Fibula Free Flap: A New Method of Mandible Reconstruction

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The fibula was investigated as a donor site for free-flap mandible reconstruction. It has the advantages of consistent shape, ample length, distant location to allow a two-team approach, and low donor-site morbidity. It can be raised with a skin island for composite-tissue reconstruction.

Twelve segmental mandibular defects (average 13.5 cm) were reconstructed following resection for tumor, most commonly epidermoid carcinoma. Five defects consisted of bone alone, and four others had only a small amount of associated intraoral soft-tissue loss. Eleven patients underwent primary reconstructions. At least two osteotomies were performed on each graft, and miniplates were used for fixation in 11 patients. Six patients received postoperative radiation, and two patients received postoperative chemotherapy.

The flaps survived in all patients. All osteotomies healed primarily. The septocutaneous blood supply was generally not adequate to support a skin island for intraoral soft-tissue replacement. The aesthetic result of the reconstruction was excellent in most patients, particularly in "bone only" defects. There was no long-term donor-site morbidity.

Free-tissue transfer has become a preferred method for reconstructing major segmental defects of the mandible. Vascularized rib was one of the earliest donor sites reported.[1,2] Since then, a variety of other donor sites have been used, including ilium, radius, metatarsal, and scapula.[3-9] Each of these donor sites has significant limitations resulting from either the length of bone available, the reliability of the associated soft tissue, or donor-site considerations such as undesirable location or the potential for significant morbidity. There does not appear to be a consistent rationale that favors the selection of one donor site over another.

The fibula has had wide application as a free flap for long-bone replacement in extremity trauma and cancer.[10-15] There are a number of features that make it appealing as a donor site for mandible reconstruction as well. For example, there is enough bone length available (25 cm) to reconstruct any length mandibular defect. The flap can be conveniently dissected in the supine patient from a lateral approach.[16] This donor site is far enough away from the head and neck area to allow ample room for two surgical teams to maneuver. Donor-site morbidity has been shown to be low.[17] The course of the peroneal vessels parallel to the bone would seem to guarantee adequate vascularity of the separate bone segments following multiple osteotomies. Finally, soft tissue is available with the bone based on a septocutaneous blood supply.[18,19]

Materials and Methods

Clinical Material

Twelve patients underwent mandibular reconstruction with the fibula as a free flap. Eleven patients were reconstructed primarily, and the most common etiology was epidermoid carcinoma (Table I). The average defect length was 13.5 cm. Half the patients underwent reconstruction of the anterior arch of the mandible; the other half had mostly lateral or hemimandibular reconstructions. Nine of the patients had primarily defects of bone with only limited adjacent soft-tissue loss within the oral cavity. Interosseous wires were used for fixation in the first patient, and miniplates were used for the last 11 patients. Two patients had received radiation preopera-

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TABLE I
Mandible Defects

Patient, Age, Sex	Timing of Reconstruction	Tissue Diagnosis	Bone Defect Length	Soft Tissue Defect	Fate of the Skin Island	Adjuvant Therapy
1. J.P. 68 M	Primary	Epidermoid carcinoma	12 cm	Intraoral	Survived 70 percent	Postoperative 5700 rads
2. J.G. 53 F	Secondary	Epidermoid carcinoma	16 cm	Intraoral	Excised intraoperatively	Preoperative, 5000 rads
3. J.C. 43 M	Primary	Epidermoid carcinoma	14.5 cm	Intraoral	Excised intraoperatively	Postoperative, 6200 rads
4. M.A. 61 M	Primary	Recurrent lymphoma	14 cm	External	Survived	Preoperative, 5400 rads Preoperative chemotherapy
5. K.Z. 34 M	Primary	Ossifying fibroma	14.5 cm	None	None used	None
6. R.H. 44 F	Primary	Epidermoid carcinoma	16 cm	Intraoral	Excised intraoperatively	Postoperative, 6300 rads
7. J.K. 41 F	Primary	Osteogenic sarcoma	12 cm	None	None used	None
8. J.K. 53 M	Primary	Epidermoid carcinoma	12 cm	None	None used	Postoperative, 5600 rads
9. M.R. 52 F	Primary	Osteogenic sarcoma	13 cm	None	None used	Preoperative, postoperative chemotherapy
10. L.P. 37 F	Primary	Adenoid cystic carcinoma	8 cm	None	None used	Postoperative, 5000 rads
11. W.G. 61 M	Primary	Osteogenic sarcoma	15 cm	None	None used	Postoperative chemotherapy
12. S.F. 61 M	Primary	Epidermoid carcinoma	15 cm	None	None used	Postoperative, 5000 rads

