Double-Barrel Fibula Flap Versus Vascularized Iliac Crest Flap for Mandibular Reconstruction

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Purpose: The double-barrel fibula flap and vascularized iliac crest flap are both commonly used for mandibular reconstruction. The present study compared the usage and reconstruction outcomes of transplanted bone with these 2 methods.

Patients and Methods: The data from 30 patients who had undergone mandibular osteotomy and reconstruction were retrospectively reviewed. Of the 30 patients, 20 received a vascularized iliac crest flap (group A) and 10 received a double-barrel fibula flap (group B). The following variables were compared between the 2 groups: volume of bone flap (VBF), volume of effective bone flap (VEBF; ie, overlap between the volume of the ideal mandible [VIM] and the VBF), usage of the bone flap (VEBF divided by the VBF), mandibular reconstruction rate (VEBF divided by the VIM), volume of needless bone flap (VNBF; ie, VBF minus VEBF; the VNBF included the volume of needless buccal bone flap [VNBBF] and the volume of needless lingual bone flap [VNLBF]), percentage of alveolar crest restoration (PACR; ie, effective bone flap width divided by ideal alveolar crest width), and height of the bone flap (HBF). The independent-samples t test and the χ^2 test were used to compare the variables between the 2 groups. Statistical significance was at $P \leq .05$.

Results: Usage of the bone flap and the length of the mandibular defect were significantly greater in group B than in group A ($P = .039$ and $P < .001$, respectively). The VBF, VNBF, and VNLBF were significantly greater in group A than in group B ($P < .001$ for both). The mandibular reconstruction rate, VNBBF, PACR, HBF, and tooth implantation rate were comparable between the 2 groups.

Conclusions: The double-barrel fibula flap can effectively restore the height of the alveolar crest, reconstruct longer mandibular defects, and provide a better buccal and lingual appearance compared with the vascularized iliac crest flap. Although the vascularized iliac crest flap can provide sufficient bone quantity, it must be contoured to the mandible.

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The vascularized fibular flap for mandibular reconstruction, first described by Hidalgo[1] in 1989, is a highly reliable and popular technique.[2] Its advantages include the long pedicle length, wide vessel diameter,

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and the ability to incorporate skin, muscle, and bone components.[3] However, the height discrepancy between the fibula and natural mandible can cause difficulties in wearing conventional dentures or the placement of osseointegrated implants.[4] To compensate for the width of the fibula, the dental implant superstructure must be extra-tall to reach the occlusal plane. However, this will result in excessive leverage forces and implant overload, shortening the lifespan of the implant.[5] For better long-term stability of the implant, the fibula will be connected to the alveolar bone of the mandible. However, the discontinuity at the inferior border of the mandible will lead to facial asymmetry.[6] Several options are available to resolve the height discrepancy between the mandible and the fibula and improve the esthetic profile and reconstructive function. Fibular vertical distraction osteogenesis can restore the mandibular height and optimize denture stability.[7] In 1995, Horiuchi et al[8] used the double-barrel fibula flap for mandibular reconstruction in 5 patients and was able to provide a satisfactory alveolar height. Mandibular reconstruction has also been performed using the deep circumflex iliac artery flap. The iliac crest can provide adequate bone height in large composite defects.[9]

The purpose of the present study was to compare the usage and reconstruction outcomes of transplanted bone with the double-barrel fibula flap versus the vascularized iliac crest flap.

Patients and Methods

STUDY DESIGN

The present retrospective cohort study enrolled patients who had undergone mandibular reconstruction with either the double-barrel fibula flap or vascularized iliac crest flap after mandibulectomy for removal of benign tumors at the Peking University School and Hospital of Stomatology from January 2012 to June 2019. The inclusion criteria were *1)* stable occlusal status before and after surgery; and *2)* the presence of a unilateral lesion involving the mandibular body and ramus. Of the 30 patients who met the eligibility criteria, 20 had undergone reconstruction with the vascularized iliac crest flap and 10 had undergone reconstruction with the double-barrel fibula flap. The preoperative and postoperative data of the patients were collected from the hospital records for analysis.

The ethical review board of Peking University School and Hospital of Stomatology approved the present study (approval no. PKUSSIRB-201522051). All the procedures conformed to the tenets of the Declaration of Helsinki.

