The Vascularized Fibular Flap for Mandibular Reconstruction

Torstein Lyberg, Olav Anders Olstad

Dept. of Maxillofacial Surgery (Head: T. Lyberg, M.D., D.D.S. Ph.D.)
Ullevaal University Hospital, Oslo, Norway

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Introduction

Reconstruction of mandibular defects due to trauma or tumour surgery has long been a challenge in maxillofacial surgery. During recent decades several pedicled osteomuscular flaps have been developed to accomplish mandibular reconstruction. These include the sternomastoid with the attached clavicle (Siewmensen et al., 1978), the trapezius with scapula (Panje and Cutting, 1980; Radcliffe et al., 1982), squama temporalis with the temporalis muscle (Conlay, 1972; Cutting et al., 1984; Munoz et al., 1990) and the pectoralis major with the sternum (Green et al., 1981) or ribs (Serafinm et al., 1977; Cuono and Arieran, 1980; Radcliffe et al., 1982). Reliability in these techniques has been found to be variable. With the advent of microvascular free tissue transfer, several new possibilities for mandibular reconstruction opened up. Rib, based on the posterior intercostal artery and vein was the first vascularized free living bone graft (Fredrickson et al., 1979a) and its clinical use (Taylor et al., 1979b; Taylor, 1982). Alternative free vascularized bone transplants in clinical use for mandibular reconstruction include the dorsalis pedis second metatarsal flap (O'Brien et al., 1979; Duncan et al., 1985), the radial forearm flap incorporating the radius (Sotlar et al., 1983) and the osteocutaneous scapular flap (Sicart et al., 1986).

The very first reported case of free vascularized bone transfer in human beings was performed using a midfibular section for the repair of large tibial defects (Taylor et al., 1975). Gilbert's (1979) description of an easy method of raising this bone graft has greatly increased its popularity as a donor site. Providing a long length of rigid, strong cortical bone, the fibula has later become the most commonly used vascularized bone graft for reconstruction of diaphyseal bone defects in the tibia, femur, humerus and radius. Despite the obvious similarities between fibula and mandible regarding dimensions and bone structure, the fibular graft for mandibular reconstruction has not received much attention, in fact only one previous report has been published in the literature of maxillofacial or plastic and reconstructive surgery (Hidalgo, 1989). In this paper we report eight cases in which a free vascularized fibular graft has been used successfully to reconstruct defective mandibles due to gunshot injuries, chronic osteomyelitis and tumour surgery.

Anatomical considerations

The fibula is supplied by a nutrient, endosteal artery arising from the peroneal artery and periosteal circulation, usually arising below the fibular head. After exposing the muscular fascia, access to the fibula was gained along the intermuscular fascia between the peroneus longus and brevis muscles and part of the extensor hallucis longus muscle were then exposed as carefully as possible. After sectioning the fibula proximally and distally, using an oscillating saw, the freed mid-portion can be distracted laterally, allowing easy identification of the peroneal vessels. The flexor hallucis longus and the tibialis pos-

Summary

Vascularized fibular bone grafts have advantages over other bone grafts in the restoration of the contour and function of defective mandibles. The fibular graft can be tailored to fit even major mandibular defects; in combination with preformed temporomandibular joint prostheses total mandibular reconstruction can be performed in a single procedure. The fibular transplant is considered ideal for the insertion of implants to support dental suprastructures to obtain maximal oral rehabilitation. We have used fibular grafts in eight cases for primary or secondary reconstruction of a variety of mandibular defects resulting from cancer, chronic osteomyelitis or gunshot injuries. The results have been most encouraging with respect to function and cosmetic appearance. There have been no transplant failures and minimal donor site complications.

Key words

Microvascular surgery — Fibular free flaps — Mandibular reconstruction
Fig. 1 Schematic view showing the contouring of a fibular graft to provide an exact replica of the lower jaw. The fibular graft can be equipped with a preformed condylar prosthesis for temporomandibular joint reconstruction.