tively, and six received it postoperatively. Two patients had received chemotherapy preoperatively, and two patients received it postoperatively.

Flap Dissection

A lateral approach to dissection of the fibula was used in all patients. Most of the bone is taken regardless of the length of the segment needing reconstruction. This gives the greatest flexibility in shifting the graft in relation to the point where the vessels join the bone. This also maximizes the available length of the pedicle, in that its final location in relation to the recipient vessels can be precisely planned.

Dissection is performed with a tourniquet inflated to 450 mmHg. In cases where a skin island was included, the skin was first raised together with the deep fascia from the lateral compartment musculature and then in similar fashion from the superficial posterior compartment musculature. At this point, the skin island remains attached to the bone only by the intermuscular septum. Dissection from this point on is the same in cases where only the bone is used.

The electrocautery is used to remove the lateral compartment muscles from the bone. This leaves a cuff of muscle on the bone that is only 1 to 2 mm in thickness. The septum between the lateral and anterior compartments is then divided, and the anterior compartment muscles are removed from the bone. Proximally, care must be taken not to damage the anterior tibial vessels and the deep peroneal nerve. The interosseous membrane is then divided.

Attention is then turned posteriorly, and the gastrocnemius and soleus muscles are reflected from the bone. The vascular pedicle is then

identified as it enters the substance of the flexor hallucis longus muscle and courses distally, parallel to the bone.

The bone is then osteotomized proximally and distally. The peroneal artery and vein are then divided and ligated *distally*. The tourniquet is released so that the final dissection can be performed while palpating the peroneal and posterior tibial vessels as necessary. The fibula is placed on traction away from the leg, and the tibialis posterior muscle is viewed from its anterior aspect to identify its median raphe. It is safe to divide the muscle in a distal to proximal direction along this median raphe. It appears to be a reliable landmark that prevents inadvertent injury to either the peroneal or posterior tibial vessels as long as it is followed carefully. Proximally, the peroneal vessels cross from medial to lateral, and it is quite easy to injure the vessels here if a plane is not first developed between the muscle and the vessels and a narrow, malleable retractor is placed to protect the vessels. After the tibialis posterior muscle is completely divided, the flexor hallucis longus muscle is divided either longitudinally or only distally, depending on how much muscle bulk is needed with the flap. The flap then remains attached only by the vascular pedicle, which is then dissected further under loupe magnification.

Shaping the Graft

The graft osteotomies are planned so that the position of the vascular pedicle is at the angle of the new mandible. This maximizes pedicle length. The osteotomies are performed before the graft is divided and transferred to the head. The bone is divided completely through at each osteotomy site. Two to four osteotomies are made in the graft, and they are then fixed with miniplates. Measurements taken from the surgical specimen and templates fashioned from x-ray studies and CT scans assist in accurately shaping the graft at the donor site.

Graft Insetting and Revascularization

After transfer of the graft to the defect, the ends are modified as necessary to provide a precise fit. Intermaxillary fixation is helpful to maintain occlusion during final modification of the graft. After fixation with miniplates, the graft is revascularized using either the facial artery or external carotid artery and a nearby vein. The flexor hallucis longus muscle is then trimmed as necessary depending on the soft-tissue requirements adjacent to the bone. Intermaxillary fixation is maintained for only 2 weeks. Its purpose is solely to minimize movement near the vascular pedicle and not for additional fixation.