SURGICAL PROCEDURE

Mandibular Reconstruction With Vascularized Iliac Crest Flap

The preoperative maxillofacial and iliac computed tomography (CT) scan data were imported to ProPlan CMF software (Materialise NV, Leuven, Belgium). Virtual mandibulectomy was performed according to the clinical and radiologic findings. The 3-dimensional (3D) iliac image was superimposed on the mandibular defect in its desired orientation according to the ideal mandibular contour. A reconstructed mandibular and iliac stereo model was manufactured by bioengineering using 3D printing technology. A reconstruction plate was prebent and fixed on the reconstructed mandibular model using 6 titanium screws. The .stl file format of the prebent reconstruction plate was acquired by the 3D scanner and imported into the intraoperative navigation system (iPlan, version 3.0; Brainlab, Feldkirchen, Germany) to implement the virtual plan. The position of the osteotomy lines and relevant parameters of the shape of the iliac flap were marked in the navigation system. The reconstruction plate was fixed on the remaining mandible according to the 6 marked points indicating the position of the titanium screws. The iliac crest flap was shaped according to the virtual plan and fixed with the reconstruction plate (Fig 1).

Mandibular Reconstruction With the Double-Barrel Fibula Flap

High-resolution CT scans of the maxillofacial skeleton and lower extremities were acquired and imported into ProPlan CMF software (Materialise NV), and 3D virtual models of the maxillofacial skeleton and fibula were created for simulation of the mandibular osteotomy. The 3D fibular image was superimposed on the mandibular defect in the desired orientation, with the upper border of the fibular segment positioned according to

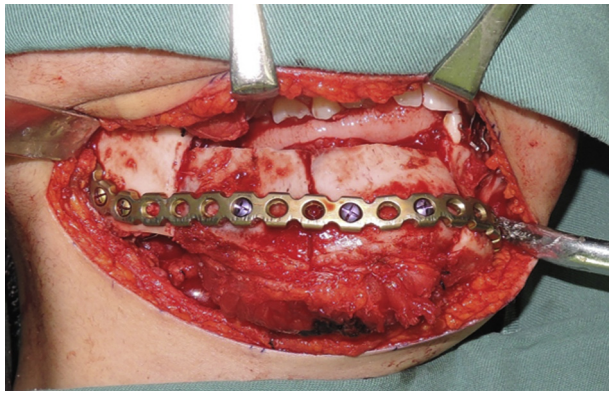

FIGURE 1. The iliac crest flap shaped according to the virtual plan was fixed to the reconstruction plate.

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the location of the upper teeth (Fig 2). The harvested fibula was osteotomized into several segments to fit the mandibular defect. A 2-cm segment of bone between the 2 layers of the double-barrel fibula was removed to maintain the paddle space of periosteal blood (Fig 3). Miniplates were used for osteosynthesis between the fibula segments and the residual mandible.

STUDY VARIABLES AND DATE COLLECTION METHODS

A maxillofacial CT scan with a 1-mm slice thickness was acquired preoperatively and at 1 month after surgery and used for making the measurements. For mandibular reconstruction with the double-barrel fibular flap, the measuring object was the folded fibula and the corresponding lower segment. For the iliac crest flap, the measuring object was the entire bone flap. Three-dimensional virtual models of the preoperative and postoperative mandible were created using ProPlan CMF software (Materialise NV) and imported into iPlan 3.0 (Brainlab). Registration between the preoperative and postoperative mandible models was accomplished using iPlan 3.0 (Brainlab). The model of the bone flap, ideal mandible, and remaining mandible were separated to measure the volume.

The volume of the effective bone flap (VEBF) was defined as the overlap between the volume of the ideal mandible (VIM) and the volume of the bone flap (VBF; Fig 4). The VBF minus the VEBF was considered the volume of the needless bone flap (VNBF). The usage of the bone flap was the VEBF divided by the VBF, and the mandibular reconstruction rate was the VEBF divided by the VIM. The VNBF included the volume of the needless buccal bone flap (VNBBF) and the volume of the needless lingual (VNLBF). The width of the effective bone flap in the alveolar crest and the ideal alveolar crest were measured. The percentage of alveolar crest restoration (PACR) was the effective bone flap width divided by the ideal alveolar crest width. The height of bone flap (HBF) was measured. All measurements were taken by the same, nonblinded, biomedical engineer (W.-B.Z.).

