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Combined Use of Endoscopic Techniques and Virtual Surgical Planning for Intraoral Approach for Hemi-mandibular Resection and Reconstruction

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Background: The study aimed to describe our experience in using endoscopic procedures to aid hemi-mandibular reconstruction with bone flaps through transoral approach.
Methods: Five patients with huge benign mandibular tumors underwent transoral mandibulectomy and hemi-mandibular reconstruction, using endoscopy. Facial symmetry, occlusion, bone healing, and mandibular similarity were all evaluated postoperatively. The paired-samples *t* test was used to compare quantitative data, and a *P* value less than 0.05 was considered a significant difference.
Results: All five patients who received transoral mandibular surgery recovered in terms of TMJ functionality, facial symmetry, and aesthetic results. Endoscopy monitored and ensured that bone flaps were correctly connected and fixed. The accuracy of endoscopy-guided mandibular reconstruction was confirmed by quantitative examination for four cases, which revealed no statistically significant variations between postoperative CT analysis and preoperative virtual surgical planning data.
Conclusions: Endoscopy-assisted virtual surgery may resolve concerns with transoral hemi-mandibular reconstruction and broaden indications for mini-invasive mandibular reconstruction. However, only patients with benign mandibular tumors were included in our study, so surgeons should be very cautious if applying this technique to malignant lesions or bony tumors invading soft tissues. *(Plast Reconstr Surg Glob Open 2024; 12:e5644; doi: 10.1097/GOX.0000000000005644; Published online 4 March 2024.)*

INTRODUCTION

A satisfactory surgical approach should offer an adequate visual field, preserve vital anatomical structures, and ensure the best aesthetic effect, especially when the surgery involves facial parts. For defects caused by severe trauma and tumors in the mandible, bone flap is commonly used to restore mandibular continuity and oral functions.[1] However, a sizeable transplant surgery may require a combined oral-facial-cervical incision, which would inevitably leave patients with a massive faciocervical scar. Due to tissue traction and resection, such surgical approaches may also result in sensory and facial nerve dysfunction, leading to complications such as numbness, skewed mouth, and lagophthalmos.[2]

Digital virtual surgery and three-dimensional (3D) printing technology may be used to create an osteotomy guide plate and increase the precision of the 3D shaping of bone flap as well as matching dental implant sites. Likewise, prebending titanium plates according to 3D models enabled perfect shaping of bone flaps and preservation of drilling holes in vitro, which may considerably simplify the in situ adjusting process and make it possible to perform intraoral mandibular reconstruction.[3] Since 2014, several surgical teams have attempted to use intraoral incisions to remove jaw tumors and perform microsurgical bony repair aided by digital guiding plates. Bolzoni et al compared 21 patients who underwent

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mandibular reconstruction, using free fibula flaps through an intraoral incision or conventional faciocervical incision, which revealed comparable effects between two groups. However, after surgery, the minor scar noticeably enhanced patients' confidence and reduced disorders of facial movement and sensation impairment.[4] Despite the optimistic findings, intraoral reconstruction has always been limited to defects in the anterior parts of the mandible. It is difficult to perform tumor resection, osteotomy, and reconstruction plate fixation through an intraoral approach for lesions invading the mandibular ramus and condylar head.[5]

Traditional surgical approaches for temporal mandibular joint surgery have been altered by endoscopic technology. Its application in the reduction and fixation of condylar fractures also proved its effectiveness.[6,7] We believe that by combining endoscopic technology and virtual surgical planning (VSP), intraoral jaw reconstruction may be acquired in cases with larger mandibular reconstruction. In this article, we shared our experience in using an endoscope to facilitate hemi-mandible reconstruction, which enabled precise placement and accurate fixation of bone grafts.

Takeaways

Question: Intraoral mandibular reconstruction has always been limited to defects in the anterior parts of the mandible. It is difficult to perform tumor resection, osteotomy, and reconstruction through an intraoral approach for lesions involving the mandibular ramus and condylar head.

Findings: Endoscopic technology may assist microsurgical hemi-mandibular reconstruction for huge benign tumors through an intraoral incision.

Meaning: We believed that by combining endoscopic technology and virtual surgical planning, we could achieve breakthroughs in intraoral jaw reconstruction.

MATERIALS AND METHODS

This prospective nonrandomized study investigated five patients who underwent surgical resection of tumors invading subcondylar regions, followed by vascularized bone flap reconstructions from February 2019 to May 2021 at the Department of Oral and Maxillofacial Surgery, School of Stomatology, the Fourth Military Medical University in Xi'an, China. All patients signed informed consent, and this work was authorized by the hospital directorate. As shown in Table 1, information about patients, tumor locations, and treatments was collected. During the hospitalization, flap perfusion, wound healing, and infection onset were all monitored daily. The follow-up visits were provided monthly during the first half year, and then once every 3 months. The postoperative complication rate and the facial recovery were assessed during the follow-up period, and the evaluation criteria included free flap survival, facial symmetry, mouth openness, and occlusion of the dentition.

