Limb salvage after loss of bone and soft tissue may require many operations to obtain soft-tissue cover and bony continuity. We describe a fibula-flexor hallucis longus osteomuscular flap which can provide both soft tissue and bone in a single stage. The flap is based on the peroneal vessels and is covered by a split-thickness skin graft.

We report the results in five patients with an average bone defect of 8.3 cm and soft-tissue and skin loss. All regained a normal gait on the donor side; four had clinical and radiological union with excellent soft-tissue cover, but one required later amputation due to diffuse coagulopathy.

The flap provides free vascularised bone with muscle cover. It has a dependable, long pedicle with minimal morbidity at the donor site, and allows monitoring of the vascularity of the fibular graft.

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The use of vascularised bone grafts is well recognised. They do not undergo cortical resorption and provide union independent of soft-tissue vascularity; many show cortical hypertrophy. They have been advocated for large corticocancellous defects, infected nonunion, congenital pseudarthrosis, and soft-tissue damage preventing normal free grafts.

Limb salvage often requires multiple procedures. Early cover by free or pedicled muscle flaps is followed by secondary bone reconstruction; composite bone and soft-tissue transfer can provide both bone and soft tissue.

We describe a flap which can cover soft-tissue defects and provide bone. We report the functional results and assess the morbidity of the donor leg.

PATIENTS AND METHODS

There were three male and two female patients with a mean age of 26 years (12 to 55). All had soft-tissue and skin loss with mean segmental bone defects of 7.8 cm (5 to 11) (Table I). The two patients with 5 cm defects had infected nonunion after the failure of conventional cancellous bone grafting. The soft-tissue defects were covered by the flexor hallucis longus (FHL) part of the flap, although one upper-limb defect also needed a pedicled latissimus dorsi flap to provide posterior cover after the FHL had been placed anteriorly over the brachial artery and median nerve.

Indications. The indication was a combined bone and soft-tissue defect which would require free flap cover and bone graft or bone transport. Two were acute procedures and three were secondary reconstructions at an average interval of three months after injury.

Anatomy of the flap. The peroneal artery and its two veins originate 2.5 cm below the origin of the posterior tibial artery. The artery has a diameter of 2.6 to 4.2 mm. The vessels enter a canal formed by the fibula anterolaterally, the tibialis posterior anteromedially, and the FHL posteromedially (Figs 1 and 2). The fibula has two vascular supplies: the main nutrient artery arises about 7 cm below the origin of the peroneal artery and the periosteum is supplied by multiple branches of the peroneal artery and its muscle perforators. In 96% of specimens, the nutrient vessel enters the posterior aspect of the fibula in its middle third. FHL has multiple vascular pedicles from the peroneal artery, which often pass within the substance of the muscle.

Operative technique. Preoperative planning requires arteriography of the involved limb and of the donor lower leg, with radiographs, including comparison views, to allow the preparation of a template of the bone loss. The donor leg is prepared and draped free with a sterile tourniquet after Esmarch exsanguination. A longitudinal incision is made at the posterior border of the fibula, and the superficial peroneal nerve is identified and protected. Peroneus longus and peroneus brevis are incised and reflected anteriorly and soleus is reflected posteriorly, leaving a 2 mm cuff of muscle to protect the periosteum.

The peroneal artery is then identified proximally, the fibula is divided above and below the graft and the peroneal
Table I. Indications and outcome of five free vascularised fibula/flexor hallucis longus grafts

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr)</th>
<th>Defect details</th>
<th>Bone (cm)</th>
<th>Soft tissue (cm²)</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18</td>
<td>Grade III-C distal tibial fractures with infection after conventional graft</td>
<td>5.0</td>
<td>33</td>
<td>Full weight-bearing at 10 months</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>Grade III-A middle tibial fracture with infection after conventional graft</td>
<td>5.0</td>
<td>36</td>
<td>Full weight-bearing at 6 months</td>
</tr>
<tr>
<td>3</td>
<td>28</td>
<td>High-velocity GSW* with grade III-B humeral fracture and radial nerve injury</td>
<td>11</td>
<td>40</td>
<td>Bony union 4 months, elbow range 20 to 130°</td>
</tr>
<tr>
<td>4</td>
<td>55</td>
<td>Resection of distal tibial osteosarcoma</td>
<td>10</td>
<td>64</td>
<td>Bony union at 1 year, walking independently at 1.5 years</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>Grade III-C distal tibial fracture</td>
<td>8</td>
<td>60</td>
<td>Coagulopathy requiring below-knee amputation</td>
</tr>
</tbody>
</table>

* gunshot wound

![Figure 1a](image1a.png) ![Figure 1b](image1b.png) ![Figure 1c](image1c.png)

Figure 1a – Diagram of the fibula-FHL osteomuscular flap. The bipennate shape of the muscle helps to distinguish it from the underlying tibialis posterior.

