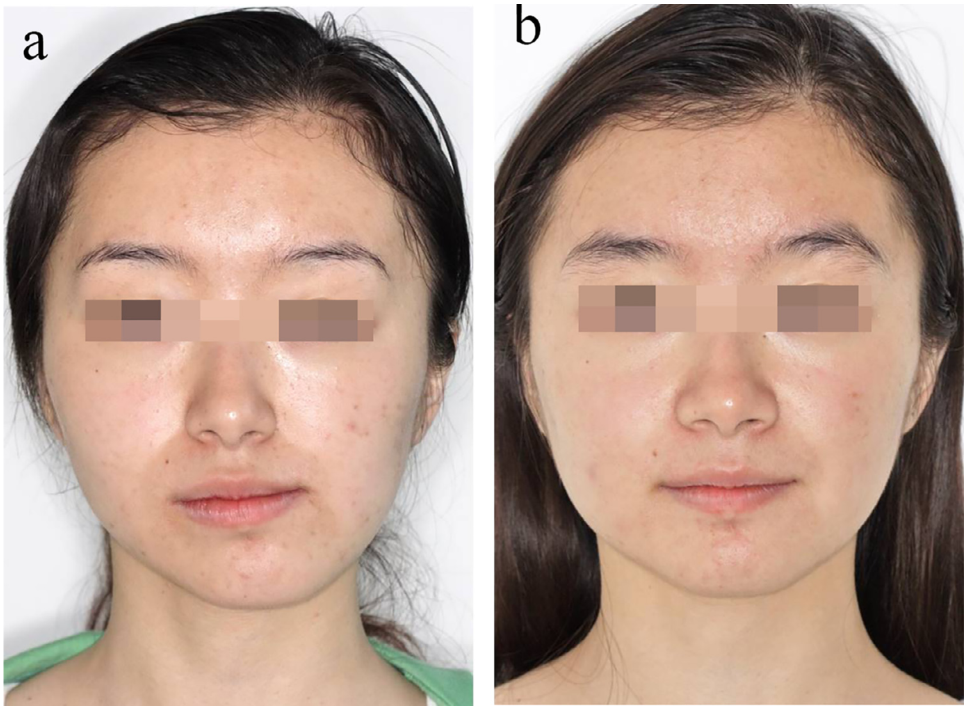

Figure 6 Preoperative view of a 23 year old woman in Case 2 (a). Postoperative view (b) 7 months after Le Fort I osteotomy, BSSRO, genioplasty, combined with mandibular "V-line" ostectomy as well as zygoma and zygomatic arch reduction. Note the balanced and symmetric facial profile.

genioplasty was performed for chin deviation; left zygoma and zygomatic arch reduction as well as V-line osteotomy were used to correct unilateral hyperplasia of the mandible inferior border and zygoma. The surgical procedures were successful with no evident complications observed. Negative-pressure drainages were removed after 3 days. Four weeks of intermaxillary fixation was used to stabilize the occlusion. The diagnosis of condylar neoplasm based on the histologic report was condylar osteochondroma. One month after surgery, the patient received postoperative orthodontic treatment. Spiral CT was performed 1 week and 6 months after surgery; then, 3D evaluation was performed again. Results showed the deviated facial bones were evidently corrected, with no recurrence of condylar osteochondroma. Additionally, postoperative occlusion and facial frontal imaging were improved remarkably (Figure 5b and d). From the anterior view, the width of the lower face as well as the cheekbone was narrowed. Excessive facial length and asymmetry were effectively corrected. From the lateral view, the square and prominent mandibular angle was corrected significantly and the contour of the inferior mandible became smooth. The patient was satisfied with the aesthetic outcomes.

Patient 2

A 23 year old woman presented with progressive facial deviation for more than 10 years. She was characterized by two-jaw deviation, with chin deviated 10 mm to the left, thereby leaving an impression of an evident facial asymmetry (Figure 6a). Intraoral examination revealed a posterior cross bite on the left. Her clinical diagnosis was laterognathism deformity, mandibular asymmetry, left maxillary vertical hyperplasia, left mandibular angle, malar prominence, and chin deviation. Le Fort I osteotomy and ipsilateral wedge osteotomy were performed to correct the right maxillary vertical hyperplasia and the deviated occlusal plane. Bilateral SSRO were performed to correct the mandibular asymmetry. Mandibular inferior border osteotomy was performed to improve the mandibular contour, and the zygoma and zygomatic arch reduction was performed to correct the right malar prominence. After 4 weeks of intermaxillary fixation, the patient received orthodontic treatment. Seven months later, photographs were taken (Figure 6b). Both radiographic imaging and photographs showed satisfactory outcomes.

Patient 3

An 18 year old man presented with mandibular deviation for approximately 5 years. This patient was characterized by deviation and protrusion of the mandible, without severe canting of the occlusal plane. His prominent chin deviated 8 mm rightward with right mandibular inferior border lower than the left side (Figure 7a). Intraoral examinations revealed anterior cross bite and Angle Class III malocclusion. After preoperative examination and orthodontic treatment, this patient received bilateral SSRO combined with mandibular angle and inferior border osteotomy. Negative-pressure drainages were removed after 3 days, and stable occlusion was maintained by intermaxillary fixation, which was removed 2 weeks after operation. Photographs taken 11 months after surgery (Figure 7b) showed effective correction of the deviated and protruding mandible and a significant improvement in his lower facial contour.