The data of four patients who underwent segmental mandibular reconstruction with fibula flaps were included in the quantitative evaluation. The actual neomandible was reconstructed in Mimics 21.0 software (Materialise, Leuven, Belgium), using postoperative cone beam computed tomography (CBCT) data at 1-year follow-up. Then the file was exported in standard tessellation language file format. Both the preoperative model and the postoperative result were introduced into Geomagic Wrap 2021 (3D Systems Inc, the Netherlands). The facial midline was established according to the anatomical marks. Axial, coronal, and bilateral SMAs were measured and recorded, respectively. Then the similarity of the virtual and actual postoperative mandibles can be assessed using a paired-samples t test, with P values less than 0.05 indicating statistical significance (SPSS, version 23.0).

Surgical Procedure

Preoperative Planning

Before the surgery, an osteotomy line was designed using VSP depending on the location and size of the tumor (Fig. 1A, B). As for planning the resection in the subcondylar area, a new osteotomy guide plate was designed for this novel technique. In comparison with the traditional plate, which is designed according to the faciocervial incision (Fig. 1C), this guiding plate suits better for the intraoral incision and endoscopic field owing to its retention on the mandibular sigmoid notch, which presents fewer anatomical variations (Fig. 1D).

The required length of flaps as well as the angle and length of each segment were determined by VSP (Fig. 1).

Mandibular Osteotomy with Endoscopy and Flap Preparation

A transverse incision was made on the alveolar ridge and gingiva. According to the depth of invasion of the tumor into adjacent soft tissue, the involved oral mucosa

Table 1. Summary Data of Five Patients

Patients (Age, Sex)	Tumor Diagnosis	Vascular Anastomosis	Defect Scope	Flaps	Condyle Preservation	Flap Failure	Operative Time (h)	Time to Oral Diet (d)
F, 36	Ameloblastoma	Intraoral	Ramus + body (left)	Fibular bone	Yes	No	9.5	7
M, 28	Myxoma	Intraoral	Ramus + body	Illac crest	Yes	No	10	5
M, 32	Ameloblastoma	Subm-mini	Ramus + body	Fibular bone	Yes	No	8.7	6
F, 51	Ameloblastoma	Subm-mini	Ramus + body	Fibular bone	Yes	No	10.5	6
F, 39	Ameloblastoma	Subm-mini	Body (L + R) + Ramus (L)	Fibular bone	Yes	No	9.5	7

F: Female; M: Male.