Case Reports

Case 3: Secondary Reconstruction of an Anterior Mandibular Defect in a Radiated Field

This 53-year-old woman underwent resection of a 3.5-cm anterior floor of the mouth epidermoid carcinoma that included resection of the anterior mandible and bilateral upper neck dissections. She received 5000 rads of radiation therapy postoperatively. Reconstruction of the mandible defect required a 16-cm fibular graft with two osteotomies in the midportion of the graft. A skin island harvested with the bone was intended to supplement an otherwise tight intraoral closure. However, after fixation of the bone and graft revascularization, there was noted to be poor perfusion of the skin island, particularly when the septum of the graft was folded on itself to bring the skin island inside the oral cavity. The skin island was therefore excised and the oral defect closed directly. A vestibuloplasty was performed 6 months later. Although this patient demonstrates well the ability of the fibula to restore normal lower facial appearance even in difficult secondary cases, it also shows the hazards of using a skin island with the fibula for simultaneous intraoral soft-tissue replacement (Fig. 1).

Case 5: Primary Reconstruction of a Combined Mandibular and External Soft-Tissue Defect

This 60-year-old man developed recurrence of a gingivobuccal sulcus lymphoma 2 years following radiation therapy. Resection was performed after failure to respond to chemotherapy and a metastatic workup was negative. A through-and-through defect resulted that included a 14-cm mandible gap and a large external soft-tissue component (Fig. 2). The intraoral defect was closed primarily. A 9 × 17 cm skin island was raised with the fibula graft and used to close the external soft-tissue defect. The mandible and facial soft tissues healed uneventfully, and the patient is free of disease at 1 year. This patient demonstrates the feasibility of using the fibula with a skin island for reconstructing a composite defect with a large external soft-tissue component.

Case 6: Primary Hemimandible Reconstruction without an Associated Soft-Tissue Defect

This 34-year-old man with a 12-year history of ossifying fibroma of the right mandible underwent a hemimandibulectomy for persistent pain. The defect included the temporomandibular joint and extended to the ipsilateral parasymphysis. A 14.5-cm fibular graft was used to reconstruct the bony defect. The fibula was osteotomized twice to establish appropriate contour. The condyle, which was free of disease, was attached to the end of the fibula as a conventional bone graft to reconstruct the temporomandibular joint. Intermaxillary fixation was used to maintain occlusion while the graft was shaped and fixed with miniplates. The intermaxillary fixation was removed at the end of the pro-

FIG. 1. (*Above, left* and *right*) Secondary reconstruction of an "Andy Gump" deformity. (*Below, left* and *right*) Appearance 6 months following fibular free-flap reconstruction. The patient is shown prior to dental reconstruction.

cedure. This patient demonstrates the superiority of the fibula in achieving accurate mandibular contour (Fig. 3).

RESULTS

All flaps survived. This was determined by persistent Doppler pulses detectable along the length of the graft, uncomplicated wound healing in the presence of significant muscle tissue associated with the graft, rapid healing of osteotomy sites on sequential panorex studies, and positive bone scans performed in equivocal cases. All osteotomy sites healed primarily. The skin