<table>
<thead>
<tr>
<th>PATIENT</th>
<th>DIAGNOSIS</th>
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<tr>
<td>1. (56) ♂</td>
<td>Gunshot injury</td>
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<tr>
<td>2. (25) ♀</td>
<td>Malignant fibrous histiocytoma</td>
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<td>3. (17) ♂</td>
<td>Ossifying fibroma</td>
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<td>4. (21) ♂</td>
<td>Gunshot injury</td>
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<tr>
<td>5. (56) ♂</td>
<td>Chronic osteomyelitis</td>
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<tr>
<td>6. (52) ♀</td>
<td>Epidermoid carcinoma</td>
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<tr>
<td>7. (56) ♀</td>
<td>Chronic osteomyelitis</td>
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<tr>
<td>8. (23) ♂</td>
<td>Gunshot injury</td>
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Fig. 2 Site and size of mandibular defects. The sites of the fibular intratransplant wedge osteotomies are marked with arrow-heads.

The straight fibular bone graft was contoured by wedge osteotomies (Fig. 1), using an oscillating saw and rotating burs, after reflecting the periosteum from the outer and inner cortex. Completion of the osteotomy is preferably made by the saw, taking extreme care not to sever the nutrient vessels. Attempts to make a green-stick fracture of the remaining cortical plate is not advised, because it often results in an irregular fracture with cortical spicules hampering the angulation. The degree of angulation at the osteotomy sites was calculated on drawings of the resected part of the mandible if available. Triangular cortico-cancellous bone pieces were removed, taking extreme care to remove the correct amount of bone, making the intratransplant junctions as flush as possible. In order to obtain an optimal aesthetic and functional result, care must also be exerted to create a transplant angulation with the mandible, which corresponds closely to the original mandibular plane. Fragments on either side of the osteotomy site are held in the desired position of angulation by titanium miniplates, preferably two miniplates at each osteotomy site. Remaining defects at the osteotomy sites are packed tightly with bone chips.

The patients were treated with 500 ml of low molecular weight Dextran (Macrodex®), starting peroperatively and repeated on postoperative days 1, 3 and 5. Dipyridamole (Persantin®) 40 mg was given intravenously at the time of vessel anastomosis and four times daily during the first three days, thereafter 75 mg three times daily orally for a week. Acetylsalicylic acid was given in daily doses of 0.5 grams for 10 days. A single intraoperative dose of Heparin (5000 I.U. subcutaneously) was administered to patients 1-3 just before the vessel clamps were released upon completion of the anastomosis, but has been omitted in the later part of the series. The patency of anastomosis was followed daily in the postoperative period by Doppler ultrasonography and the viability of the bone graft was confirmed by Technetium bone scan at the recipient site, 7–14 days postoperatively.

Case Reports

Altogether 8 patients are presented to illustrate the various refinements of this method for mandibular reconstruction. The extent of the mandibular resections is summarized in Fig. 2.

Patient 1

A 56-year-old man presented with an intentionally, self-inflicted shotgun injury with a massive soft tissue laceration, and a mandibular defect ranging from the right canine region to the left first molar region. One year post-injury, permanent bone reconstruction was performed using a vascularized fibular graft. The graft united to the mandible satisfactorily, but unfortunately, the patient committed suicide by hanging, 3 months after the mandibular reconstruction. Autopsy was performed and the lower jaw was removed for examination. Removal of miniplates and screws showed that there was excellent bone union between the graft and the mandible and at the midline fibular osteotomy. X-ray examination demonstrated callus formation and healing characteristics compatible with the healing time, and no bone resorption (Fig. 3). Histological examination showed vital bone tissue in all parts of the graft, and new bone formation at the junction between the graft and the mandible (Fig. 4).
anticipated canine regions as described under "surgical technique". The patient has a very good chin contour, oral continence and jaw function (Fig. 5). Later, seven titanium fixtures (ad modum Bränemark) have been implanted in the fibular graft, all of which became osseointegrated and now form the basis of a well-functioning dental supra-structure (Fig. 5).

Patient 4
A 21-year-old man was admitted to our department after an intentionally self-inflicted gunshot injury, with widespread disruption of the hard and soft tissues of the anterior mandible, premaxilla and the nose. Two years later, after a series of soft tissue reconstructive operations, the mandibular defect was reconstructed, using a vascularized fibular graft. Later, six titanium dental implants have been inserted in the graft, all of which became osseointegrated and carry a dental bridge construction. The healing was uneventful, and he has very good chin contour and jaw function.

