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Original Article

Optimized design for using of double-barrel vascularized fibular flap in various types of mandibular defects

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Surgical guides

Abstract *Background/purpose:* The functional and aesthetic reconstruction of the mandible can be achieved by using the double-barrel vascularized free fibula flap. The purpose of this study was to use multiple integrated techniques to more effectively reconstruct the mandible, some contains of our unique ideas.
Materials and methods: 21 patients were included in this study. Computed tomography (CT) data of the patient's mandible and fibula were acquired preoperatively. Individualized surgical simulation was performed by using computer-aided surgical simulation (CASS) technology, about 6 kinds of integrated 3D design ideas were simultaneously perfectly transferred to real surgery. The accuracy of reconstruction was evaluated by superimposing the postoperative and preoperative image of mandible, measuring the linear and angular deviation of landmarks between the planned and actual outcomes.
Results: The mandibular reconstruction was effectively performed on all patients, and the result analysis showed that the surgical plan was precisely performed. The facial contours of the postoperative patients were harmonized and the largest mean linear and angular differences were 1.47 $\pm$ 0.31 mm and 3.97 $\pm$ 0.63°, respectively.
Conclusion: This study system illustrates how to select and position the fibula for reconstruction of various types of segmental mandibular defects by using double-barrel vascularized free fibula flap. It will provide valuable guidance and enhance the accessibility and efficiency of mandibular defects treatment.

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Introduction

The mandible bone not only shapes the lower face, but also facilitates masticatory movements and aids in the articulation of various phonemes.[1] Unfortunately, mandibular health can be compromised by various pathologies, such as cysts, tumors and infections, leading to the need for surgical resection of a significant portion of the mandible. Several options have been explored to reconstruct the mandible, including the use of the iliac crest, scapula, and fibula et al. Among these options, the vascularized fibular flap has been considered the gold standard for treating mandibular defects.[2–4] However, even experienced surgeons may find it difficult due to factors such as the execution of osteotomies, calculation of appropriate fragment sizes, and plate contouring.[5]

With the rapid development of CASS technology, which allows a predictable and repeatable approaches for managing complicated defects, determining the optimal protocol, accurate preoperative planning and precise intraoperative execution, there is the potential to reduce surgical time.[6,7] However, the size and location of reconstructed defects varied, and there was few consensus on which side of the fibula free flap should be chosen as the donor area for a particular defect when using the double-barrel vascularized fibula flap.[8] The choice of flap was often based on the individual surgeon's own preference or experience. Many previous studies have primarily focused on only one type of mandibular defect and lacked systematic design clarification regarding the selection and repositioning of the fibula flap.[9,10] In addition, the vascularized fibula flap was often limited in width to match the height of the mandible.[11] In previous studies, few scholars paid attention to the advantages and disadvantages of various placement of the fibula, most of them only paid attention to restoring the continuity of the jaw. In some reports, the lower or upper barrel fibula segments were set as non-vascularized style, resulting in an increased risk of surgical prognosis.[3,12–14] Even, in some studies the placement of the fibula was totally wrong from our perspectives, which only maintaining the continuity of the mandible.[3,14] A fibula flap without careful design may also significantly impact the placement of implants. Some previous studies, have no bone segment repositioning guide plate or sharing drill-holes technique may increase bone damage.[3,10,13]

The purpose of this study was to apply integrating many advanced design skills at the same time including but not limited to the following: the best height and width of the upper layer of fibula bone bed for the future implanting area; the non-tension anastomosis of the vascular receiving area; modified placement of lower layer of fibula for the better contour of the face without losing blood supply; increasing the area of bone healing surface without of condylar head dropping; saving drill hole amounts for both of the fibula and the remaining mandible; and the complex which includes pre-bent titanium plate, shaped segmented fibula, and repositioning guide that does not affect the placement of the whole graft in the recipient area, moreover, this complex has been prefabricated at the donor site. Discuss how to individually select which side of the lower extremity fibula to design a double-barrel vascularized free fibula flap to reconstruct various types of mandibular defects, that achieve harmonious balance between function and contour.

Materials and methods

This was a retrospective study. 21 patients who had undergone mandibular reconstruction with vascularized fibula flap using the computer-aided design and manufacturing (CAD/CAM). There were 4 classes of mandibular defects, according to Brown classification of mandibular defects.[8] The surgeries were performed in the Department of Oral and Maxillofacial Surgery, Kunming Medical University School and Hospital of Stomatology between January 2019 and August 2023. All patients signed informed consent forms.

