Mandibular Reconstruction with Scapular Systems: A Single-Center Case Series Involving 208 Flaps

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Background: The scapular flap is the most versatile composite flap used for mandibular reconstruction. The purpose of this study was to review and summarize findings of cases of mandibular reconstruction with a scapular flap and describe associated outcomes and complications.
Methods: A total of 208 microvascular scapular free flaps were performed for mandibular reconstruction in a total of 205 patients from 2003 to 2018. This study involved a retrospective review of all eligible patients' medical records.
Results: There were seven cases (3.4 percent) of microvascular thrombosis. Postoperative bone union was achieved by 201 patients, except for five with total flap necrosis and two with partial flap necrosis. There were four cases (1.9 percent) of mandibular condyle dislocation. Two major types of complications were observed at the donor site, including four cases of infection and six cases of scapular body fracture. Postoperative denture prosthesis was introduced to 97 patients (47.3 percent). Implant treatment was performed in 10 patients (4.9 percent). Functional and aesthetic outcomes were good to excellent.
Conclusions: The scapular composite free flap for mandibular reconstruction was associated with favorable outcomes and demonstrated satisfactory results. Although scapular bone fracture is rare, patients who have undergone mandibular reconstruction using a scapular flap should be monitored for its presence. (*Plast. Reconstr. Surg.* 148: 625, 2021.)
CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

The use of the scapula as a donor site for osseous-free tissue transfer, based on the circumflex scapular artery, was originally described by Saijo,[1] but Swartz et al.[2] and Baker and Sullivan[3] popularized the use of the flap for reconstructive surgery of the head and neck regions. The subscapular system offers a wide array of hard- and soft-tissue components that can be used to reconstruct highly complex defects.

The primary limitation of the traditional lateral border of a scapular flap is related to the shortness of the pedicle because of the circumflex scapular artery. However, compared with the lower extremity flap, this flap has several distinct advantages, including a lower risk of atherosclerosis and donor-site morbidity, superior skin color match, and unimpeded capacity for early postoperative ambulation.[4] Moreover, the subscapular vascular system allows harvest of multiple chimeric flaps of the soft tissue and bone from separate vessels, typically based on a single vascular pedicle, and permits versatility in the reconstruction of complex and extensive defects.[4,5] However, few case series on mandibular reconstruction with a scapular flap have been previously reported. The purpose of this single-center case series involving 208 flaps was to evaluate the patients who had received mandibular reconstruction with a scapular flap and to report on the associated outcomes and complications.

PATIENTS AND METHODS

This study included patients who had undergone microvascular reconstruction with a scapular flap from 2003 to 2018 at the Department of Oral and Maxillofacial Surgery of Tokyo Medical and Dental University. Patients' medical records were retrospectively reviewed. The variables of interest included age, sex, body mass index, smoking status, alcohol consumption status, American Society of

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Anesthesiologists classification, total operative time, pathologic diagnosis, preexisting comorbidities, specific flap components, complications in the donor or recipient site, and functional and aesthetic results. The location of the mandibular defects was grouped according to the classification proposed by Brown et al.[6] This classification considers the four corners of the mandible (two angles and two canines) and involves the following four main groups: class I (lateral), class II (hemimandibulectomy), class III (anterior), and class IV (extensive). Further groups (Ic, IIc, and IVc) include cases of condylectomy. Feeding and aesthetic outcomes were evaluated in 151 patients at a minimum of 12 months after surgery.

Feeding outcomes were evaluated based on the examination and medical records and categorized as follows based on the type of food consumed: unrestricted, soft, liquid, and tube feed. The attending physician evaluated the aesthetic outcomes based on the examination findings and medical photography, and the outcomes were categorized as excellent, good, fair, or poor. Speech intelligibility was assessed using the monosyllable Japanese speech intelligibility test,[7] and 100 Japanese utterances were used in this test. Each patient read all items on the list twice. Speech intelligibility was scored by five independent listeners; the mean scores of three of these listeners (excluding the highest and lowest scores) were used as a measure of speech intelligibility. This test was performed in 11 patients who had undergone segmental mandibulectomy alone and 21 patients who had undergone glossectomy along with segmental mandibulectomy.