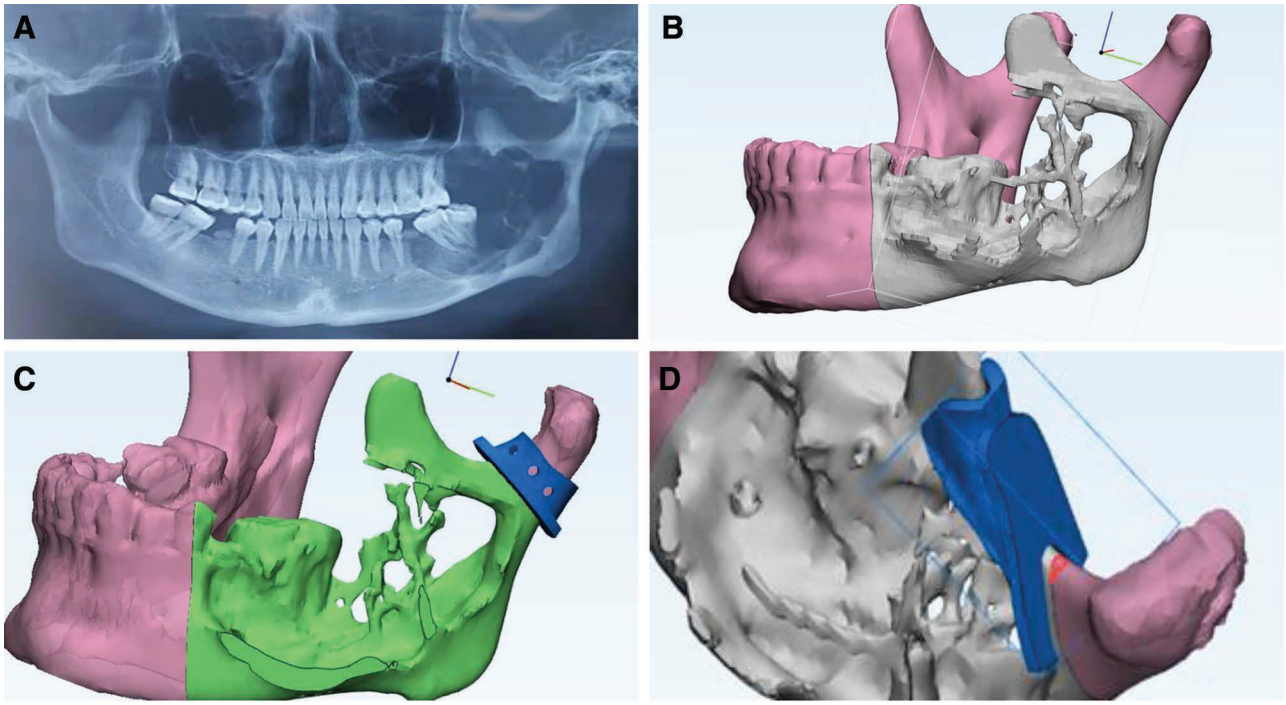


Fig. 1. Virtual surgical planning for tumor resection and bone reconstruction. A, A preoperative panoramic radiograph showing a sizeable multilocular lesion on the left side, with molars and mandibular ramus invaded. B, Planned osteotomy lines for tumor resection. C, Traditional osteotomy guide plate designed based on the extraoral incision, showing that the plate was positioned through the subcondyle area from the buccal side. D, Modified virtual osteotomy guide plate, designed according to the characteristics of the intraoral approach and endoscopic field; the sigmoid notch was chosen for retention.

was removed, and tissue was separated along tumor capsule or fascia with the aid of endoscope which was likewise placed through an intraoral incision (30', adult endoscope) so as to achieve complete resection of the lesion. Then the proximal osteotomy was performed using the proximal cutting guide. The endoscope was then inserted through the intraoral incision to visualize the site of the distal osteotomy; as a result, a precise transoral segmental mandibulectomy was guaranteed after the distal cutting plate was positioned through the sigmoid notch.

According to the magnitude of the defect, a fibular flap or an iliac crest flap was selected for neo-mandibular construction. The flap was prepared based on the standard procedure.

Shaping Bone Flaps In Vitro

The titanium plate was bent according to printed 3D model created by virtual surgery. During such process, the position of titanium screws could be identified on both the contralateral mandible and residual condyle through the fixation of plates, thereafter restoring the position of the condyle. Further, the fibula flap was shaped under the guidance of cutting guides and connected with prebent titanium plate (Fig. 2A). The entire process was performed ex vivo, as illustrated in Figure 2.

The Placement and Fixation of Shaped Bone Flaps

The distal continuity of the mandible was first restored under endoscopy monitoring, and guidance after the flap was implanted into the defect area through an intraoral incision (Fig. 2B). The prebent plate was used to confirm the placement of the drilling hole on the condyle, and then the transbuccal trochar instrumentation was applied to fix the titanium plate through a percutaneous puncture in front of the tragus, connecting the condylar head with the flap (Fig. 2C-D). [**See Video (online),** which shows the titanium screw being fixed under the view of the endoscope during surgery.] Then the remnant mandible was also fixated to the flap through the titanium plate, forming a neo-mandible.

Vascular Anastomosis

The free length of the vascular pedicle on the flap should be used to assess whether vascular anastomosis was accomplished intraorally or through a tiny submandibular incision. After bone shaping, the sufficient length of the peroneal artery and vein allowed intraoral anastomosis with the buccal facial vein and the facial artery. Under this circumstance, the pedicle of the peroneal artery and vein were dragged to the front part of the oral cavity to facilitate the microsurgical practice, and an end-to-end anastomosis between the peroneal artery and the facial artery was performed under microscope. In terms of venous anastomosis, a microvascular coupler was used to connect the peroneal and facial veins. Sometimes, the length of flap vascular pedicles was insufficient to be dragged out for anastomosis if the defect was wide and the required bone was long. In such cases, a small submandibular incision