Virtual planning

A preoperative CT scan was performed on the patient's mandible and fibula (with concomitant CT angiography) with a slice thickness of 1.25 mm (Siemens AG, Munich, Germany). The Digital Imaging and Communications in Medicine (DICOM) data were imported into the Mimics 19.0 software (Materialise NV, Leuven, Belgium), to segment the mandibular model and fibula model (including the peroneal artery). Subsequently, the stereolithography (STL) files were imported into Pro-Plan CMF software (Materialise, Leuven, Belgium) for surgical planning.

Class I: The ipsilateral iliac crest flap was most commonly chosen.

Class Ic (Fig. 1A): After determination of suitable margins, the simulation of mandibular osteotomies was performed. The ipsilateral fibula flap was used to reconstruction mandibular defects. The distal fibula served as the upper barrel to restore the condyle, ramus, and alveolar bone, while the proximal fibula served as the lower barrel to align with the border of the mandible. It was important to note that a 6 mm segment of bone between the upper and lower barrels needs to be excluded (between 2 and 3 segment of bone, Fig. 1B). In cases where the width of the double-barrel vascularized free fibula flap exceeds the height of the mandible, a portion of the lower barrel (anterior margin of the fibula) will be removed to align with the border of the normal mandible. The position of the vascular pedicle was designed to be located in the gonial angle region to make sure tension-free anastomosis of blood vessels. The 3-matic software (Materialise, Leuven, Belgium) was used to design a reconstructed mandibular model, cutting guides for both mandibular and fibular osteotomies, and a repositioning guide for the fibular segments (designed to reposit the upper barrel), the screw holes of the cutting guide were aligned with the repositioning guide. The concept was similar to that reported previously by Wang et al. (Fig. 1B).[15–17] Ultimately, the models were produced through 3D printing (FlashForge Guider II, FlashForge, Jinghua, China) using a biocompatible material (resin).

Class II (Fig. 2A): Both sides of the fibula can be chosen as the donor area. When the contralateral fibula flap was

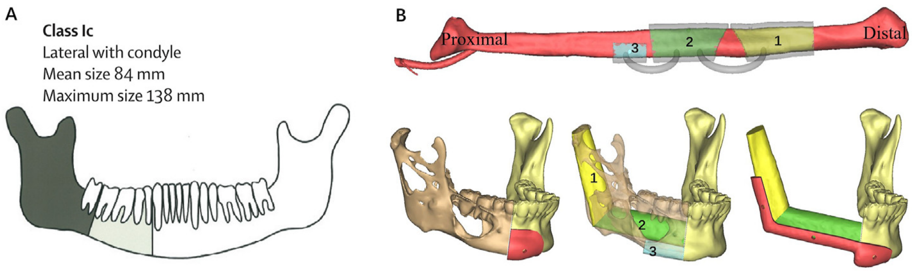

Figure 1 Computer assisted design and virtual planning. (A) Class Ic of mandibular defects (From Brown et al.). (B) Simulation of fibular osteotomies (exclusion of about 6 mm segment of bone between 2 and 3) and shaping and placement of fibular bone. Cutting guide and repositioning guide design.

used, the proximal fibula served as the upper barrel and the distal fibula served as the lower barrel (Fig. 2B). When the ipsilateral fibula flap was used, the fibula was placed in the opposite position. The subsequent surgical planning was similar to Class Ic.

Class IIc (Fig. 3A): The ipsilateral fibula flap to was used and the surgical planning was similar to Class Ic, but it was imperative to augment the number of fibular segments (Fig. 3B). However, when the mandibular defect extends beyond the incisor midline and reaches the contralateral mandible, because of the vascular pedicle length not allows, the single-layer fibula design was performed and placement of the fibula 0.5—1 cm superior to the lower border of the native mandible.[18] The proximal fibula to restore the condyle and ramus bone, the distal fibula to the anterior portion of the mandible. The location of the vascular pedicle was designed to be located in the gonial angle region.

Class III (Fig. 4A): The ipsilateral fibula flap was used. The distal fibula served as the upper barrel, while the proximal fibula served as the lower barrel, and the location of the vascular pedicle was designed to be located in the side of the mandible with more defects (Fig. 4B). The repositioning guide for the fibular segments was designed to reposit the lower barrel. When the vascular pedicle length not allows, the single-layer fibula design was performed, the location of the vascular pedicle was also designed to be located in the side of the mandible with more defects.

Class IV, Class IVc: With in both two classifications, the single-layer fibula design was performed.

