Ipsilateral vascularised fibular transport for massive defects of the tibia

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The ipsilateral and contralateral fibulae have been used as a vascularised bone graft for loss of tibial bone usually by methods which have involved specialised microvascular techniques to preserve or re-establish the blood supply.

We have developed a method of tibialisation of the fibula using the Ilizarov fixator system, ipsilateral vascularised fibular transport (IVFT), and have used it in five patients with massive loss of tibial bone after treatment of an open fracture, infected nonunion or chronic osteomyelitis. All had successful transport, proximal and distal union, and hypertrophy of the graft without fracture. One developed a squamous-cell carcinoma which ultimately required amputation of the limb.

The advantage of IVFT is that the fibular segment retains its vascularity without the need for microvascular dissection or anastomoses. Superiosteal formation of new bone occurs if the tibial periosteal bed is retained. Other procedures such as corticotomy and lengthening can be carried out concurrently.

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A number of surgical methods have been used for salvage of the limb when there is a defect in the tibia of more than 6 cm, with a usable fibula, following trauma, infection or tumour (type-4 bone loss). The ipsilateral and contralateral fibulae have been used as substitutes, both as vascular and avascular grafts.

We have obtained good results with the circular external fixator of Ilizarov in the treatment of infected nonunion, segmental bone loss and acute high-energy open fractures of the tibia.

We now describe a method of replacement of the defect in the tibia by a portion of the fibula, using the Ilizarov fixator system, in which the fibular segment retains its vascularity without the need for microvascular anastomoses or dissection of the bone, blood vessels or muscles.

Patients and Methods

Between 1993 and 1997 five patients had ipsilateral vascularised fibular transport (IVFT) for type-4 bone loss of the tibia (Table I).

The limb was first stabilised with an Ilizarov frame of the desired configuration (Figs 1 to 3). The tibial deficiency is usually a result of surgical excision of avascular bone or infected sequestrum, in which care has been taken to keep the excision subperiosteal, or acute bone loss after trauma. The length of the defect was measured and any overlying wounds debrided. The bone loss can be replaced by IVFT alone or by using a corticotomy of the proximal or distal tibia, which is performed concomitantly or at a later stage.

Using an image intensifier, a segment of fibula of preplanned length, adjacent to the defect, was transfixed from the posterolateral to anteromedial position by two ‘pulling’ wires which have stops such as olives or kinks. These wires were at least 1 cm from the proposed sites of the osteotomies, and passed through the centre of the tibial bed (Fig. 4).

The fibula was then osteotomised, either by using a well-cooled saw or by multiple drill holes and an osteotome, taking care to ensure that the length was adequate. It was approached either through limited separate posterolateral incisions or the posterolateral aspect of the cavity of the excised tibia. If present, a coexistent fibular fracture was used as a substitute for the osteotomy. Each wire was then attached to the anteromedial aspect of the frame to ‘motors’ constructed in a standard fashion. The fibula was transported gradually into the bed of the tibia. The rate depended on the suppleness of the soft tissues and was usually 2 to 3 mm per day, divided into four equal amounts. Once the fibula was well centred in the tibial bed, the proximal and distal ends of the tibia were compressed on to the transported segment to anchor it. After transport was completed, weight-bearing was allowed to encourage bone union and fibular hypertrophy.
Results

In all five patients, the transferred fibula united proximally and distally, without major complications (Fig. 5, Table I). The range of time to union was 12 to 35 weeks. Two different bone-forming processes were seen. First, all fibular segments showed hypertrophy after union. Secondly, all tibial beds except one showed subperiosteal formation of new bone around the fibular segment, presumably from the intact tibial periosteal sleeve (Figs 5 to 7). All had satisfactory healing of soft tissue over the tibia. None had fractures of the graft. Four patients can actively invert, evert and dorsiflex the foot, demonstrating adequate function of the peroneal, tibialis posterior and tibialis anterior muscles. All movement is considerably less than on the opposite normal side. One patient (case 2) has a dorsiflexed great toe with no activity of flexor hallucis longus. Another (case 1), who had had chronic osteomyelitis of the tibia for over 40 years, had IVFT after resection. Routine histopathological examination of the skin showed features suggestive of squamous-cell carcinoma distally. Further resection of the distal skin, periosteal bed and adjacent tibia was carried out leaving margins free from tumour. Union occurred proximally and distally. Graft hypertrophy was present and the soft tissues healed. No subperiosteal formation of new bone was seen. Unfortunately, five months later, he developed a squamous-cell carcinoma at the distal end of the previous wound which required a below-knee amputation.

Discussion

The blood supply to the shaft of the fibula comes from a branch of the peroneal artery. It usually enters the posterior aspect of the fibula in the middle third, 7 cm below its origin. It also gives off multiple branches to the periosteum along its extraosseous course. These usually traverse the flexor hallucis longus muscle before arborising on bone.