Harvesting of the scapular flap was performed in a lateral position for all patients. Before surgery, a bite plate was prepared based on a dental model, which was inserted intraorally to maintain the occlusion; concurrently, a repositioning plate was constructed based on a three-dimensional computed tomographic image of the mandible, allowing the maintenance of the location of the mandibular fragment (Fig. 1).[8] In case of a thin mandibular ramus posterior border, a repositioning plate was attached to the coronoid process, except for cases involving lesions to the coronoid process. During the operation, we set a temporary repositioning plate, before proceeding to osteotomy (Fig. 2). After mandibulectomy, we set an intermaxillary bite plate and a repositioning plate between the bone fragments. Then, the harvested scapular bone was trimmed and plated by using a miniplate. This study complied with the principles of the Declaration of Helsinki, and its protocol was approved by the Institutional Review Board of Tokyo Medical and Dental University.

Fig. 1. (*Above*) A repositioning plate made for a three-dimensional mandibular model, constructed based on computed tomographic scans to determine the location of the mandibular fragment. *Black line* indicates osteotomy line. (*Center*) In cases where the posterior border of the mandibular ramus is thin, a repositioning plate should be attached to the coronoid process, unless its excision is warranted. The location of the resected area is set without letting the mandibular bone adhere to the scapular bone. (*Below*) A bite plate on the dental model made preoperatively.

RESULTS

During the study period, 205 patients (132 men and 73 women) underwent 208 harvests of scapular osseous free flaps for mandibular reconstruction (Table 1). The average patient age was 58.2 years (range, 13 to 84 years). Mean body

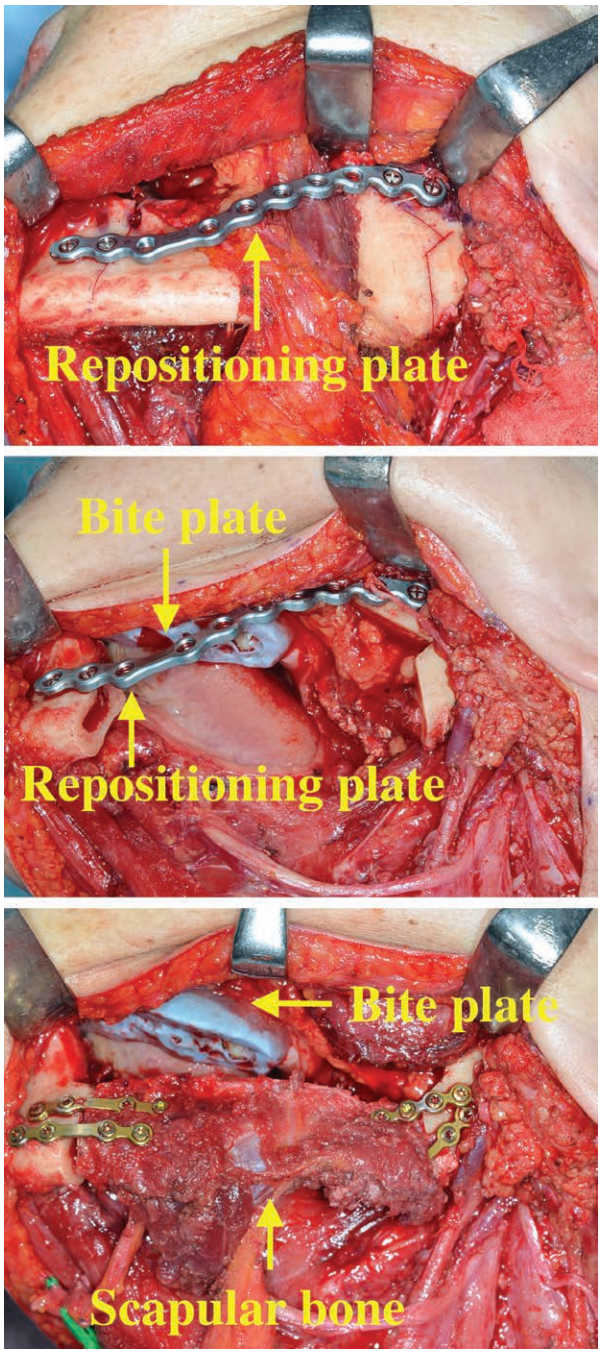

Fig. 2. (*Above*) During the operation, we temporarily set a repositioning plate, before proceeding with osteotomy. (*Center*) After mandibulectomy, we set an intermaxillary bite plate and a repositioning plate between bone fragments. (*Below*) The harvested scapular bone is trimmed and plated using the miniplate before coronoidectomy.