Surgical technique

The titanium reconstruction plate was pre-bent along the contours of the 3D printed reconstruction mandible model preoperatively (Fig. 5A). During surgery, the cutting guide was used to perform the mandibular resection and fibular harvest by two group (Fig. 5B and C). Prior to severing the vessel pedicle, the positioning guide was used to align the osteotomized fibular segments and the pre-bent reconstruction plate was fixed with the fibular segments to form a composite structure (Fig. 5D). Subsequently, the vessel pedicle was severed and the composite structure (consisting of aligned fibular segments, reconstruction plate, and positioning guide plate) was transferred into the mandibular space, and the repositioning guide screw holes were aligned with the mandible. With the screws screwed in the mandible, the original position of condyle was automatically restored and the fibular segments were automatically moved into the final position. Simultaneously, the reconstruction plate was fixed to the mandible by the screws (Fig. 5E). Finally, the repositioning guide were removed and the lower barrel was fixed by mini titanium, followed by vascular anastomosis and standard wound closure (Fig. 5F).

Statistical analysis

Postoperative CT scan was obtained for each patient one months after the operation and postoperative 3D mandibular models were segmented just like preoperative. First, Assessing the position of the fibular segment within the temporomandibular joint fossa. Second, the postoperative and preoperative mandibular models were imported into Geomagic Studio 2014 (3D Systems, Rock Hill, SC, USA), and superimpose the images. A color-coded discrepancy map was used to evaluate the overall difference. Third, Intercondylar distance (CoL-CoR), intergonial angle distance (GoL-GoR), anteroposterior distance (using a perpendicular line drawn from the gnathion to the center point of the

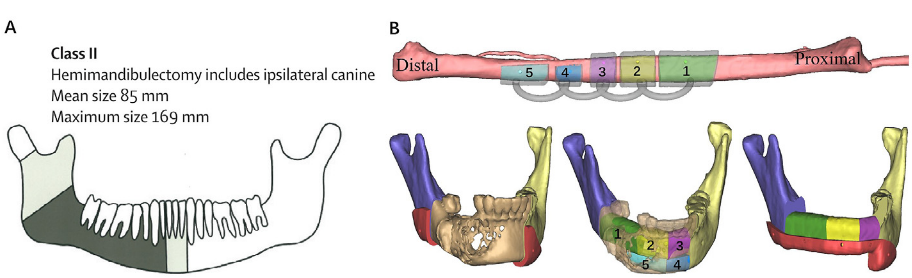

Figure 2 Computer assisted design and virtual planning. (A) Class II of mandibular defects (From Brown et al.). (B) Simulation of fibular osteotomies (exclusion of about 6 mm segment of bone between 3 and 4) and shaping and placement of fibular bone. Cutting guide and repositioning guide design.

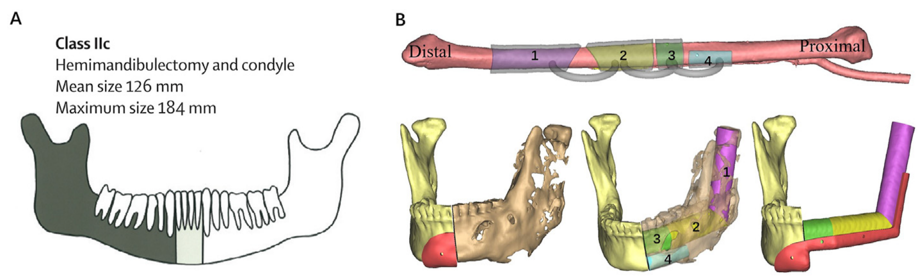

Figure 3 Computer assisted design and virtual planning. (A) Class IIc of mandibular defects (From Brown et al.). (B) Simulation of fibular osteotomies (exclusion of about 6 mm segment of bone between 3 and 4) and shaping and placement of fibular bone. Cutting guide and repositioning guide design.

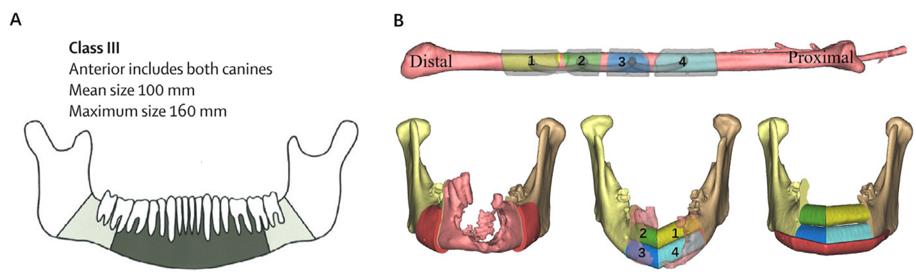

Figure 4 Computer assisted design and virtual planning. (A) Class III of mandibular defects (From Brown et al.). (B) Simulation of fibular osteotomies (exclusion of about 6 mm segment of bone between 2 and 3) and shaping and placement of fibular bone. Cutting guide and repositioning guide design.