Figure 1b – The relationship of the peroneal vessels, the nutrient artery of the fibula, and the segmental perforating vessels to the FHL. Figure 1c – Cross-sections to show FHL protecting the peroneal and the nutrient vessels (Ta, tibialis anterior; Tp, tibialis posterior; EHL, extensor hallucis longus; EDL, extensor digitorum longus; PL, peroneus longus; FHL, flexor hallucis longus; FDL, flexor digitorum longus; G, gastrocnemius; S, soleus).

![Figure 2a](image2a.png) ![Figure 2b](image2b.png) ![Figure 2c](image2c.png) ![Figure 2d](image2d.png)

Case 2. Figure 2a – Radiograph of a 12-year-old boy at nine months after a grade-III open tibial fracture with a wound 8 × 6 cm which had healed by secondary intention. Two conventional cancellous grafts with external fixation had failed. Figure 2b – Eight weeks after a fibula-FHL graft there is persistent new bone along the fibula with early union. Figure 2c – At 3.5 months, union and hypertrophy are obvious and protected weight-bearing in a patellar tendon-bearing orthosis was allowed. Figure 2d – At six months the patient was fully weight-bearing without bracing.
vessels are ligated distally. The interosseous membrane is then released (Fig. 1) and the origin of the bipennate FHL freed from tibialis posterior at the upper one-third of the fibula. The FHL tendon is then cut and the fibula externally rotated to allow completion of the separation of FHL from tibialis posterior. If an innervated graft is desired, the branch to FHL from the tibial nerve may be preserved. The peroneal artery and its two veins are dissected proximally to their origins from the posterior tibial vessels. The tourniquet is then released and perfusion of the flap confirmed for at least 20 minutes. The composite graft is transferred to its recipient site and the bone graft fixed in position using a plate, an intramedullary rod or an external fixator.

In each of our five patients, the fibular graft was contoured proximally and distally to allow an intramedullary placement, making small troughs in the donor bone to obtain overlap. We did not use additional free cancellous grafts because of the soft-tissue defects or the presence of infection. In three patients we used dynamic compression plates; the other two had interfragmentary screws and external fixators.

Vessel repair was end-to-side into the posterior tibial artery in four cases and end-to-end into the brachial artery in one. Case 2 required vein grafting of the artery and both veins (Fig. 2).

The average tourniquet time was 1 hour 50 minutes and the average duration of the whole operation was 7 hours 40 minutes. The three patients with defects of the lower limb used a patellar tendon-bearing orthosis until the graft had hypertrophied.

**Evaluation.** All four patients were examined at a mean of 2.6 years (2.2 to 3.8) and evaluated using the SF-36 score, the McGill pain/visual analogue scale, and the McCabe cold sensitivity scale.

We defined a satisfactory result as that showing bony union and soft-tissue coverage with function equal to or superior to that of a prosthesis. **Donor limb.** The donor limb was evaluated at one year using the McGill pain/visual analogue scale and a cold sensitivity scale. Patients were asked about ankle pain and loss of strength.

**RESULTS**

**Complications.** Case 5 had grafting for a distal type III-C fracture of the tibia and fibula. The upper tibia had been degloved and distal venous outflow was by the deep venous circulation only.

Three days after operation, the deep venous system became obstructed and the remaining muscles of the posterior compartment were dark and congested. Venous Duplex scanning showed occlusion of the deep femoral veins to the proximal thigh. Attempted vein grafting failed and a below-knee amputation was performed. There were no other complications or failures in our series.