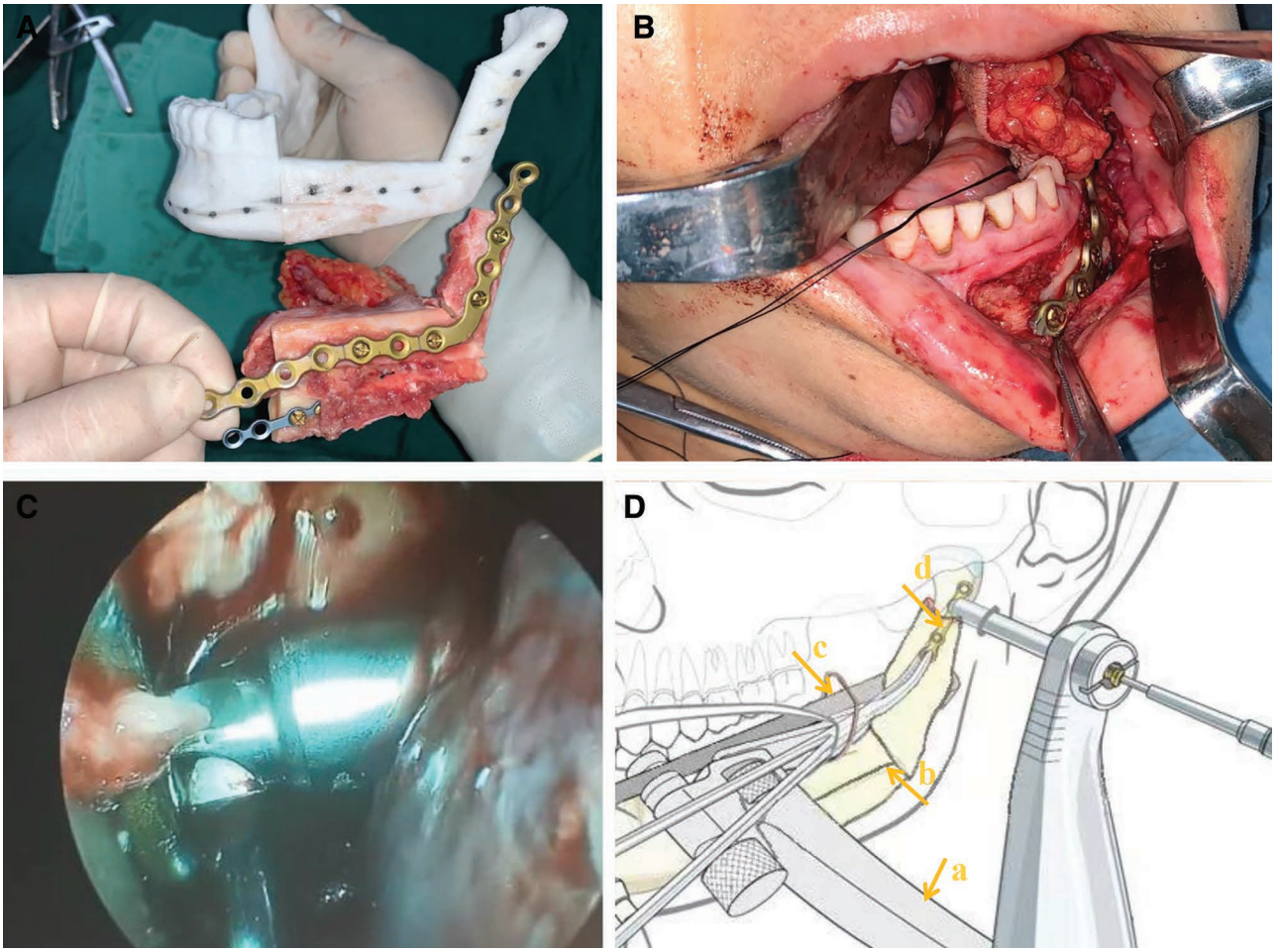


Fig. 2. The process of intraoral reconstruction for the left mandible. A, The printed 3D model marked with the positions of drilling holes on the condylar head and fibula construct, suggesting that the restoration of the condyle position and placement of the fibular flap can be guaranteed by fixing the titanium plate in the appropriate position. B, Placing a fibular flap into the defect area through an intraoral incision. C, The endoscopic view showed drilling holes and fixing pins in the subcondylar area. D, Schematic description showing fixing the fibular flap with the condylar head through a transbuccal stab. The yellow arrows a, b, c, and d indicate transbuccal stab, fibular construct, retractor, and titanium plate, respectively.

(2–3 cm) was required to release longer facial vessels for anastomosis.