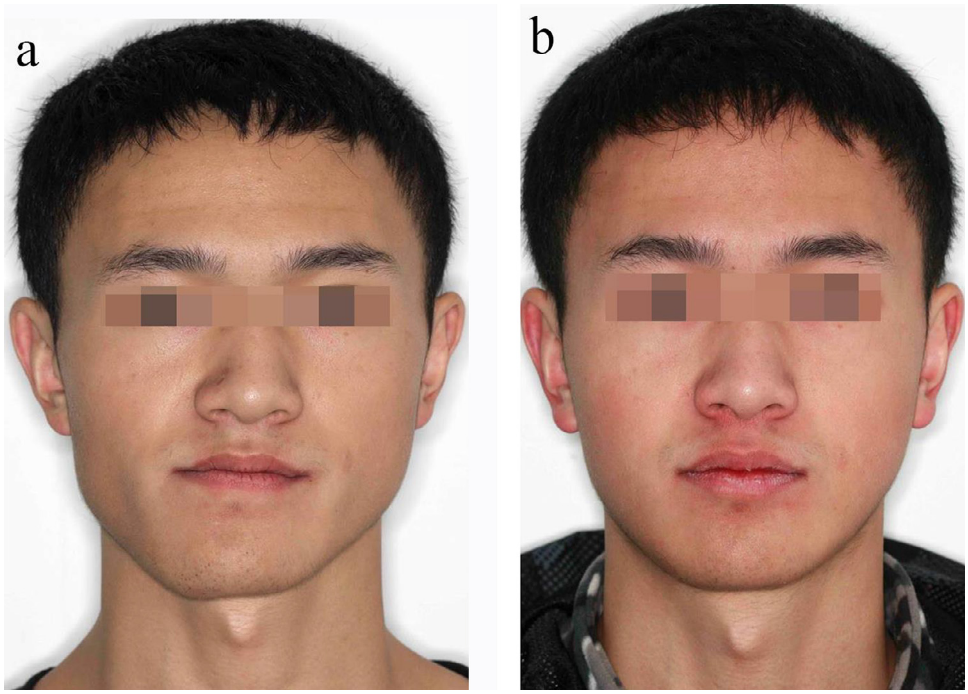

Figure 7 Preoperative view of an 18 year old man in Case 3 (a) and 11 months postoperative view (b) after Le Fort I osteotomy, BSSRO, and mandibular "V-line" ostectomy. The deviated and protruding mandible was effectively verified, and his lower facial profile was significantly improved.

Discussion

Facial symmetry is established on the balance of position, shape, and volume of the maxillofacial tissues. Many pathological conditions contribute to facial asymmetry such as hemimandibular or unilateral condylar hyperplasia. The usual method for correcting facial asymmetry involves orthognathic surgeries including Le Fort I osteotomy, sagittal split ramus osteotomy (SSRO), and VRO, as well as genioplasty. However, orthognathic surgery only corrects the asymmetry caused by jaw position. Condylar hyperplasia or osteochondroma and contour deficiency required additional surgical procedures.[2,14,15]

Mandibular condylar hyperplasia is a progressive and pathological condition that is generally observed as an acceleration of growth in young patients. Condylar osteochondroma, also known as osteocartilaginous exostosis, is one of the most common benign bone tumors and usually occurs in the metaphyseal regions of long bones. Both pathological conditions may lead to facial asymmetry, malocclusion, speech, and masticatory problems. Safranin O staining and safranin-fast green staining are proved to be effective in differential diagnosis.[9] For patients with mandibular condylar hyperplasia or condylar osteochondroma, condylectomy was used to remove the hypertrophic condyle or condylar tumor in this study.[16]

The shape and volume of the bones should be corrected by contouring surgery, especially in East Asians. The anatomical elements of the East Asian face are generally smaller than those of Caucasians. Thus, facial features with a prominent mandibular angle or cheekbone are considered as undesirable in Asian cultures. If these aesthetic features are not considered, it is possible that patients will be disappointed with their postoperative appearances. This cultural preference should draw adequate attention even though the patients' main complaint may be other problems.[5,6]

Previously, there have been publications on two-stage surgical treatment including orthognathic and contouring surgery in correcting maxillofacial asymmetry. However, two-stage surgical procedure is more time-consuming and less acceptable by patients. One-stage surgery of simultaneous orthognathic and contouring surgery is still preferred by patients and surgeons in terms of time and expenses.[3] Although one-stage surgical procedure increases the time of operation and the risks of complications, our practice proved it was feasible.

Three-dimensional CT imaging is an effective tool in diagnosing facial asymmetry, for it can directly reflect the condition of maxillofacial bones without any radiographic magnification. With measurements based on 3D constructions, surgeons can evaluate the severity and characteristics of facial asymmetry and understand how the maxillofacial bones should be rectified in three dimensions.[17] Virtual surgical planning and 3D-printed surgical templates serve as reliable assistances of the whole treatment process and provide support from preoperative measurement and analysis to diagnosis and surgical design, intraoperative osteotomy, bone reposition, rotation, and fixation.[8,18] In this study, virtual surgical planning was simulated and successfully transferred to simultaneous orthognathic and contouring surgery. The cutting guide of the bone attachments could guide the osteotomy line so that the exact amount of bone was removed quickly and accurately. The clinical outcome of the asymmetry cases suggested a favorable effectiveness. In conclusion, virtual surgical planning and 3D-printed surgical templates ensure accuracy in simultaneous orthognathic and contouring surgery for the treatment of maxillofacial asymmetry.

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Conflict of interest

Conflicts of interest: None of the authors has financial interests in any of the products, devices, or drugs mentioned in this article.

Ethical approval

This study was approved by the West China Hospital of Stomatology Institutional Review Board (WCSHIRB).

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