The other four limbs had healed without malalignment, and in the three legs no bracing or aids were used for walking. No patient had any further drainage after two weeks including the two (cases 1 and 2) in whom operation had been performed for infected nonunion of the tibia. The results of the SF-36 evaluation at two years are shown in Table II, which records satisfactory results. The results of the McCabe cold sensitivity scale showed that there was little difficulty with cold intolerance after limb salvage, and no more than mild discomfort in cold weather. The McGill pain questionnaire showed that all four patients continued to have mild to moderate aching in the limb with an average score of 57 (0 = no pain and 10 = worst possible pain).

**Bone union.** The average time to union was six months (4 to 12) (Fig. 3). There was graft hypertrophy by 12 months in three, and by 16 months in case 4. There were no stress fractures.

**Donor site.** All the patients had ankle pain and swelling after operation, but were able to walk with crutches within two weeks. Some pain on ankle eversion and difficulty on uneven ground persisted for six months, but there were no complaints of ankle instability. No loss of push-off strength was reported. There were no extension contractures of the hallux.

The McGill pain analogue scale for the donor limb showed that all patients had occasional mild throbbing in the lateral aspect of the limb even after two years.

**DISCUSSION**

Many composite tissue transfers have been described to give one-stage reconstruction for specific combined defects. The ideal composite graft provides a long reliable vascular pedicle, rigid well-perfused cortical bone, muscle cover, ease of monitoring, and minimal donor site morbidity.

The fibula-FHL flap has a long reliable pedicle of 6 to 9 cm, compared with the 3 to 4 cm of the fibula-soleus flap. This increased length allows the microvascular anastomosis to be placed outside the zone of injury. The vascular pedicle to the fibula and its periosteum is on its posterior aspect under the FHL, so that inclusion of the muscle protects the vessels (Fig. 1c).

Donor-site morbidity is minimal, comparable with rupture of the FHL which gives few symptoms even in com-

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**Table II. Health-related quality-of-life scores by category**

<table>
<thead>
<tr>
<th>Category</th>
<th>Average score</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical functioning</td>
<td>80</td>
<td>65 to 100</td>
</tr>
<tr>
<td>Role limitations due to physical health</td>
<td>60</td>
<td>25 to 100</td>
</tr>
<tr>
<td>Role limitations due to emotional problems</td>
<td>89</td>
<td>67 to 100</td>
</tr>
<tr>
<td>Energy and fatigue</td>
<td>66</td>
<td>30 to 90</td>
</tr>
<tr>
<td>Emotional well-being</td>
<td>74</td>
<td>32 to 100</td>
</tr>
<tr>
<td>Social functioning</td>
<td>65</td>
<td>50 to 100</td>
</tr>
<tr>
<td>Pain</td>
<td>61</td>
<td>32 to 100</td>
</tr>
<tr>
<td>General health</td>
<td>70</td>
<td>40 to 100</td>
</tr>
</tbody>
</table>

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petitive runners. Our five patients had some weakness in eversion for four months, consistent with reports of other vascularised fibular grafts, but all had a normal gait at six months, with no hyperextension of the interphalangeal joint of the hallux.

The fibula-FHL flap provides good muscle cover, which has theoretical advantages in chronic osteomyelitis. The muscle flap is more easily contoured to defects than skin flaps, and the donor site does not require skin grafting. The split-thickness skin graft required to cover the FHL graft can be harvested from a cosmetically acceptable donor site.

The composite graft provides straight rigid cortical bone which is ideal for diaphyseal defects. Internal fixation is possible, hypertrophy is rapid and stress fractures, which were not seen in our series, will heal.

We used laser Doppler flow measurements to monitor the muscle flap. Bone scanning at three days can provide an indication of viability, but does not allow timely intervention after acute flap failure. Clinical monitoring and laser Doppler flow are easier to use.

Composite tissue transfer is an excellent method of reconstructing large bony defects, but is probably not appropriate for the immediate reconstruction of a massive defect. Most of such injuries have widespread damage requiring that any vascular anastomoses should be 10 to 15 cm from the fracture. Such major defects are best treated by either amputation or early free rectus abdominis or latissimus dorsi transfer followed by bony reconstruction at a later date.

**Conclusion.** The fibula-FHL flap provides biomechanically rigid, easily monitored, vascularised bone with a large vascularised muscle, and is valuable for carefully selected cases including those of infected nonunion.

**REFERENCES**