Patient 5
A 56-year-old man who, for 7 years, had suffered from a chronic sclerosing osteomyelitis of the lower jaw extending from the condyle on the left side crossing the midline to the angle region on the right. Because of constant pain, periodic swelling and restricted mouth opening, he was unable to perform his daily work. After careful evaluation we decided to do a mandibular resection incorporating the segment from the left condyle to the right canine region. Mandibular reconstruction was performed using a fibular graft, osteotomized in the left canine and angle region, and supplied with a preformed vitallium temporomandibular joint prosthesis for condylar replacement (Fig. 6). Five months after the operation, an intraoral fistula developed at the osteotomy site in the left canine region. After removal of one of the miniplates together with a tiny bone sequestrum and some granulation tissue, the fistula healed. There was clinical union at the osteotomy site, and X-rays showed no bone resorption. Later, the horizontal part of the right mandible has been replaced by a vascularized iliac crest graft. The cosmetic result is excellent, the patient is relieved of pain, has good mouth opening and is now a candidate for dental implants.

Patient 6
A 52-year-old woman suffered from an epidermoid carcinoma originating in the gingiva of the anterior lower jaw and infiltrating the underlying bone structure and floor of the mouth. After preoperative radiation therapy (50.00 Gy) a one-stage reconstruction procedure was undertaken with composite resection of the floor of the mouth, ventral aspect of the tongue and mandible (angle-to-angle) with incontinuity radical neck dissection. Reconstruction was performed with a vascularized jejunum graft, coupled to the facial artery and prevertebral veins on the right side, and with a fibular graft coupled to the facial artery and the retromandibular vein on the left side. There was clinical union of the graft with a good range of movement and full oral rehabilitation by dental implants is planned.

Patient 7
A 56-year-old woman who had suffered from a debilitating chronic osteomyelitis for 35 years. Originally the process started in the left molar region and spread through the
years to involve the whole mandible. A nearly total mandibulectomy was performed, ranging from the mid-ramus on the right side to the angle on the left. The fibular graft was osteotomized at three points, i.e., the right angle and the canine region on either side (Fig. 7). Eight days after the operation this patient developed a deep vein thrombosis in the donor leg which healed satisfactorily following heparin treatment. By six weeks there was clinical union and the facial contours were comparable to the preoperative status. A bone scan confirmed the viability of all four parts of the fibular transplant (Fig. 7). The patient has no pain, and the lower jaw has a good range of movement.
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Results and Discussion

Following extensive resection of the mandible, particularly if preceded by radiotherapeutic damage, the vascularized bone graft has come to play an increasingly important role. In these extreme cases, the vascularized rib, metatarsal, scapular or radius flaps, in our opinion, often contribute too little bone tissue to give cosmetically ideal results, and the bone graft is of too poor quality or is too thin to allow the insertion of endosteal implants to accomplish full dental rehabilitation, which must be the ultimate goal of orofacial reconstructive surgery. Revascularized iliac crest (Taylor et al., 1979a, b; Taylor, 1982) provides a large volume of predominantly cancellous bone that can easily be shaped to form a hemimandible, indeed successful reconstruction of the whole mandible, using bilateral iliac grafts, has been described (Taylor, 1982). However, the large volume of muscle tissue necessary to include the vascular pedicle with safety sometimes creates practical problems in skin readaptation without undue tension, especially in cases where mandibular reconstruction is performed secondarily and soft tissue shrinkage in the mandibular bed has occurred. Also, sometimes the bulk of the bone transplant itself and the shape of the iliac crest produces untoward cosmetic effects. In the search for a more acceptable bone transplant to repair mandibular defects, the vascularized fibula transplant has turned out to be a good alternative which has several advantages. The pedicle vessels are fairly long (5–8 cm) and have luminal dimensions of both artery and veins which are suitable for microsurgical anastomosis techniques. Fibula harvesting is technically straightforward, and usually leaves no functional impairment at the donor site. The fibular transplant is superficially located and has a fairly constant vascular anatomy, and a large and reliable pedicle. The advantage of raising the graft under local ischaemia is obvious. Usually, the midportion of the fibula is used, preserving sufficient bone at both ends so as not to interfere with the function of the ankle- and knee joints respectively. Still, as much as 25 cm of the fibula can be removed. This amount of bone is highly sufficient for replacement of large mandibulectomy defects. Angle-to-angle defects, even additional defects of the ascending ramus, can be adequately replaced, especially when the fibular graft is used in combination with preformed temporo-mandibular joint prostheses (Olstad and Lyberg, 1987). Fibular contouring to simulate mandibular shape can be performed by multiple wedge osteotomies, both in the chin and in the angle region and is secured by miniplate osteosynthesis, preferably two plates at each osteotomy site, which makes intermaxillary fixation superfluous. At the 25 mandibular/fibular interfaces and wedge osteotomies in our eight patients 23 united without requiring further surgery. In total, 35 miniplates secured by 144 screws have been used for fixation of the transplants; only one of these plates has been removed because of complications. Two temporomandibular joint prostheses are firmly attached to the bone grafts and functioning well after observation periods of 49 and 15 months, respectively.