The outcome variables included usage of the bone flap, mandibular reconstruction rate, VBF, VNBBF, VNLBF, PACR, HBF, length of mandibular defect, and dental prosthesis rate. The predictor variables were the reconstruction methods used (double-barrel fibula flap vs vascularized iliac crest flap).

STATISTICAL ANALYSIS

The variables (ie, usage of bone flap, mandibular reconstruction rate, VNBBF, VNLBF, PACR, HBF, length of mandibular defect, and dental prosthesis rate) were summarized as the mean ± standard deviation or percentages. The differences between groups were compared using the independent-samples t test or the χ^2 test. Statistical analysis was performed using SPSS, version 17.0 (IBM Corp, Armonk, NY). Statistical significance was at $P \leq .05$.

Results

A total of 30 patients (14 males and 16 females; mean age, 38.4 ± 11.6 years; age range, 15 to 62 years) were included in the present study. Ameloblastoma was the most common reason for mandibulectomy (22 of 30 patients; 73.3%). In all 30 patients, the free flaps survived postoperatively with no complications.

Group A included 20 patients (10 males and 10 females), with a mean age of 34.5 ± 10.9 years (range, 19 to 62 years). Group B included 10 patients (4 males and 6 females), with a mean age of 29.1 ± 9.65 years (range, 15 to 50 years). The characteristics of the 2 groups are presented in Table 1.

Usage of the bone flap (83.3 ± 11.2% vs 72.4 ± 13.7%; P = .039) and the length of mandibular defect (9.30 ± 1.76 cm vs 5.62 ± 0.85 cm; P < .001) were significantly greater in group B than in group A. The VBF (14.520 ± 2.201 cm^3 vs 5.948 ± 1.021 cm^3), VNBF (4.425 ± 2.306 cm^3 vs 1.038 ± 6.861 cm^3;

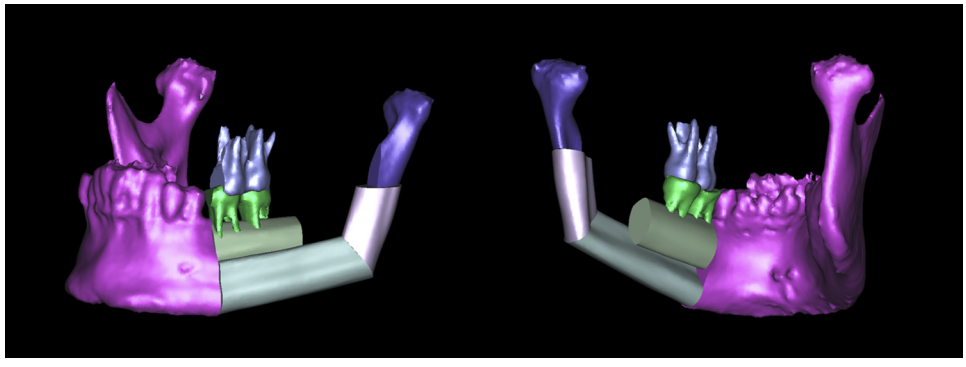

FIGURE 2. The folded fibular segment was placed according to position of the upper and lower teeth.

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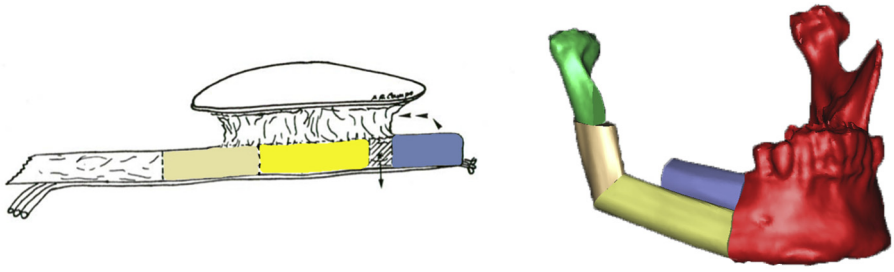

FIGURE 3. A 2-cm fibular segment was removed to make space for rotation of the folded segment.