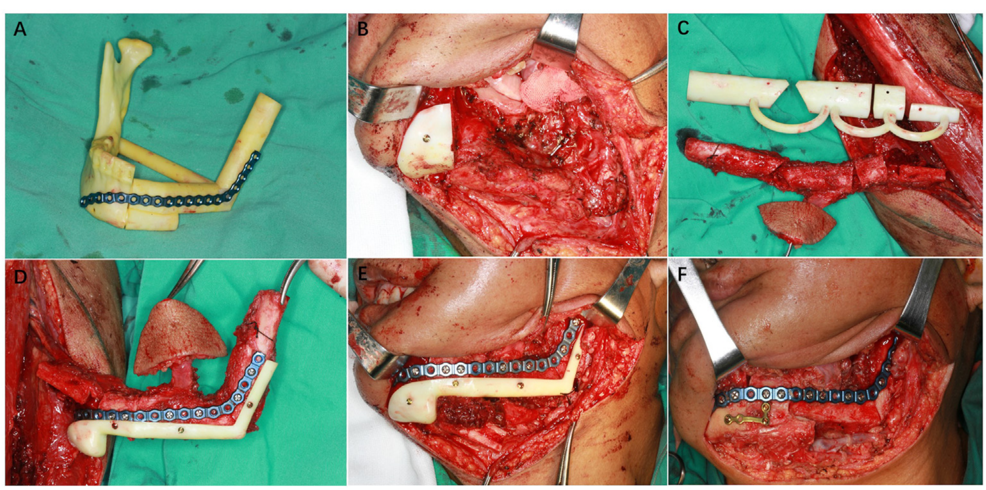

Figure 5 Surgical procedure. (A) The titanium reconstruction plate was pre-bent along the contours of the 3D printed reconstruction mandible model. (B) (C) The cutting guide was positioned as planned and attached firmly to the mandible and the osteotomy had completed. The fibular segment was shaped according to the cutting guide. (D) The positioning guide was used to align the osteotomized fibular segments and the pre-bent reconstruction plate was fixed with the fibular segments to form a composite structure. (E) The composite structure were transferred into the mandibular space, and the repositioning guide screw holes were aligned with the mandible. The reconstruction plate was fixed to the mandible by the screws. (F) The repositioning guide were removed and the lower barrel was fixed by mini titanium, vascular anastomosis were performed as usual.

intercondylar length, Gn-CoLR) and gonial angle (Go) were measured.

Descriptive statistics were calculated for all variables. The distribution of the differences data was screened, reported as mean $\pm$ standard deviation. The lower and upper limits of the differences were termed the 95% limits of agreement.

Results

Twenty-one consecutive patients underwent mandibular reconstruction with vascularized free fibula flap. During the operation, the vascular anastomosis in the recipient area was basically free of tension (Fig. 6A). One patient had wound infection and skin island was removed, but there