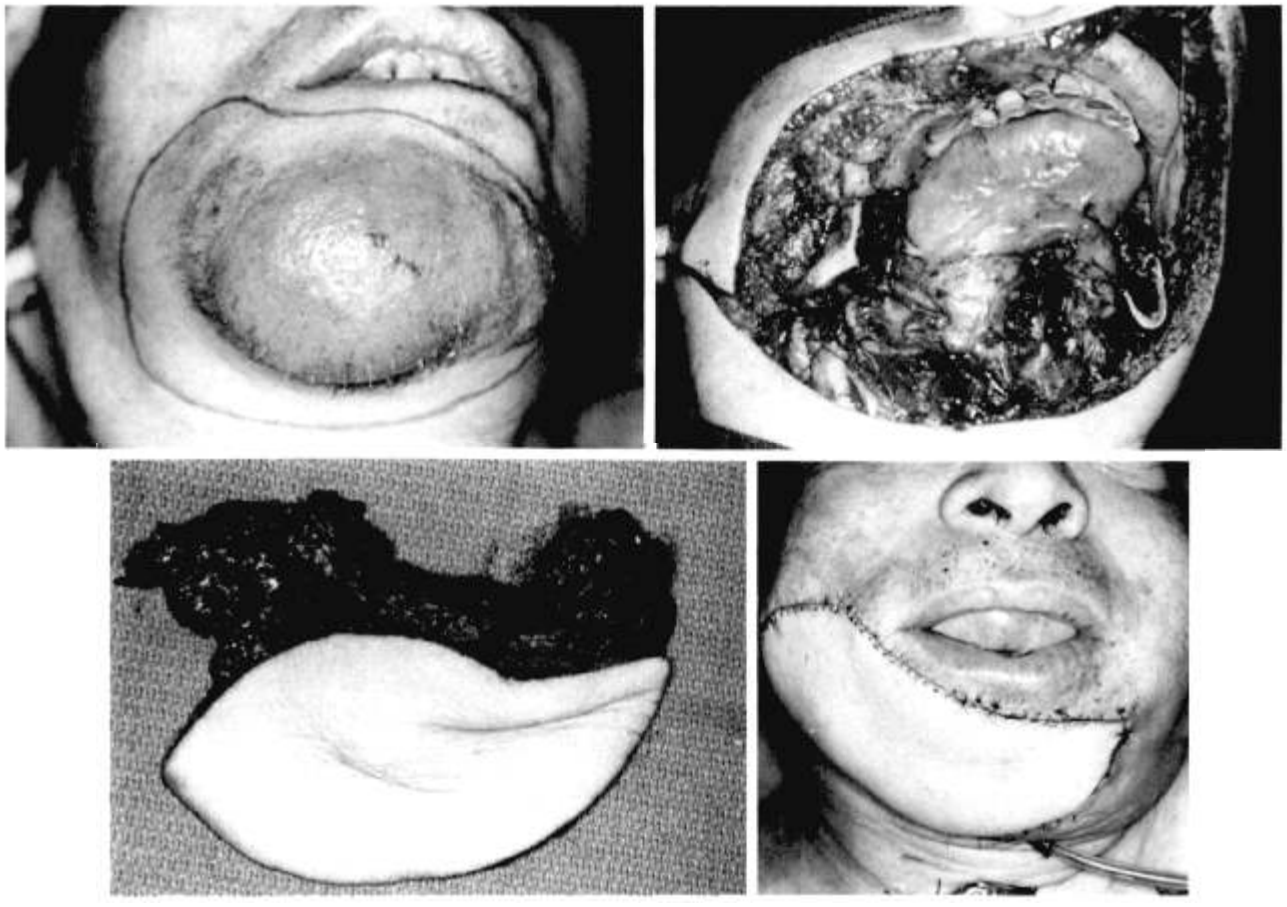

FIG. 2. (*Above, left* and *right*) A large bone and soft-tissue defect is shown prior to reconstruction with a composite fibular free flap. (*Below, left*) The osteotomized bone is visible above the skin island of the flap. (*Below, right*) Immediate postoperative appearance.

island was excised prior to final wound closure in three patients because the blood supply to the skin component of the flap was judged to be inadequate after revascularization. The skin island survived completely in one patient in whom it was used externally. There was partial loss (one-third) of the skin island in one patient in whom it was retained for use as intraoral lining. Six flaps were radiated postoperatively and two patients were treated with chemotherapy, all without failure to heal osteotomy sites.