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$P < .001$), and VNLBF (2.904 ± 2.377 cm^3 vs 0.429 ± 0.614 cm^3; $P < .001$) were significantly greater in group A than in group B. The mandibular reconstruction rate, VNBBF, PACR, HBF, and tooth implantation rate were not significantly different between the 2 groups (Table 1).

Discussion

The disadvantages of the free fibular flap include *1)* the height difference between the mandible and fibula, and *2)* the need to excise a longer length of the fibula than needed for the reconstruction to obtain an adequately long vascular pedicle. Using the double-barrel free fibular flap, the height discrepancy can be decreased, although a longer length of the fibula will need to be excised. The length of the fibula that can be harvested is limited because of the risk of donor site morbidity. Therefore, the double-barrel free fibula flap is not suitable when the mandibular defect is longer than 10 cm.[10] A partial double-barrel free fibula flap can be used if the defect is longer than 10 cm or if the pedicle is not long enough.[11]

The length of the free fibular flap used for mandibular reconstruction will depend on the position of 2 points: the point where the peroneal vessels branch from the posterior tibial vessels, and the point where the peroneal vessels run away from the fibula (Fig 5). Preoperative lower extremity angiography can be used to determine the position of these 2 points and to estimate whether the entire double-barrel fibula flap will be enough for mandibular reconstruction. If the length of the available fibula is not sufficient, the folded fibula should be placed at the position where implantation will be performed or where bone

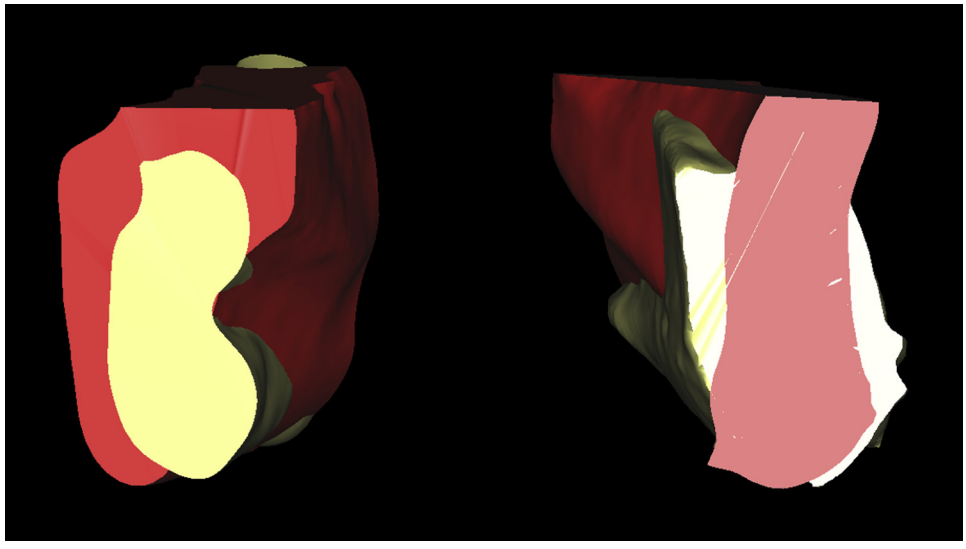

FIGURE 4. The volume of the effective bone flap was defined as the overlap between the volume of the ideal mandible and the volume of the bone flap. The red part is the ideal mandible, and the yellow part is the double-barrel fibular flap or vascularized iliac crest flap.

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Table 1. COMPARISON OF VARIABLES BETWEEN GROUPS A AND B

Group*	Patients (n)	Age (yr)	Usage of Bone Flap (%)	Mandibular Reconstruction Rate (%)	VBF (cm^3)	VNBF (cm^3)	VNBBF (cm^3)	VNBLF (cm^3)	PACR (%)	HBF (cm)	Mandibular Defect Length (cm)	Tooth Implantation Rate
A	20	34.5 ± 10.9	72.4 ± 13.7	63.3 ± 8.9	14.520 ± 2.201	4.425 ± 2.306	1.521 ± 1.549	2.904 ± 2.377	82.2 ± 16.1	2.33 ± 0.38	5.62 ± 0.85	6/20
B	10	29.1 ± 9.65	83.3 ± 11.2	56.7 ± 11.5	5.948 ± 1.021	1.038 ± 6.861	0.609 ± 0.687	0.429 ± 0.614	76.8 ± 16.5	2.33 ± 0.21	9.30 ± 1.76	5/10
P value			.039	.133	<.001	<.001	.089	<.001	.396	.976	<.001	.425

Abbreviations: HBF, height of bone flap; VBF, volume of bone flap; VNBBF, volume of needless buccal bone flap; VNBF, volume of needless bone flap; VNLBF, volume of needless lingual bone flap; PACR, percentage of alveolar crest restoration.