Table 1. Summary of Data of the Patients Who Underwent Mandibular Reconstruction with Scapular Flaps

Characteristic	No. of Patients
Total no. of patients	205
Sex	
Male	132
Female	73
Age, yr	
Mean	58.2
Range	13–84
BMI, kg/m^2	
Mean	22.9
Range	16.4–34.2
Current smoker	
Yes	51
No	154
Habitual alcohol	
Yes	76
No	129
ASA class	
1	108
2	94
3	3
Radiotherapy	28
Chemoradiotherapy	17
Total operative time, min	
Mean	563
Range	324–799
Time for positioning change (n = 148), min	
Mean	37
Range	22–69
Follow-up period, mo	
Mean	65
Range	6–202

BMI, body mass index; ASA, American Society of Anesthesiologists.

mass index was 22.9 kg/m^2. The American Society of Anesthesiologists category was class 1 in 108 patients, class 2 in 94 patients, and class 3 in three patients. Radiotherapy and chemoradiotherapy were performed in 28 and 17 patients, respectively. The mean operative time (including resection) was 563 minutes (range, 324 to 799 minutes). The mean time required for patients' position change (from supine to lateral position, and from lateral to supine position) was 37 minutes (range, 22 to 69 minutes) in 148 patients whose operative records were available. The mean follow-up period was 65 months (range, 6 to 202 months). Bilateral scapular flaps were harvested metachronously in three patients. The majority of patients underwent reconstruction for a malignant disease (n = 137). The remaining patients had benign tumors (n = 45), including ameloblastoma in 37 patients, myxoma in three patients, and other types of tumors in five patients. Osteoradionecrosis (n = 16) and osteomyelitis of the mandible (n = 7) were observed. Primary and secondary reconstructions after mandibular ablation were performed in 200 and eight cases, respectively.

All 208 osseous flaps used in the present patient sample comprised the lateral border of the scapula, including the branches of the scapular circumflex artery and vein (angular branch), as required. The mean length of mandibular resection was 8.0 cm (range, 4.3 to 13.0 cm). Table 2 shows the number of osteotomy procedures to the

scapular bone, stratified by the mandibular defect class.

The composite soft-tissue flaps used in the patients were as follows: bone-only flap in two patients, scapular flap in 182 patients, latissimus dorsi flap in 13 patients, combined scapular and parascapular flaps in six patients, and separate scapular and latissimus dorsi flaps in five patients (Table 3). The number of anastomosis of the artery procedures was one in 205 flaps and two in three flaps. The number of anastomosis of the vein procedures was one in 190 flaps, two in 17 flaps, and three in one flap. The use of a vein graft to lengthen the arterial and venous pedicles was required in three and eight patients, respectively. There were seven cases (3.4 percent) of microvascular thrombosis, three of which were arterial thrombosis that required removal of the scapular bone flap and replacement with a reconstruction plate and pectoralis major myocutaneous flap. There were four cases of venous thrombosis, two of which underwent a thrombectomy and revision of the venous anastomosis, whereas the remaining two cases underwent removal of the scapular bone flap and reconstruction with a reconstruction plate, with the primary suture in the oral cavity. Postoperative bone perfusion was observed in 201 cases, except for five patients with total flap necrosis and two patients with partial necrosis (Table 4).

There were four cases (1.9 percent) of dislocation of the mandibular condyle, three of which occurred during the operation. The case depicted in Figure 3 shows a dislocation of the distal bone fragment at 3 months after the resection of the ameloblastoma, although bone perfusion of the circumflex scapular artery was preserved. At 9 months after dislocation, bone union was confirmed by panoramic radiography.

Two major types of complication were observed at the donor site, including infection in four cases and prolonged scapular pain and scapular body fracture confirmed by computed tomography in six cases (Fig. 4). These cases were managed with a conservative approach. In this study, 154 patients underwent computed tomography or positron emission tomography/computed tomography as part of the follow-up care for malignant tumors, yielding an overall incidence of scapular fracture of 3.9 percent (six of 154).