RESULTS

As shown in Table 1, medical data from five patients were collected and analyzed. The average operating time in this study was 9.64 ± 0.67 hours (range: 8.7–10.5), which is about 2 hours longer than that of traditional constructive surgery. The average time allowing oral diet was 6.2 ± 0.84 days (range: 5–7) after surgery. In terms of the expenditure, traditional mandibular reconstructive surgery in China costs patients between $9600 and $11,000. With this technique, the expenditures are approximately $1400 higher than those of the traditional surgery. The average follow-up in this study was 19.2 ± 4.82 months (range: 13–25). Patients underwent 7–9 days' hospitalized observation, and no complications occurred during the short- and long-term follow-up periods. In this study, intraoral flap techniques were used with no difficulties in condylar preservation involving in hemi-mandibular reconstruction. When compared with the traditional group (**See figure, Supplemental Digital Content 1**, which shows medical data about a patient who underwent traditional mandibular constructive surgery. A, Preoperative frontal view of the patient who underwent traditional mandibular reconstruction. B, Conventional faciocervical incision. C, Postoperative frontal view of the patient at 12 months showing skew mouth due to the intraoperative injury to marginal mandibular branch of the facial nerve. D, Massive scar left around the neck 1 year after surgery. **http://links.lww.com/PRSGO/D87**.), no detectable scars or skewed mouth was presented, and the postoperative contours were symmetrical and close to normal appearance. Dental examination showed that stable occlusion was achieved in all patients. Two patients acquired normal mouth openings at 2 months after surgery (>35 mm), two after a follow-up period of 6 months, and one at 1 year after surgery. There was no disturbance in food intake, deglutition, or speech postoperatively. A postoperative CBCT

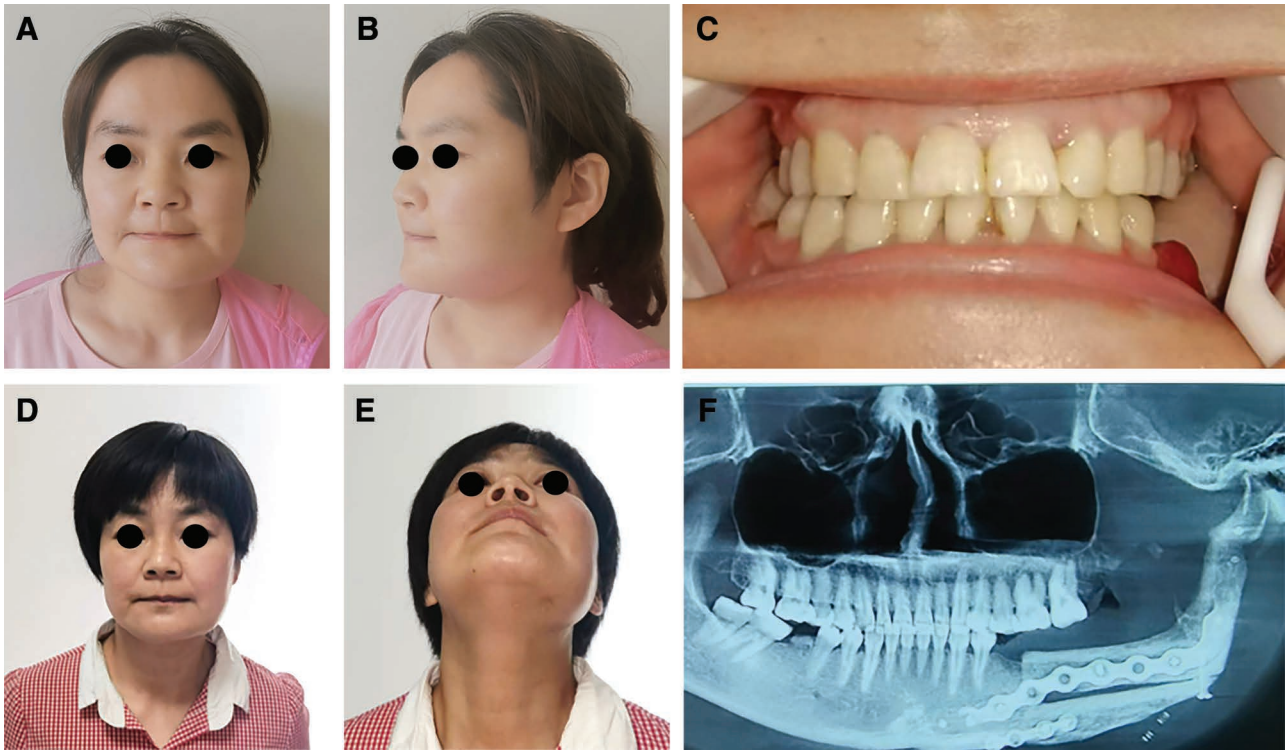


Fig. 3. Postoperative outcomes of intraoral reconstruction of the hemimandible. Frontal and lateral views of the patient at 2 weeks (A, B) and 17 months (D, E) after surgery showing no obvious scar and a relatively symmetrical facial contour. Postoperative images at 17 months showing a tiny scar on the submandibular region due to the placement of a drainage tube. C, Postoperative dentition occlusion at 2 weeks. F, Postoperative CBCT scan at 1 year, showing continuity of the jaw, adequate position of the condylar head, as well as bone healing at the junction of the transplanted flap and the residual mandible.