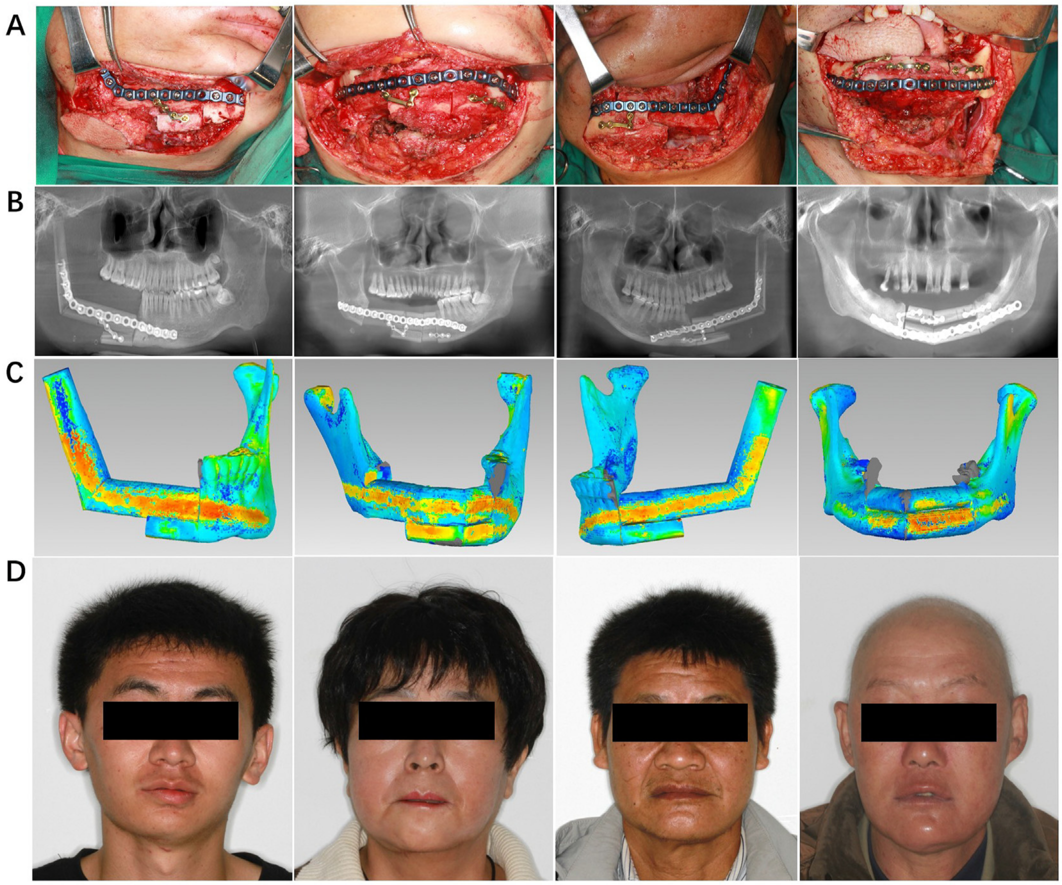

Figure 6 Example of class Ic-III reconstruction after ablation. (A) The proper fibular segments were transferred to reconstruct the defect. (B) Postoperative orthopantomograms for class Ic—III mandibular defects. (C) Color-coded discrepancy map of reconstruction mandible with the double-barrel vascularized free fibula flap. (D) Frontal images of the patient after surgery.

were no exposure or fracture of the titanium plate and the all fibula bone were survived. The facial contours of the postoperative patients were harmonized (Fig. 6D). The position of the fibular segments was consistently within the temporal mandibular joint fossa, without any downward displacement or lateral protrusion (Fig. 6B). The color-coded discrepancy map showed that the surgical plan was precisely performed. The largest deviation was 2.23 mm (SD = 1.88 mm), with the most obvious area of deviation around the osteotomy line (Fig. 6C). The linear and angular mean differences of the landmarks were shown in Table 1. The largest mean linear difference was 1.47 mm (SD = 0.31 mm) and the largest 95% limits of agreement were between 1.32 mm and 1.61 mm. The mean angular difference was 3.97° (SD = 0.63°) and the largest 95% limits of agreement were between 3.68° and 4.25°.

Discussion

Brown et al. provide a new classification system from Class I to IV of mandibular defects based on the four corners of the mandible.[8] Individualized design was needed for different defect types. Currently, the vascularized fibular flap was considered the gold standard treatment mandibular defects, and the main disadvantage of the vascularized fibula flap is the limited width to match the height of mandible. Different techniques can be used to overcome the height discrepancy. Options include vertical distraction osteogenesis, double-barreling of the fibula et al.[1] Double-barrel vascularized fibular flap for mandibular reconstruction was first recommended by Horiuchi et al.[19] However,

Table 1 Linear and angular mean differences of the landmarks between the preoperative and the postoperative Mandibles.

Parameter	Mean	SD	95% Limits of agreement	
			Lower	Upper
CoL-CoR (mm)	1.43	0.41	1.25	1.61
GoL-GoR (mm)	1.47	0.31	1.32	1.61
Gn- CoLR (mm)	1.36	0.22	1.26	1.46
Go°	3.97	0.63	3.68	4.25

SD, The standard deviations; Co, Condylion; Go, Gonion; Gn, Gnathion. CoL-CoR (mm), Intercondylar distance or distance between the two condyles; GoL-GoR (mm), Intergonial angle distance or distance between the two gonions; Gn- CoLR (mm), Anteroposterior distance (using a perpendicular line drawn from the gnathion to the center point of the intercondylar length); Go°, Gonial angle.

geometrically, the mandible bone has a complex structure and the U-shaped curve of alveolar was smaller than lower border, that even experienced surgeons can be challenging.[5] Additionally, there exists little consensus regarding the preferred side of the fibula free flap to be chosen as the donor area for a specific defect when utilizing the double-barrel vascularized fibula flap technique. Many previous studies have mostly focused on only one type of mandibular defect and have not provided systematic design clarification of the selection and repositioning of the fibula.[8,10]

CAD/CAM have revolutionized the reconstructive surgery and it allow accurate preoperative planning precise, intraoperative execution thereby having the potential to decrease operative time.[6,7,15,20] In our study, we mainly discuss how to individually select which side of the lower extremity fibula to design a double-barrel vascularized free fibula flap to reconstruct various types of mandibular defects, and each fibula segment have blood supply, that achieve harmonious balance between function and contour.