Postoperative denture prosthesis was provided to 97 patients (47.3 percent). Implant treatment was performed in 10 patients (4.9 percent) (Fig. 5). All patients needed flap revision, and three patients required an additional bone graft from the iliac bone before the implant embedding. The median follow-up period for evaluating the feeding and aesthetic outcomes was 14 months (range, 12 to 58 months) after surgery. At the time of evaluation, no patient required feeding through a tube (Table 5). The proportion of patients with an unrestricted diet was 85.4 percent. The ratio of patients with soft and liquid diet to patients with an unrestricted diet was higher in cases involving a central defect than in cases involving a lateral defect. The aesthetic outcomes were excellent (8.6 percent), good (72.2 percent), fair (15.9 percent), and poor (3.3 percent) in the present sample. Poor aesthetic outcomes were observed among patients with external skin deficits, requiring an external skin island. The articulation test was performed in 11 patients who had undergone segmental mandibulectomy alone and in 21 patients who had undergone glossectomy along with segmental

Table 2. Number of Osteotomies According to the Type of Mandibular Defect

No. of Osteotomies	Mandibular Defect Classification					
	I	Ic	II	IIc	III	IV
0	76	11	19	2	2	—
1	22	12	40	2	12	2
2	—	—	—	—	7	1
Total	98	23	59	4	21	3

Table 3. Scapular Flap Characteristics

Characteristic	No. of Patients
Flap type	
Bone only	2
Scapular flap	182
Latissimus dorsi flap	13
Scapular and parascapular flap	6
Scapular and latissimus dorsi flap	5
Vein graft	
Arterial anastomosis	3
Venous anastomosis	8

Table 4. Complications

Complication	No.
Microvascular thrombosis	7
Artery	3
Vein	4
Total flap failure	5
Success of revision of microvascular anastomoses	2
Partial flap failure	6
Infection	18
Recipient-site complication	
Temporomandibular joint luxation	4
Donor-site complication	
Infection	4
Scapular fracture	6

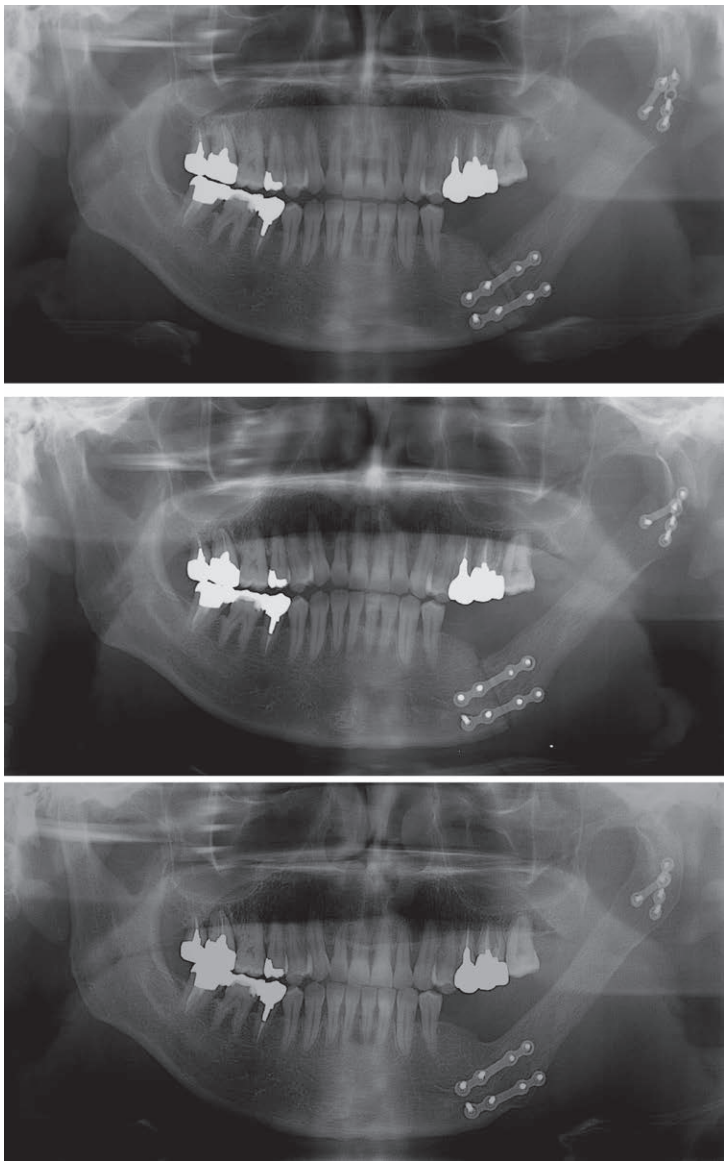

Fig. 3. A 43-year-old man diagnosed with ameloblastoma had undergone segmental mandibulectomy and scapular bone reconstruction. After 3 months, the screw was detached. (*Above*) A panoramic radiograph obtained 1 week after surgery shows good bone junction. (*Center*) At 3 months after surgery, a panoramic radiograph shows dislocation of the distal bone fragment, although bone perfusion is preserved. (*Below*) At 9 months after surgery, bone union is confirmed.