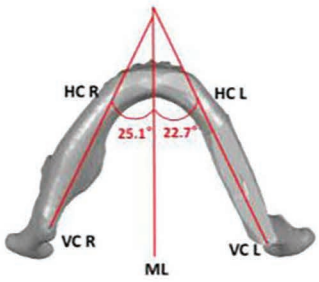
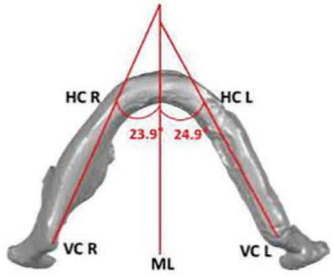
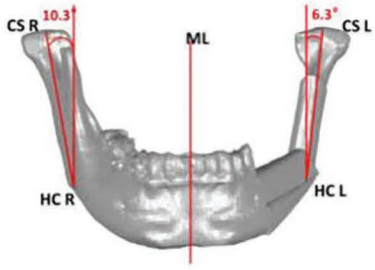
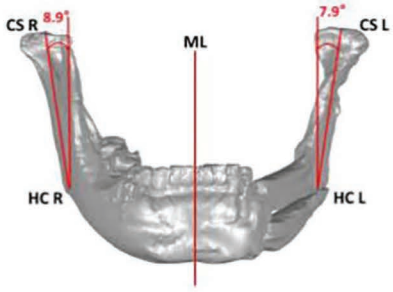
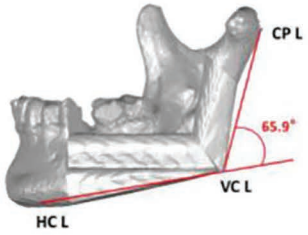
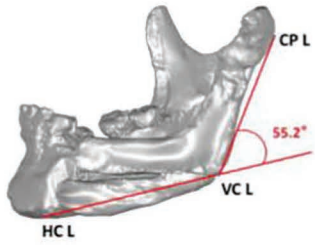
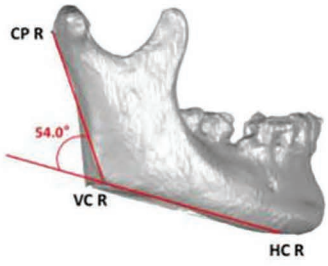
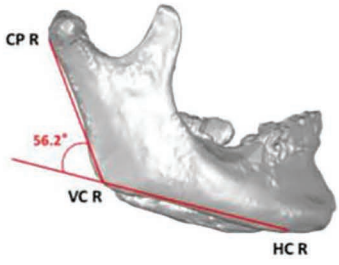
scan was routinely taken at follow-up of each patient, and the symmetry of the bilateral mandibular condyle could be evaluated. All bone flaps healed well with surrounding tissue, and survived completely with no partial necrosis. All patients showed normal nerve function after surgery.

Typical Patient 1: Intraoral Reconstruction of Mandibular Body and Ramus with a Fibular Flap

A 36-year-old woman presented with a mass in the left mandible that had gradually increased in size over a period of 6 months. The pathologic diagnosis was ameloblastoma. On physical examination, the size of the mass was found to be 7 × 5.5 cm (Fig. 1A). The gingiva in the molar region was affected by a tumor, which presented an unhealable ulcer, a soft-tissue mass, and loosening molars. Segmental resection was performed through an intraoral approach with preservation of the left condylar process and the resected tissue included the left mandibular body, ramus, and attached gingiva. The fibular flap was used to repair the large defect through an intraoral incision, and an intraoral vascular anastomosis was performed. Follow-up at 2 weeks postoperatively showed that the flap survived without complications, and the patient acquired symmetry in facial appearance, stable occlusion and a minimal scar (Fig. 3A-C). At 12 months after surgery, the facial symmetry was satisfactory and the fibular bone healed well and compactly attached to the neighboring bone (Fig. 3D-F). Related statistical data were recorded by the above methods and included in the quantitative evaluation (Fig. 4).