First, when surgical plan was performed, the height and width of the bone bed in the future planting area, the non-tension anastomosis of the vascular receiving area and the aesthetic premise will be given priority thinking. When performing image segmentation of the fibula, it was necessary to also segment the peroneal artery. This facilitates the real-time assurance of the vascular pedicle being located in a safe position on the inner side during the whole design period (Fig. 7A). In addition, the shape of the fibula bone was triangular at the head and converts to a more quadrilateral in the middle, then irregular or oval at the malleolus and the vessel pedicle was located behind the fibula medialis (Fig. 7B).[18] After our repeatedly calculated in clinical practice, we have determined that superior bone mass and morphology could be achieved by repositioning the posterior margin of the fibula towards the crest of the alveolar ridge when adjusting the upper barrel fibular segment, and by positioning the posterior margin of the fibula flush with the lower margin of the mandible when adjusting the lower barrel fibular segment (Figs. 1B, 2B and 3B, 4B, 7C). Moreover, when the width of the double-barrel vascularized free fibular flap more than the height of the mandible, part of the lower barrel (the anterior edge of the fibula) was removed to match the normal mandibular margin (Figs. 1B, 2B and 3B, 7C). In this way, the anterior fibular margin was resected with minimal risk of injury to the vascular pedicle while ensuring adequate blood supply to the posterior fibular margin (Fig. 7A—C).

When mandibular defects were classified as class Ic, II, IIc and III, the ipsilateral double-barrel vascularized free fibula flap was used to reconstruction mandibular defects. The distal segment was placed at the upper barrel as mandibular body alveolar or ramus, the position of the upper barrel was in harmony with the bite of the maxilla. The proximal segment with vessel pedicle as the last segment was placed at the lower barrel. In addition, when the contralateral fibula flap was used to reconstruction in class II. The upper barrel was the proximal fibular to restore the alveolar bone for implants placement, the lower barrel was the distal fibular bone to match the border of the normal mandible. When the length of the vascular pedicle does not permit the use of a double-barrel technique for mandibular defects classified as IIc, III, IV, and IVc, a single-layer fibula design is employed. In this approach, the fibula is placed 0.5—1 cm superior to the lower border of the native mandible.[18] When designing the above defect types, the location of the vascular pedicle was designed to be located in the gonial angle region in favor of easy vessel anastomosis.

Second, It was important that the curvature of the alveolar ridge was smaller than that of the mandible border, the upper fibular barrel should be placed more lingually than the lower barrel to mimic mandibular nature anatomy more closely.[11] In our design, in order to ensure the symmetry of the postoperative face shape of the patient, we deliberately rotated or shifted the lower barrel outward to match the lower mandibular margin, so that the postoperative facial shape of the patient could recover very