* Group A, vascularized iliac crest flap; group B, double-barrel fibula flap.

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support is needed for an esthetic facial appearance. For defects that involve the mandibular body and ramus, the shorter upper fibular segment can be used to provide a bone base for the dental prosthesis and to ensure buccal fullness. For lateral–central mandibular defects, the folded segment can be used to restore lip support.

The iliac crest free flap provides a large volume of well-vascularized bone, has structural similarity to the mandibular body, and is more straightforward to reshape than the fibula flap.[12,13] However, mandibular mobility can make accurate shaping and placement of the vascularized iliac crest challenging. Computer-aided design and computer-aided manufacturing allow for faster and more precise planning and reconstruction.[14,15] Yu et al[16] and Zheng et al[17] demonstrated how computer-assisted techniques can improve the accuracy of mandibular reconstruction using the vascularized iliac crest flap. Prebending of the reconstruction plate on the stereo model of the reconstructed mandible and the navigation system were the main computer-assisted techniques used. Both studies evaluated the mandibular width, bilateral condylar deviation, and position of the reconstruction plate to measure the success of the reconstruction. These studies focused on the postoperative position changes of the remaining mandible but did not report whether the bone flap could effectively restore the width of the alveolar crest and the height of the mandible.

Although the iliac crest flap has structural similarity to the mandibular body, its width can pose problems. Moreover, because of its blood supply, the iliac crest flap cannot be osteotomized into several segments to fit the mandibular defect. It can be difficult to reduce the width of the iliac crest flap because of the presence of the lateral bone cortex. The volume of the needless buccal bone flap is significantly less than the volume of the needless lingual bone flap. Although the excessive bone might benefit the implantation, it will adversely affect the facial appearance. Usually, the prebent reconstruction plate will be used to determine the buccal border of the iliac crest; thus, most of the needless bone flap will be located on the lingual side, reducing the volume of the oral cavity. In patients who have undergone resection of lingual muscle and mucosa because of neoplasm invasion, the lingual distribution of the bone flap could actually be beneficial because it occupies this space and prevents infections and the accumulation of fluid and saliva.

In the present study, the mandibular reconstruction rate, PACR, and HBF were not significantly different between the patients treated with the iliac crest free flap and the patients treated with the double-barrel fibular flap. Both methods provided approximately the same effective bone base for the insertion of implants. The fibula has the same cortex/medulla ratio