Symmetry and contour of the mandible were judged to be excellent in all patients based on comparisons of preoperative and postoperative photographs and panorex studies (Figs. 3 and 4). Mandible range of motion was less than normal in all patients, although in no patient was there compromise great enough to impair the ability to eat. One patient was fitted with conventional dentures, and several others are candidates for osseointegrated implants, although none have been placed at the time of this writing.

The donor-site morbidity of this flap was particularly low when the flap was raised without a skin island (Table II). Early postoperative morbidity was limited primarily to flaps that included skin islands and consisted of minor skin graft slough in one patient, skin edge necrosis in one patient in whom a tight closure was performed without a skin graft, and leg edema in one patient that ultimately resolved. There was one patient in whom a flexion contracture of the toes developed, and this required secondary tendon lengthening of the flexor digitorum longus at the level of the ankle. There has not been any long-term donor-site morbidity seen in this study.

DISCUSSION

A number of free-flap donor sites currently exist that provide vascularized bone for mandible reconstruction. However, an ideal donor site does not yet exist for all applications. Donor-site limitations include positioning problems that can preclude a two-team approach and add a signifi-

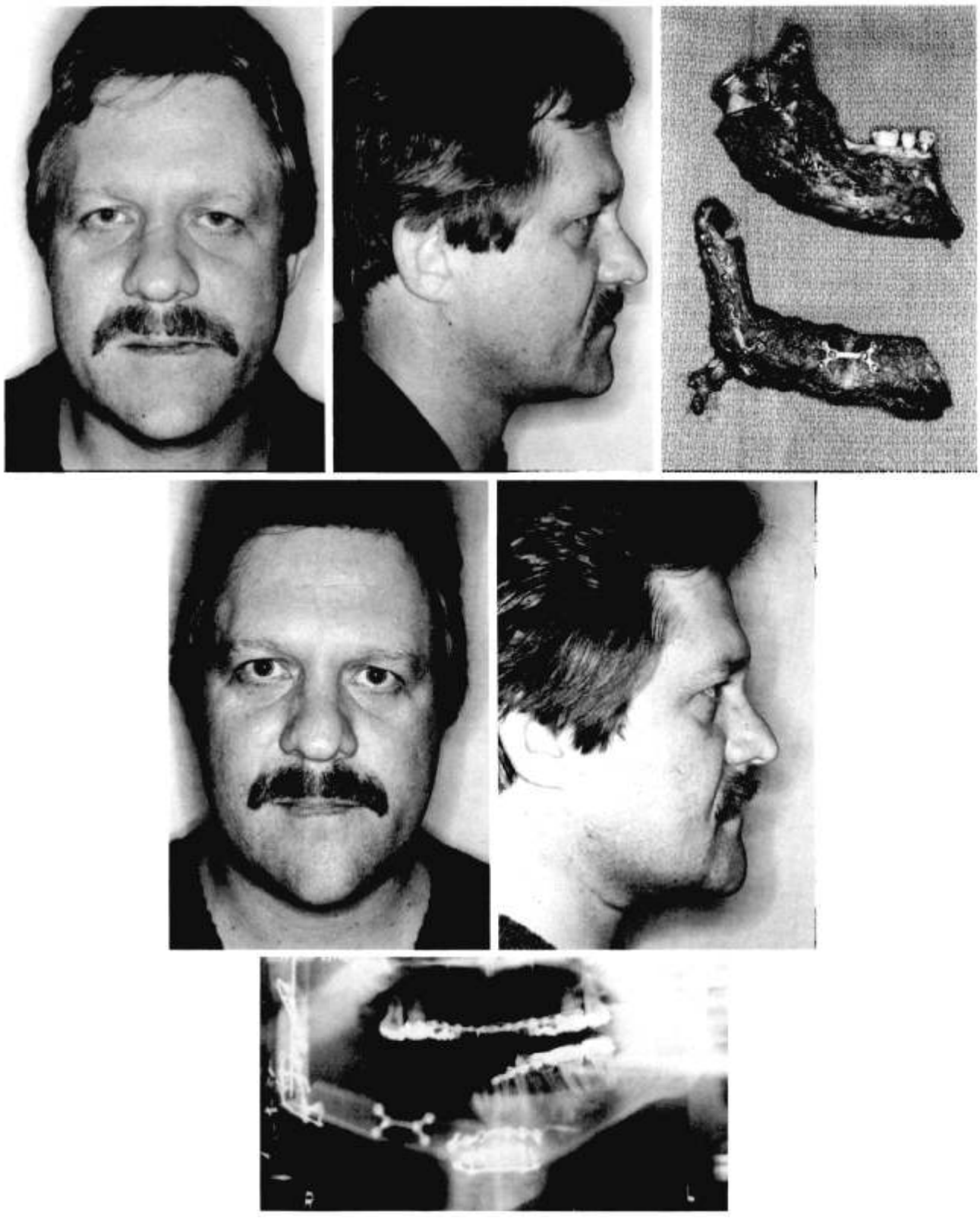

FIG. 3. (*Above, left* and *center*) Preoperative appearance prior to hemimandible resection. (*Above, right*) The resected hemimandible is shown above the contoured fibular graft. The vascular pedicle of the fibula is visible at the angle of the hemimandible graft. Postoperative appearance (*center, left* and *right*) and panorex (*below*).