Typical Patient 2: Reconstructing the Left Mandibular Body and Ramus with an Iliac Crest Flap

A 28-year-old man presented with an increasingly enlarged left mandibular mass over a period of 11 months. The pathologic diagnosis was myxoma. On physical examination, a mass occupied the left mandibular body and ramus, the size of which was 5.5 × 4 cm. Part of the left ramus and two-thirds of the mandibular body were affected by the tumor. Segmental resection was performed with preservation of the left condylar head. The "L-shaped" iliac crest flap with a 3.5 × 5 cm internal oblique abdominis island was used to repair the defect. Vascular anastomosis was also performed through an intraoral incision. The patient's facial contour was considered symmetrical and a satisfying occlusion was restored. The flap survived without complications and compactly attached to the neighboring bone at the 25-month follow-up. The anterior part of the plate was removed through an intraoral incision at 12 months postoperatively. [**See figure, Supplemental Digital Content 2**, which shows postoperative medical data about typical patient 2, who underwent reconstruction of the left mandibular body and ramus with an iliac crest flap. A, Postoperative photograph of patient 2, who underwent intraoral iliac crest flap reconstruction; the

	Virtual planning	Postoperative result
Axial mandibular angle		
Coronal mandibular angle		
Sagittal mandibular Angle (L)		
Sagittal mandibular Angle (R)		

Remarks:
VC: Vertical Corner HC: Horizontal Corner CS: The condyle superior
CP: The condyle posterior ML: The midsagittal line

Fig. 4. Tabular chart showing axial, coronal, and sagittal angles of typical patient 1's virtual and actual neo-mandible.

patient acquired satisfactory and stable occlusion (B) and appropriate TMJ position as well as complete bone healing at 25 months postoperatively (C). **http://links.lww.com/PRSGO/D88**.]

Typical Patient 3: Reconstructing the Right Mandible with Mini-plates

A 51-year-old woman presented with an increasingly enlarged right mandibular mass over a period of 4 months. The pathologic diagnosis was ameloblastoma. On physical examination, a mass occupied the right mandibular body and ramus, the size of which was 7.5×5 cm. Segmental resection was performed with preservation of the right condylar head. The fibular flap with a 3.5×5 cm skin island was harvested and fabricated into a double-barrel construct according to VSP, which was further connected with the condylar head and residual mandible with mini-plates. Vascular anastomosis was performed through a mini-submandibular incision. No facial contour change was noticed, and stable occlusion was achieved. The flap survived without complications, healed well, and compactly attached to the neighboring bone after a 13-month follow-up. [**See figure, Supplemental Digital Content 2**, which shows postoperative medical data about typical patient 3, who underwent reconstruction of the right mandible with mini-plates. D, Postoperative photograph of patient 3, who underwent intraoral mandibular reconstruction with a mini-plate connected fibular bone. Postoperative intraoral images (E) and CBCT scan (F) presenting satisfactory and stable occlusion, symmetric mandibular shape and an accurate position of joint. **http://links.lww.com/PRSGO/D88**.]

The quantitative evaluation of VSP and the actual postoperative results are shown in Figure 5. The mean values of axial mandibular angle (AMA), coronal mandibular angle (CMA), and sagittal mandibular angle (SMA) of VSP on the surgical area were evaluated as 23.66 ± 3.44 degrees, 9.27 ± 2.48 degrees and 61.88 ± 4.48 degrees, and a mean of 25.32 ± 3.65 degrees, 9.07 ± 1.66 degrees and 56.43 ± 3.04 degrees postoperatively. Besides, the mean values of VSP on the unaffected side were AMA 24.29 ± 2.66 degrees, CMA 11.35 ± 2.29 degrees and SMA 57.14 ± 2.82 degrees, and AMA 24.71 ± 3.99 degrees, CMA 9.90 ± 1.49 degreesand SMA 57.70 ± 3.49 degrees postoperatively. Little discrepancy between AMAs, CMAs, and SMAs of preoperative design and postoperative image on both sides can be observed ($P > 0.05$; Fig. 5).

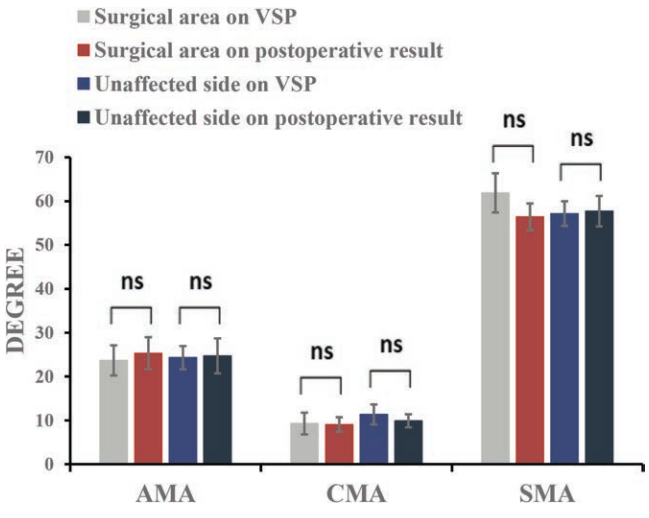


Fig. 5. Representative image showing the similarity and symmetry between the actual postoperative image and preoperative design using axial, coronal, and bilateral SMAs.