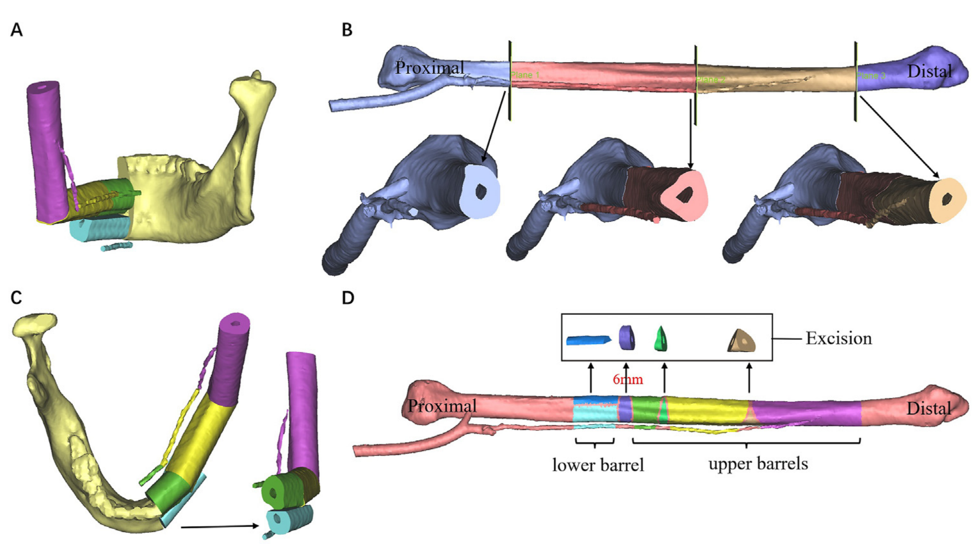

Figure 7 Computer assisted design and virtual planning. (A) The lingual aspect of the mandible. (B) The shape of the fibula bone and the vessel pedicle position. (C) The superior aspect of the mandible. (D) Illustration of the fibular osteotomy.

well. The double-barrel vascularized free fibula flap design has increased the contact area with the remaining mandible, leading to excellent postoperative resistance and strong weight-bearing capacity (Fig. 7C). Upon follow-up, we have observed that in condylar reconstruction cases, there was a notable absence of significant fibular segments downward displacement or lateral extension out of the temporal mandibular joint fossa (Fig. 6B). This may be attributed to the additional benefits brought by the preoperative double-barreled design, which maximizes the contact area for better healing and provides additional loading capacity from the lower barrel to the upper barrel.

Third, based on our accumulated experience, exclusion of about 6 mm segment of bone between the upper and lower barrels was appropriate, when planning the osteotomies for the double-barreled fibula (Fig. 7D). By discarding this segment, the periosteal blood supply can be safely bridged between two barrels after folding, without compression, kinks, or twists. In past studies, some scholars exclusion of a 3 cm segment of bone between the upper and lower barrels,[21] which would have lost a certain amount of vascular pedicle length and we now proved that's unnecessary. In addition, it was worth noting that the length of every segment should be designed to be greater than 1.5 cm to ensure adequate blood supply.

Fourth, before the vessel pedicle was cut off, the positioning guide was used to align the osteotomized fibular segments and the pre-bent reconstruction plate was fixed with the fibular segments to form a composite structure (Fig. 5D). The fibula could be fixed to the recipient area with high accuracy immediately after the vessel pedicle cut off, and the vascular anastomosis could be performed immediately. Through the combination of these composite techniques, the operation time could be greatly shortened. In addition, according to our design, the vascular anastomosis in the recipient area was basically free of tension and no vascular grafts were required. The facial contours of the postoperative patients were harmonized and the result showed that the surgical plan was precisely performed by drill-hole sharing guides.

Fifth, the screw holes of the cutting guide were aligned with the repositioning guide. This concept was similar to the single-layer design previously reported by Wang et al.[17] The repositioning guide was designed to reposition the upper barrel in cases where mandibular defects were classified as class Ic, II, and IIc. The lower barrel of the fibula was deliberately not loaded (omitted) so that the titanium plate—bone complex could be easily placed in the recipient area and was vascular friendly. The upper barrel of the fibular segments was fixed by reconstruction plate the lower barrel was fixed by mini titanium. The repositioning guide was designed to reposition the lower barrel in cases where mandibular defects were classified as class III. The lower barrel of the fibular segments was fixed by reconstruction plate the upper barrel was fixed by mini titanium (Fig. 6A). Antu'nez-Conde et al. designed a customized double-barrel titanium plate to replace the repositioning guide for mandibular reconstruction, these techniques was shown with high functional and aesthetic results.[4] However, the economic costs using these techniques were very high, making it impractical for some grassroots institutions to afford 3D printing and personalized titanium plates. In contrast, our surgical guides exhibited a higher degree of accessibility. However, more patients need to be enrolled in future studies. Finally, an accurate and optimal guideline was established for conducting and evaluating of mandibular reconstruction.

We simultaneously applied multiple design concepts and transferred to approximately various types of real mandibular defect types surgeries and got excellect outcomes. It will provide valuable guidance for management choices in mandibular reconstruction. Ultimately, enhancing the accessibility and efficiency of mandibular defect treatment.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