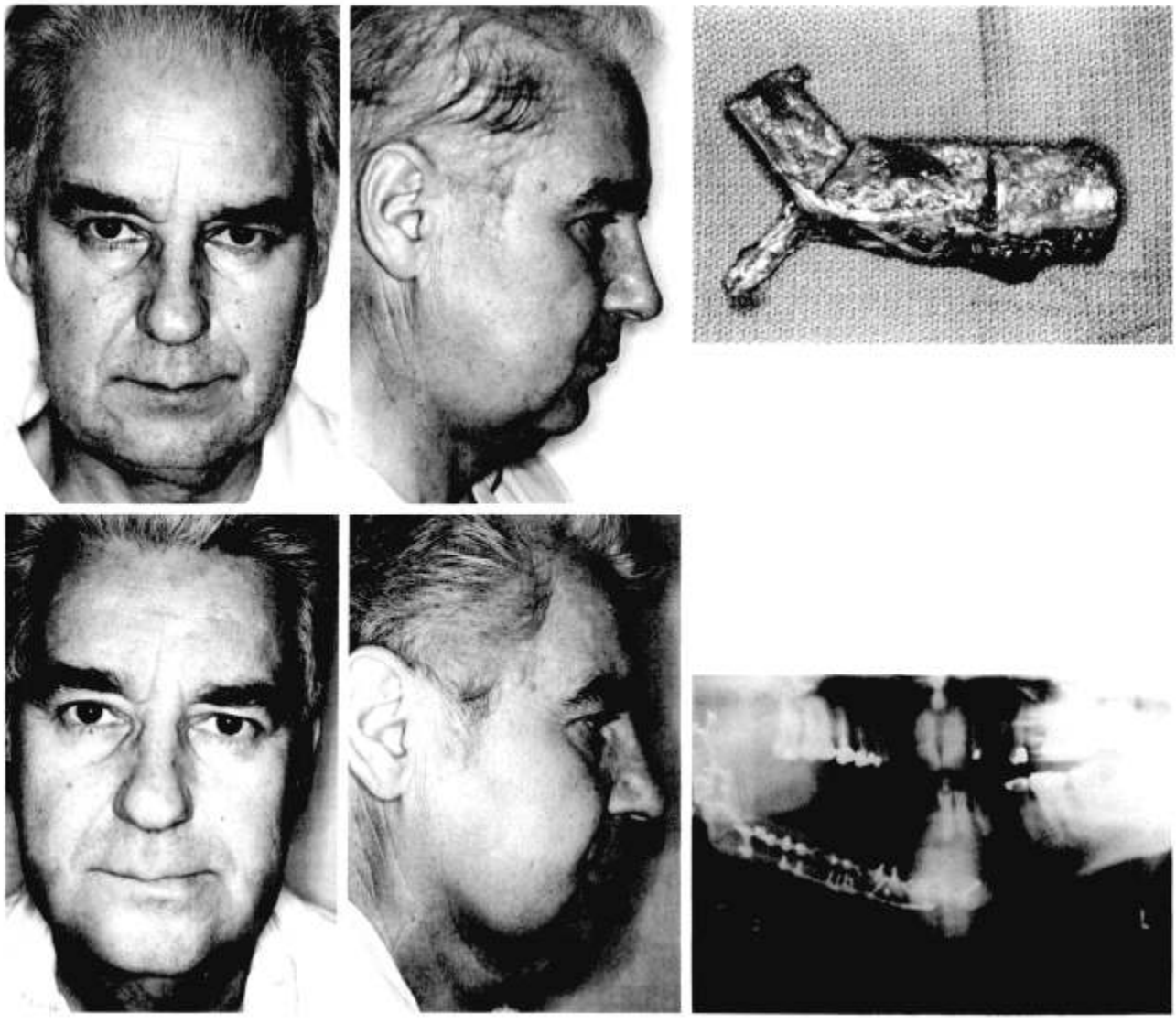

FIG. 4. (*Above, left* and *center*) Preoperative views of a patient with an epidermoid carcinoma of the gingiva. Resection left a small intraoral soft-tissue defect that was closed primarily. (*Above, right*) The fibular graft is shown following osteotomy. The vascular pedicle is seen at the angle of the new mandible. Postoperative views (*below, left* and *center*) and panorex (*below, right*).

TABLE II
Donor-Site Morbidity

Patient	Skin Island	Wound Closure Method	Early Postoperative Morbidity	Postoperative Ambulation Begins	Long-Term Morbidity
1. J.P.	Yes	Direct	Leg edema	Day 8	None
2. J.G.	Yes	Direct	Wound edge slough	Day 14	None
3. J.C.	Yes	Direct	None	Day 7	None
4. M.A.	Yes	Graft	Minor graft slough	Day 24	None
5. K.Z.	No	Direct	Scar tenodesis of toe flexors	Day 5	None
6. R.H.	Yes	Graft	None	Day 15	None
7. J.K.	No	Direct	None	Day 5	None
8. J.K.	No	Direct	None	Day 6	None
9. M.R.	No	Direct	None	Day 6	None
10. L.P.	No	Direct	None	Day 11	None
11. W.G.	No	Direct	None	Day 5	None
12. S.F.	No	Direct	None	Day 5	None

cant amount of operating time (scapula); morbidity from delayed healing (metatarsal); pain and an inability to ambulate the patient early, with possible late hernia (ilium); or hand stiffness and the possibility of fracture (radius). Some donor sites have limited lengths of bone available (scapula, radius, metatarsal), while the ilium has a predetermined shape that hampers accurate contouring in some patients.

The fibula has a number of characteristics that make it an attractive alternative for mandible reconstruction. There is ample bone length available to reconstruct any defect, unlike other donor sites. The fibula is a straight piece of bone stock with consistent (and ideal) cross-sectional dimensions. Osteotomies can be performed wherever necessary along the length of the graft, since there are no major variations of bone shape such as those seen with the ilium. These features of the fibula permit great flexibility in contouring the graft to simulate the shape of the mandible.

The peroneal vessels parallel the course of the bone throughout its length. Periosteal blood supply is abundant and permits multiple osteotomies to be performed that are as little as 1 cm apart. Viability of multiple small segments in series has been well demonstrated in this study, despite the presence of multiple miniplates on each segment to provide fixation. The endosteal supply to the bone therefore does not appear essential to survival of the graft, which has been shown before.[19,20] This vascular arrangement in which the major vessel courses with the bone and provides ample segmental periosteal blood supply is another feature that contributes to great flexibility in contouring the graft.