mandibulectomy. The median period from surgery to speech evaluation was 44 days (range, 22 to 364 days). Table 6 presents the patients' articulation scores. In patients that underwent segmental mandibulectomy, the mean score was 87.3 percent (n = 11); the corresponding values for those that underwent partial glossectomy (n = 14), hemiglossectomy (n = 3), and subtotal glossectomy (n = 4) were 84.0, 61.0, and 48.3 percent, respectively.

DISCUSSION

Multiple donor-site options are available for mandibular reconstruction, including the fibula, scapular system (lateral border and tip of the scapula), and iliac crest. Previous studies have attempted to define the advantages and disadvantages of these donor sites.[9–18] Some previous studies have compared these donor sites, concluding that the use of some sites is preferable over the use of the others.[11,12,14,16,18] Wilkman et

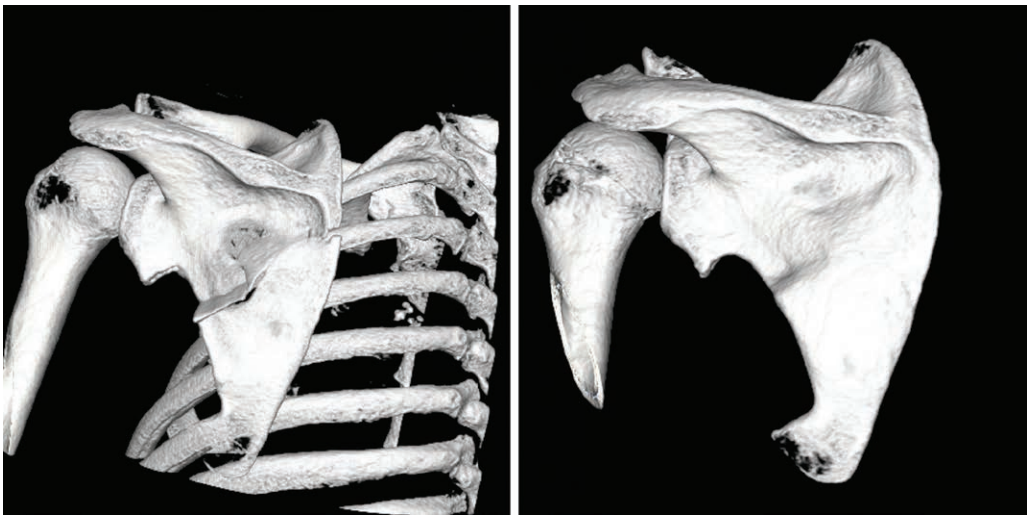

Fig. 4. A 32-year-old man had undergone segmental mandibulectomy and scapular bone reconstruction. One month later, he complained of shoulder pain while cycling. (*Left*) A three-dimensional computed tomographic scan obtained 1 month after surgery shows fracture of the scapular body. (*Right*) At 1 year after surgery, healing of the bone fracture was observed.

al. reported the results of the clinical comparison of scapular, fibular, and iliac crest osseal free flaps for maxillofacial reconstruction.[18] The failure rate was 0, 5.6, and 13.1 percent, respectively. They showed that the scapula is a reliable flap and has a low risk of donor-site complication. The fibula flap has become the standard donor site for mandibular reconstruction because it has an extensive amount of bone available for harvesting with minimal donor-site deficit, capacity to sustain multiple osteotomies without compromising vascularity (because of its dual blood supply), and a sufficient bone quality to allow for dental implant osseointegration.[11] In contrast, the fibula is considered a poor donor for this type of harvesting because of its extensive lining, skin, and soft-tissue requirements[11–15,19] and unpredictable vascularity.[20]