The fibular flap can be used as an osteocutaneous flap (Hidalgo, 1989). However, the skin island obtained without jeopardizing its circulation is small, and problems are created as regards primary skin closure at the donor site. When an osteocutaneous flap is needed for composite reconstruction of the mandible, the iliac crest or scapular flap is recommended.

Our experience in eight cases using vascularized fibular transplants to bridge mandibular defects, has been encouraging, with survival (confirmed by scintigraphic examina-
implants to achieve full dental rehabilitation. Defects and the bone transplant is ideal for the insertion of architecture allows tailoring to fit even major mandibular reconstruction. The length, dimensions and bony transplants have several advantages over other available grafts for mandibular reconstruction. The length, dimensions and bony transplants have taught us that vascularized fibular grafts have well functioning dental suprastructures and excellent masticatory function. The cosmetic results are, by and large, fairly good for the whole series of patients. One of the concerns in doing a complex free vascularized graft transfer is the length of time required for the operative procedure. Many cancer patients requiring mandibular resection are old and debilitated, and in poor general health. The operation time can, however, be kept to a minimum by the coordinated efforts of two surgical teams, one to remove the graft, and the other to prepare the recipient bed.

Conclusions

In conclusion, our experience with different types of bone transplants at the recipient site (observation time 12–51 months), despite previous irradiation in two of the cases. The facial artery was used for anastomosis in all cases. Two patients had minimal local complications at the recipient site, and one patient developed a deep vein thrombosis in the donor leg. The skin incisions healed uneventfully both at the donor and recipient sites. None of the patients had interference with ankle- knee joint function. The general experience up to this point is that if care is taken to avoid ankle mortise disruption (leaving a minimum of 8 cm of the distal part of the fibula, or fix it with screws) there is no long-term morbidity associated with the removal of the fibular midportion.

The bone structure of the fibula with its strong cortex renders it suitable where the vascularized bone is required to withstand weight-bearing and shear stresses in the extremities (Chen et al., 1979; Pho et al., 1983) as well as the forces created and transferred to the mandible by mastication. The dimensions of the fibula coincides well with the mandible, and the volume of transplanted tissue is ideal because of the minimal bulk of the muscular cuff compared to e.g. the vascularized iliac crest grafts. Further, the bone structure of the fibula with two strong cortical bone plates is nearly ideal for osseointegration of dental implants. Mandibular reconstruction with fibular grafts can be performed at the time of cancer ablation or secondarily. Because of its length, the fibular graft has great versatility for reconstruction of even extensive mandibular defects. Four of our patients had angle-to-angle defects and two patients had a hemimandible reconstruction. Thirteen dental implants (a.m. Brinemark) have been inserted in two of the patients. There have been no fixture losses, and the patients have well functioning dental suprastructures and excellent masticatory function. The cosmetic results are, by and large, fairly good for the whole series of patients.

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Dr. T. Lyberg, M.D., D.D.S., Ph.D.
Department of Maxillofacial Surgery
Ullevaal University Hospital
N-0407 Oslo 4
Norway