Since the endosteal supply is not critical, there does not need to be concern for the relationship of the osteotomies to the entrance of the vascular pedicle. The design of the graft can therefore be shifted in relation to the vascular pedicle in such a way that the pedicle always ends up in the ideal location with respect to the recipient vessels (Figs. 3, *above, right*, and 4, *above, right*). The inherently short pedicle of this flap is well compensated for by this design feature so that it does not constitute a disadvantage of this donor site. In most lateral mandibular reconstructions, the osteotomy to form the angle is purposely placed in close proximity to the vascular pedicle. This allows the donor and recipient vessels to lie conveniently close together.

There is an additional benefit of the vascular anatomy of this flap in mandible reconstruction. Since the peroneal artery courses the length of the bone and remains a sizable vessel throughout, it is relatively easy to monitor buried flaps with a conventional Doppler. The facial soft tissues are relatively thin, and the pulse can be detected along the reconstructed mandibular contour, away from the large neck vessels, which might otherwise cause confusion in interpreting the source of the Doppler signal.

The use of a skin island based on a septocutaneous blood supply is problematic when this donor site is used for composite reconstruction of the mandible. Injection studies of 10 cadaver legs performed during the course of this study have shown that the number of vessels that traverse the septum is quite variable and can be as few as one. A number of clinical studies have shown, however, that skin can be safely transferred with the bone in cases of extremity reconstruction.[18,19] Mandible reconstruction using the fibula often requires a shorter segment of bone than extremity cases, and it is possible that the vessels to the skin are either not included with the bone segment or are possibly compromised by the osteotomies. The experience at this institution supports this notion when comparing the number of viable skin islands in cases of fibular reconstruction of the extremities (seven of eight) with mandible reconstructions (two of five, and incomplete survival in one other). The one failure in the extremity group occurred in the case of a short bone gap. The skin perfusion was adequate with the flap raised at the donor site but was not so after the bone had been shortened the required amount.

In this study, long skin islands associated with long bone grafts offered the greatest chance for skin survival. Survival decreased with shorter skin islands, shorter bone grafts, and attempts to use the skin island within the oral cavity. Twisting the septum upon itself and passing the skin island through the tight space between the mandible and the floor of the mouth was the fatal blow to skin circulation in several instances. It is therefore not recommended that the fibula be used with a skin island for reconstructing mandible defects combined with large intraoral soft-tissue loss.

Septocutaneous perforators can be located with a Doppler device preoperatively. However, this does not guarantee that skin perfusion will be adequate after osteotomies have been performed and the graft shortened the required amount. Angiography does not allow adequate preoperative study of skin blood supply, although it may be useful to confirm that the peroneal

artery is present, free of disease, and not the dominant source of blood supply to the distal leg.

Two advantages of this donor-site location are its distance from the head and the ability to raise this flap in the supine patient. A two-team approach can be used with ample room for both teams to maneuver.

The donor-site morbidity is negligible when skin islands are not raised with the bone and the leg is properly splinted postoperatively. The one case of toe flexor tendon scar tenodesis that occurred in this series is attributable to improper splinting. Our current practice in "bone only" cases is to apply a posterior splint for the first 5 days postoperatively and then begin ambulation as soon as possible thereafter. Closures that require a skin graft prolong the time to ambulation and are associated with small areas of incomplete graft take over the tendinous portions of the lateral compartment muscles. There has not been any long-term functional morbidity associated with the use of this donor site, and the appearance of the leg is excellent when the wound can be closed without a skin graft.

CONCLUSIONS

1. The fibula provides enough bone to reconstruct any length mandible defect.
2. Multiple graft osteotomies can be made and spaced close together without loss of bone viability.
3. The fibula is relatively easy to contour, and excellent aesthetic results can be consistently achieved.
4. Donor-site location is optimal for a two-team approach.
5. Donor-site morbidity is low, particularly when a skin island is not used.
6. Owing to the unreliability of skin island blood supply, this flap is best used for mandibular defects associated with limited soft-tissue loss.

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