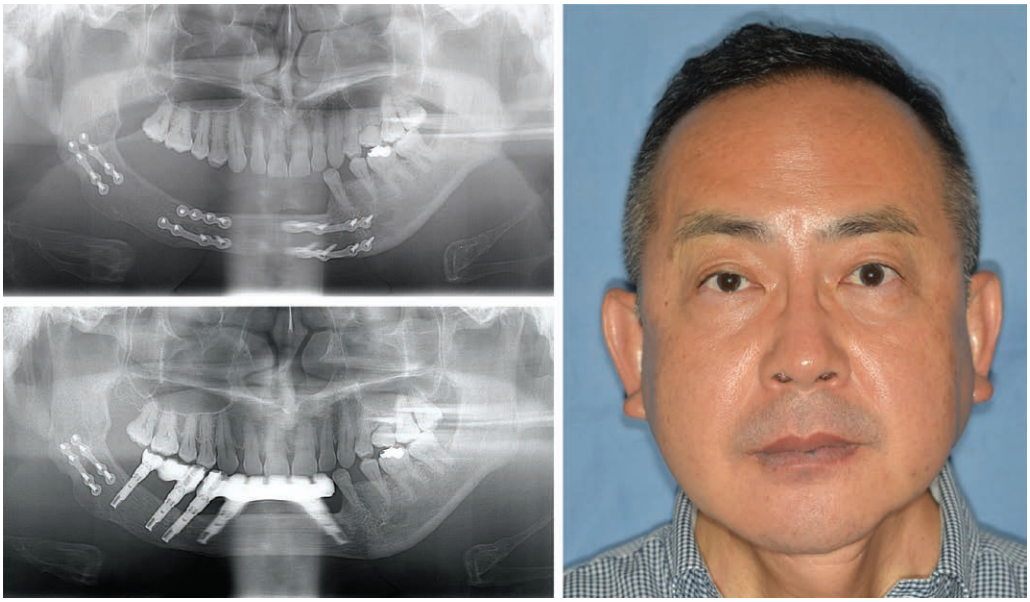

Fig. 5. Postoperative images of a 52-year-old male patient who had undergone segmental mandibulectomy (class III) and scapular bone reconstruction; after 2 years, he underwent implantation of the scapular bone. (*Above*, *left*) A panoramic radiograph obtained at 6 months after surgery. (*Below*, *left*) A panoramic radiograph obtained after implant treatment. (*Right*) Postoperative view at 3 years after surgery.

Table 5. Feeding and Aesthetic Results after Mandibular Reconstruction

	I	Ic	II	IIc	III	IV	Total (%)
No.	71	15	45	4	15	1	151
Diet							
Unrestricted	66	12	37	4	9	1	129 (85.4)
Soft	4	3	8		5		20 (13.2)
Liquid	1				1		2 (1.3)
Tube feed							0 (0)
Aesthetic results							
Excellent	6	2	3		2		13 (8.6)
Good	55	10	33	2	8	1	109 (72.2)
Fair	9	2	8	1	4		24 (15.9)
Poor	1	1	1	1	1		5 (3.3)

Table 6. Articulation Score after Mandibular Reconstruction

		Articulation Score	
	No.	Mean	Range
Segmental mandibulectomy	11	87.3	66.0–94.7
Segmental mandibulectomy and partial glossectomy	14	84.0	54.3–97.0
Segmental mandibulectomy and hemiglossectomy	3	61.0	55.3–67.3
Segmental mandibulectomy and subtotal glossectomy	4	48.3	30.7–72.3

Cordeiro et al. have proposed that scapular harvesting is recommended when a small amount of lateral bone is required alongside a large amount of skin and moderate volume of soft tissue for external covering.[11] The scapular bone is not suitable for use in cases with a long defect, as this donor site usually provides 10 to 14 cm of bone. However, as the scapular bone has a natural curvature, it allows the reproduction of a mandibular curve without osteotomy in cases with a lateral defect (class II) (Fig. 6). In addition, the scapula has a higher skin quality with a larger soft-tissue bulk than the fibula,[15] allowing raising a large and reliable skin island.[21] Moreover, a scapular flap has a low risk of atherosclerosis and donor-site morbidity, superior skin color match, and unimpeded ability for early postoperative ambulation.[4] It is impossible to allow simultaneous flap elevation during tumor resection. However, the mean time required for patients' position change (from supine to lateral position and from lateral to supine position) was 37 minutes in the present study, which is not very long.