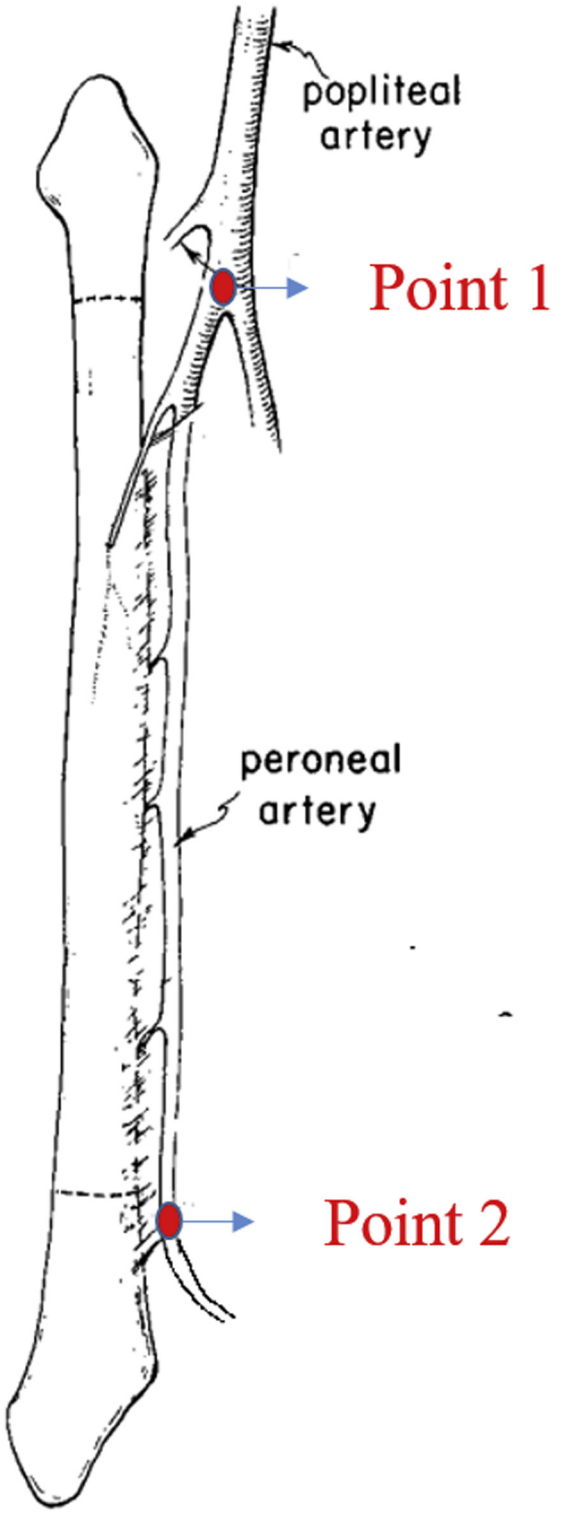

FIGURE 5. The length of the free fibular flap used for the mandibular defect depends on the position of 2 points. The first point is where the peroneal vessels branch from the posterior tibial vessels. The second is the point where the peroneal vessels run away from the fibula.

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as the mandible.[18,19] The conventional single-barrel fibular flap has a double cortical structure, which benefits the initial stability of the implant. With the double-barrel fibular flap, if the implant is enough long, 3- or 4-layer cortical bone could provide excellent stability. Although the iliac crest free flap has almost the same structure as the mandible, the porous cancellous bone with a single cortical layer cannot offer the same support as the fibula. Moreover, the rich blood supply can prevent peri-implant bone absorption and affect long-term stability. Exposure of the implant through the skin paddle or muscle fascia can lead to peri-implantitis.[18] Regardless of which flap is used, fibula or ilium, skin removal and hard palate mucosa grafting will be necessary.

A meta-analysis of iliac versus fibula-free flap demonstrated that osseointegrated dental implant loss in fibula flaps was greater than that in the iliac flaps (5.3 vs 1.7%).[20] The insufficient bone height can lead to overloading of osseointegrated implants and an unfavorable crown/implant ratio. The double-barrel fibula flap could overcome this deficiency; thus, in our sample, the success rate of implantation showed no difference between the double-barrel fibula flap and iliac crest flap. In a study of 24 cases of oromandibular reconstruction with a fibula or iliac crest flap, all 23 flaps that survived received an implant-supported prosthesis.[21] In our sample, the dental prosthesis rate (6 of 20 vascularized iliac crest flaps [deep circumflex iliac artery flaps] and 5 of 10 double-barrel fibular flaps) was lower than that reported in previous studies. These 2 methods could enable acceptable implant placement and positioning; however, the critical factor for dental prosthesis was the economic status of the patient. However, this important preliminary finding needs to be confirmed in larger studies. The long-term success rates with the 2 flaps also requires further study.

The double-barrel fibula flap has many advantages compared with the vascularized iliac crest flap for mandibular reconstruction. These include that it *1)* provides a multilayer cortical structure and adequate height and width of bone flap; *2)* enables effective usage of the bone flap; *3)* is more readily contoured to the mandible; and *4)* can reconstruct longer mandibular defects.

In conclusion, the double-barrel fibula flap can effectively restore the height of the alveolar crest. It is better than the vascularized iliac crest flap for long mandibular defects and provides better esthetic outcomes. Although the bone quantity is adequate with the vascularized iliac crest flap, it requires contouring to the mandible.

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