Acknowledgments

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References

1. Soares AP, Fischer H, Aydin S, Steffen C, Schmidt-Bleek K, Rendenbach C. Uncovering the unique characteristics of the mandible to improve clinical approaches to mandibular regeneration. *Front Physiol* 2023;14:1152301.
2. Geusens J, Sun Y, Luebbers HT, Bila M, Darche V, Politis C. Accuracy of computer-aided design/computer-aided manufacturing-assisted mandibular reconstruction with a fibula free flap. *J Craniofac Surg* 2019;30:2319—23.
3. Mahendru S, Jain R, Aggarwal A, et al. CAD-CAM vs conventional technique for mandibular reconstruction with free fibula flap: a comparison of outcomes. *Surg Oncol* 2020;34:284—91.
4. Antúnez-Conde R, Salmerón JI, Díez-Montiel A, et al. Mandibular reconstruction with fibula flap and dental implants through virtual surgical planning and three different techniques: double-barrel flap, implant dynamic navigation and cad/cam mesh with iliac crest graft. *Front Oncol* 2021;11: 719712.
5. Cedillo M, Côrdova S, Larralde S, Martínez F, Sandoval F, Suntaxi F. A comparative study of analog preoperative planning versus virtual preoperative planning for mandibular reconstruction with fibula free flap. *J Craniofac Surg* 2022;33: e680—5.
6. Zhang L, Liu Z, Li B, Yu H, Shen SG, Wang X. Evaluation of computer-assisted mandibular reconstruction with vascularized fibular flap compared to conventional surgery. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2016;121:139—48.

7. Choi JW, Kim YC, Han SJ, Jeong WS. Dual Application of patient-specific occlusion-based positioning guide and fibular cutting guide for accurate reconstruction of segmental mandibular defect. *J Craniofac Surg* 2023;34:1381—6.
8. Brown JS, Barry C, Ho M, Shaw R. A new classification for mandibular defects after oncological resection. *Lancet Oncol* 2016;17:e23—30.
9. Zavattero E, Fasolis M, Novaresio A, Gerbino G, Borbon C, Ramieri G. The shape of things to come: in-hospital three-dimensional printing for mandibular reconstruction using fibula free flap. *Laryngoscope* 2020;130:E811—6.
10. Piotrowska-Seweryn A, Szymczyk C, Walczak DA, et al. Fibular free flap and iliac crest free flap mandibular reconstruction in patients with mandibular ameloblastomas. *J Craniofac Surg* 2022;33:1962—70.
11. Qu X, Wang M, Xu L, Liu J, Bai S, Zhang C. Occlusion guided double-barreled fibular osteoseptocutaneous free flap for refined mandibular reconstruction aided by virtual surgical planning. *J Craniofac Surg* 2017;28:1472—6.
12. Ren W, Gao L, Li S, et al. Virtual planning and 3D printing modeling for mandibular reconstruction with fibula free flap. *Med Oral Patol Oral Cir Bucal* 2018;23:e359—66.
13. Bartier S, Mazzaschi O, Benichou L, Sauvaget E. Computer-assisted versus traditional technique in fibular free-flap mandibular reconstruction: a ct symmetry study. *Eur Ann Otorhinolaryngol Head Neck Dis* 2021;138:23—7.
14. Kourosh K, Mallory JH, Meryam S, Jeffrey H, Kalpesh TV. A novel approach to virtual surgical planning for mandibular and midfacial reconstruction with a fibula free flap. *J Craniofac Surg* 2022;33:759—63.
15. Femke G, Yi S, Michel B, et al. Accuracy of computer-assisted mandibular reconstructions with free fibula flap: results of a single-center series. *Oral Oncol* 2019;97:69—75.
16. Wang LD, Ma W, Fu S, et al. Design and manufacture of dental-supported surgical guide for genioplasty. *J Dent Sci* 2021;16:417—23.
17. Wang LD, Ma W, Fu S, et al. Application of digital guide plate with drill-hole sharing technique in the mandible reconstruction. *J Dent Sci* 2023;18:1604—11.
18. Patel SY, Kim DD, Ghali GE. Maxillofacial reconstruction using vascularized fibula free flaps and endosseous implants. *Oral Maxillofac Surg Clin N Am* 2019;31:259—84.
19. Horiuchi K, Hattori A, Inada I, et al. Mandibular reconstruction using the double barrel fibular graft. *Microsurgery* 1995;16:450—4.
20. Weitz J, Bauer FJM, Hapfelmeier A, Rohleder NH, Wolff KD, Kesting MR. Accuracy of mandibular reconstruction by three-dimensional guided vascularised fibular free flap after segmental mandibulectomy. *Br J Oral Maxillofac Surg* 2016;54:506—10.
21. Chang YM, Wallace CG, Tsai CY, Shen YF, Hsu YM, Wei FC. Dental implant outcome after primary implantation into double-barreled fibula osteoseptocutaneous free flap-reconstructed mandible. *Plast Reconstr Surg* 2011;128:1220—8.