The subscapular system offers an array of hard- and soft-tissue components that can be used to reconstruct highly complex defects. The two major branches of the subscapular artery are the circumflex scapular and the thoracodorsal arteries. The circumflex scapular artery runs through the muscular triangular space and separates into two small branches, which contribute to the scapular and parascapular fasciocutaneous flaps, respectively. The thoracodorsal artery arises from the subscapular artery; therefore, the latissimus dorsi can be harvested along with the scapular flap. However, in 8 percent of patients, the circumflex scapular and thoracodorsal arteries arise separately and directly from the axillary artery.[5]

We used the circumflex scapular system for mandibular reconstruction, as it provides a better blood supply to the lateral border of the scapula and is considered safe for osteotomies. These osteotomies have to be performed from the posterior

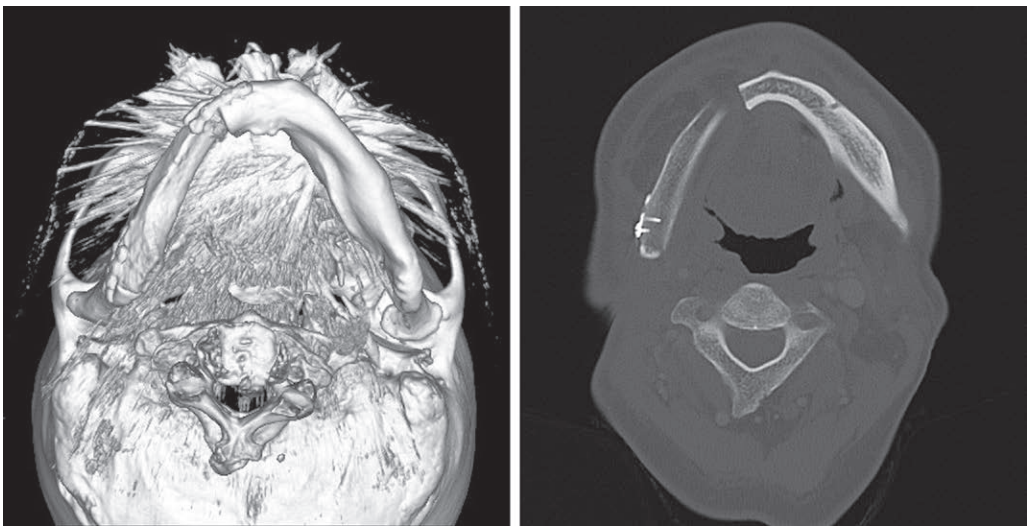

Fig. 6. Postoperative computed tomographic scan obtained at 3 months after surgery in a patient with a class II defect shows the natural curve of the scapula mimicking the curve of the native mandible body. (*Left*) Three-dimensional computed tomographic image. (*Right*) Computed tomographic image.

surface of the scapula because of peritoneal perforators, in particular, in the lateral border of the scapula. If the angular branch is included in the flap, the blood supply to the angular tip will be more favorable.

The rate of bone flap failure has been reported to be 2 to 6 percent,[9] whereas that of the scapular lateral border flap failure was 4 percent. Gibber et al.[5] have reported an overall 98 percent success rate among 105 patients who received scapular flap systems. In our case series, the rate of microvascular thrombosis was 3.4 percent (seven of 208), and that of total flap necrosis was 2.4 percent (five of 208). These findings indicate that the scapular osteocutaneous flap is a reliable approach for mandibular reconstruction.

Kang et al. reported five cases of condyle dislocation following mandibular reconstruction using a fibular flap.[22] Although they made no mention of the dislocation rate, customized computer-aided design/computer-aided manufacturing–prototyped temporomandibular condyle-connected plates may be a good alternative even if the virtual simulation surgery is to be performed preoperatively. These considerations help in reducing the incidence of condyle dislocation. In the present study, condyle dislocation occurred in four patients; of these, one patient had condyle dislocation at 3 months after surgery, leading to improper bone perfusion (Fig. 3). Bone union is associated with callus formation and typically takes 6 weeks to achieve.[10] The area of contact between the scapular bone and the edges of the distal bone fragment of the mandible is usually small. Notably, the condylar or basal segment has a restricted blood supply from the external pterygoid muscle[23]; an exclusive blood supply from the circumflex scapular artery is not favorable for the distal areas of the scapular graft, hindering the healing of the distal sides. In such cases, a more rigid fixation might be more advantageous, preserving the angular branch to provide a constant blood supply to the distal region; in the present case series, this was achieved with the use of four- and two-hole plates.