DISCUSSION

With the development of surgical technology, the goal of mandibular reconstruction has gradually changed from the recovery of facial contour and bony continuity to functional reconstruction allowing for the loading of dental implants, and is currently moving to minimal invasiveness.[8–10] VSP has been widely applied in reconstructive surgery through customized cutting guides and has been proven to shorten surgical time, simplify surgical operations, and visualize the postoperative effect.[11] The attempts to modify VSP and customize templates further rationalize the surgical procedures and improve the accuracy of mandibular reconstruction through an intraoral incision.[12] Sun et al reported the sequential application of a novel guiding plate system. These modified guiding plates were miniaturized and designed with their section resting on teeth or three-point attachment to the ramus, ensuring minimal error of the osteotomy lines between VSP and actual operation.[13] Despite these modified techniques, it remains difficult to expose the retromolar area, angle, ramus, and condyle without facial incision. In this study, for the first time, we introduce endoscopic techniques into VSP-aided mandibular reconstruction, so as to expand intraoral reconstructive surgery to larger mandibular defects that involve the ramus and condyle.

Even with long incision, intraoral surgery remains difficult owing to limited operational space and poor visual effect, especially when the tumors invade a high level of the ramus. Connecting bone flaps with condylar process accurately is particularly challenging through an intraoral incision.[5] The endoscopic technique presents the potential of application in a variety of maxillofacial benign tumors, such as salivary gland tumors. In this study, we proved that an endoscope-aided procedure may solve the above issues through its lighting function in deep tissues and satisfactory monitoring on operation in condylar regions. However, limited space also requires simplified intraoral procedures. By using preoperative planning software, the osteotomy line and double-barrel graft could be intuitively delineated on the 3D model.[14,15] Here, we designed cutting guides that may be anchored on the sigmoid incisor of the mandible. Prebending titanium plates not only aid the shaping of the fibular flap into a double-barrel construct but also determine the position of drilling holes in the condyle.[16,17] Condylar head preservation is found to be difficult even through an extraoral incision. Nevertheless, our reconstructive results are as good as those of our extraoral incision patients. The

similarity of all reconstructed mandibles with VSP was further confirmed by comparison of the postoperative CT data and preoperative planning, which was also consistent with postoperative occlusion and facial appearance. Our experience claimed that endoscopy well monitored the preservation of the condylar region, such as osteotomies, end-end connecting and drilling holes on appropriate points. As presented in Figure 2A, titanium plate-bone composites could be precisely constructed extraorally, which significantly simplified the in-mouth adjustment procedure for flaps. The precise positioning and fixation of the titanium plate are pivotal to accurate mandibular reconstruction, and the endoscopy-assisted fixation warrants the success of intraoral reconstruction.

Intraoral vascular anastomosis has been recommended to avoid extraoral scars.[18,19] However, only two patients in our study successfully underwent intraoral vascular anastomosis. In this study, the patients selected had huge tumors, and mandibular defects caused by tumor resection require longer fibular bone and therefore limited the free length of the vascular pedicle at the donor site, so that the anastomosis with facial vessels intraorally were always difficult. In addition, intraoral micro-anastomosis does require practice. However, through mini-incision in submandibular regions, the vascular anastomosis may be performed for most surgeons. Actually, a mini-incision (2–3 cm) in the submandibular area enables sufficient exposure of facial vessels, which may compensate for the pedicle length of the fibular bone.[20] Our experience proves that mini-incisions rarely damage the marginal mandibular branch of the facial nerve. It may also serve as the auxiliary entrance of endoscopy for reconstructing the condyle. Also, the scars will be scarcely detectable after 3–6 months. Interestingly, the length of the vascular pedicle in the iliac crest flap is sufficient to be anastomosed with the recipient vessel intraorally, while iliac crest flap is considered more suitable for reconstructing smaller defects owing to limited bone length.

Malignant lesions usually require wide resection, including surrounding soft tissues; implementing transoral removal remains difficult if using endoscopy as a monitoring method.[21] Therefore, only patients with benign tumors in the mandibles were tested in our study; up to 25-month follow-up results were satisfying, and no recurrence was found in any of these cases. We suggest that the indications should be chosen carefully. Even with the aid of endoscopy, only primary benign tumors of the mandible could be considered.

CONCLUSIONS

Endoscopic technology may assist microsurgical mandibular reconstruction for benign tumors invading the subcondyle and ramus through an intraoral incision. Modifying VSP according to the requirements of an intraoral incision is essential to endoscope-assisted reconstruction, which may warrant the condylar position and accuracy of occlusion. Meanwhile, a mini-size extraoral submandibular incision may facilitate microvascular anastomosis.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

PATIENT CONSENT

The patient provided written consent for the use of her image.

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