For the mandibular reconstruction, there are two commonly used types of plates available for establishing a stable osseous fixation—a miniplate and a reconstruction plate. Many researchers have reported the results of their comparative analysis on both plates.[24–26] Zhang et al. conducted a systematic review and meta-analysis to determine whether there is a significant difference in the complication rate between the use of miniplates and the use of reconstruction plates in patients with vascularized osteocutaneous flap reconstruction of the mandible,[26] and found no significant difference between the two groups. Several studies reported that the reconstruction plate was placed such that the inferior mandibular bone could adhere to it; thus, the reconstruction plate could be used for grafted bone fixation and for repositioning.[22,27] However, the command operation is usually applied for segmental mandibulectomy, and many patients undergo resection of the masseter and/or platysma muscles. Moreover, the outer side of the mandible often protrudes because of the tumor. Thus, we used the reconstruction plate for repositioning without letting the mandibular bone adhere to it. After mandibulectomy, we used the reconstruction plate for repositioning and plated the scapular bone using miniplates (Figs. 1 and 2).

To the best of our knowledge, only one previous report has assessed the scapular body fracture after a scapular flap harvest. Powell et al. evaluated the appearance of 82 scapular harvest sites on postoperative computed tomographic scans, reporting irregular fissuring in 20.5 percent of cases.[28] Moreover, scapular body irregularity was seen in 35.9 percent of cases; however, these cases included those with postoperative periosteal reaction caused by an infection, and the incidence of scapular fracture was not reported. Given that the thick part of the scapula is removed after harvesting, the fracture of the scapular body might be expected. To decrease the risk of such fractures, harvesting of the scapular tip would be desirable; however, evidence in favor of this approach remains lacking. In the present study, imaging assessment after scapular harvest was performed in 154 of the 205 cases; scapular body fracture was detected in six cases (3.9 percent). Although a scapular body fracture rarely occurs, it is a complication associated with the surgery, and patients should be monitored for it during the follow-up period. Kannan et al. reviewed the management of scapular body fracture in 97 cases and revealed that the nonoperative management of scapular body fracture had satisfactory results.[29] In the present cases, all fractures healed uneventfully after conservative treatment. At our department, rehabilitation is initiated during the 2-week postoperative hospitalization period. However, rehabilitation need not always be postponed. Future studies are required to clarify the risk factors for these fractures.

A dental prosthesis was required in 47.3 percent of the patients, and implant treatment was performed in 10 patients (4.9 percent). Lanzer et al. have reported that dental implants can be inserted after scapular free flap reconstruction.[30] However, the scapular bone tends to be thin, particularly

in women; thus, a bone graft might be necessary for implant treatment. In this study, three of 10 patients required an additional bone graft before the implant embedding. Patients were more likely to refuse to undergo an additional operation involving flap revision and/or bone graft, which is likely why the implant treatment rate was low.

Feeding and aesthetic outcomes were evaluated in 151 patients at a minimum follow-up duration of 12 months after surgery. Regarding the feeding outcomes, Hidalgo and Pusic[13] have reported that 70 percent of patients achieved normal feeding and a regular dietary pattern after fibular reconstruction. In the present study, an unrestricted dietary pattern was achieved by 85.4 percent of the patients, which was likely because of the high rate of dental prosthesis use. Cordeiro et al. have reported that the functional and aesthetic outcomes were worse among patients with a central defect than among patients with a lateral defect; the present study findings are consistent with these findings.[15]

Overall, the articulatory function did not decrease in patients who had undergone segmental mandibulectomy. Among patients who had undergone segmental mandibulectomy or partial glossectomy, the mean scores were 87.3 and 84.0 percent, respectively. Kudoh[7] has reported a mean score of 89.7 percent among patients who had undergone partial glossectomy only. The articulatory function tended to be good among patients who had undergone segmental mandibulectomy alone or partial glossectomy alongside segmental mandibulectomy. Further prospective studies involving more cases are required to validate our findings.

CONCLUSIONS

We have reviewed a total of 208 instances of microvascular scapular free flap used for mandibular reconstruction. Overall, the rate of microvascular thrombosis was 3.4 percent. Four cases developed dislocation of the temporomandibular joint. Functional and aesthetic outcomes were good to excellent for the majority of patients. Although the scapular bone is not suitable for use in cases with a long defect, the scapular composite free flap for mandibular reconstruction was associated with satisfactory outcomes.

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PATIENT CONSENT

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

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