Tibialisation of the fibula was first described by Albert in 1877 to achieve fusion between the femur and distal tibia in a patient with congenital absence of the proximal tibia. Since then, four methods with a number of variations have been described. All have their complications and limitations. Method 1. The ipsilateral or contralateral fibula is removed and used as a strut of avascular bone. This graft is osteo-conductive and may be osteoinductive, but is extremely unlikely to have true osteogenic potential. The results are not as good as in vascularised grafts. The rates of fracture

<table>
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<tr>
<th>Case</th>
<th>Age (yr)</th>
<th>Gender</th>
<th>Diagnosis</th>
<th>Reconstructive procedures</th>
<th>Defect (cm)</th>
<th>Time to union (wk)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>66</td>
<td>M</td>
<td>Chronic osteomyelitis of the tibia with squamous-cell carcinoma of skin</td>
<td>IVFT</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>53</td>
<td>F</td>
<td>Infected nonunion after IIIB open fracture in a bomb blast; failed DCIA flap</td>
<td>IVFT and concurrent distal corticotomy with lengthening</td>
<td>16</td>
<td>Proximal, 15, Distal, 35</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>M</td>
<td>IIIB open fracture of the tibia with bone loss and partially failed flap</td>
<td>IVFT and concurrent proximal corticotomy with lengthening</td>
<td>12</td>
<td>Proximal, 12, Distal, 17</td>
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<tr>
<td>4</td>
<td>26</td>
<td>M</td>
<td>IIIB open fracture of the tibia with bone loss and infection</td>
<td>IVFT and subsequent proximal corticotomy and lengthening</td>
<td>18</td>
<td>21</td>
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<tr>
<td>5</td>
<td>53</td>
<td>M</td>
<td>IIIB open fracture of the tibia with Schatzker VI fracture of the tibial plateau with deep infection</td>
<td>IVFT</td>
<td>13</td>
<td>Proximal, 12, Distal, 12</td>
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Fig. 1a
Fig. 1b

AP and lateral radiographs showing grade-IIIB open fracture of the tibia and fibula.
of the graft and of infection are higher.\textsuperscript{4} There is also the potential morbidity of surgery on the often normal, contralateral leg. This method is rarely used.

\textbf{Method 2.} This was first described by Huntington.\textsuperscript{5,6} The ipsilateral fibula is osteotomised and mobilised medially with some of the muscle attachments intact after dissecting...
off the others. Vascularity of the graft is usually maintained. Mobilisation can be carried out either in one or two stages, but can be severely restricted by previous inflammation in the area. The lateral aspect of the leg must be healthy.

Zahiri, Zahiri and Tehrany successfully used a modification of this method to treat chronic osteomyelitis of the entire tibial shaft in nine children.

Method 3. This technique was originally suggested by

Fig. 5a
Fig. 5b
AP and lateral radiographs showing proximal and distal union of the fibular segment and subperiosteal formation of new bone in the tibial bed.

Fig. 6a
Fig. 6b
AP and lateral radiographs showing the hypertrophied, united fibular segment.
Chacha, Ahmed and Daruwalla. The vascular supply of the ipsilateral fibula is isolated as a loop and the bone is transposed into the defect as one or two segments. A number of variations have since been described to fill tibial defects which may be proximal, central or distal in position. All require extensive dissection of the graft and its blood supply. Previous local inflammation increases the risk of vascular damage. Khan, Downing and Henry used this method in eight patients with segmental tibial defects following Gustilo grade-III open fractures and seven were satisfactory.

**Method 4.** The contralateral or, rarely, the ipsilateral fibula is harvested with the nutrient vessels, transferred into the defect and its vascularity re-established by microvascular anastomoses. This technique may involve removal of the graft from a normal limb and was first described in man by Taylor, Miller and Ham. It requires a highly-skilled surgical team and has a small, but definite, risk of failure. Morbidity at the donor site may be considerable and sometimes increases with time. In methods 3 and 4 it is recommended that an angiogram be done before the graft is harvested. In some cases the harvested vessel was found to be the sole feeder to the foot, the fibula had no demonstrable nutrient vessels, or the nutrient artery entered the fibula away from its usual position.

The use of a circular external fixator with fine wires after methods 3 and 4 can cause irreparable damage to the vessels of the graft. Circular external fixation carried out before the microvascular anastomoses can make the latter procedure considerably more difficult. Hence, the graft is usually fixed by screws or Kirschner wires and spanning uniaxial fixators. Such fixation does not allow early weight-bearing and subsequent fibular hypertrophy.

Ilizarov described two methods for treating ‘marked defects’ with his fine-wire fixator. In the first, the fibular segment is translated medially, creating a proximal and distal, side-to-side tibiofibular synostosis. In the second method, the fibula is split longitudinally and transverse distraction osteogenesis is performed. This technique is complex and no mention is made of the clinical results.

Our technique has several advantages. Operative dissection of the fibula is minimal. It remains well vascularised as both sources of blood supply are neither defined nor dissected. Muscle attachments are maintained without dissection. The tibial periosteal sleeve, if retained, allows profuse formation of new bone around the transported section which contributes to fibular hypertrophy and bone strength. The fibular segment is central and is held by the tibial remnants in a mechanically advantageous position in the line of the axis of the tibia. The Ilizarov fixator allows stability and longitudinal compression to be established without internal fixation. Weight-bearing can begin almost immediately after surgery and the proximal and distal joints mobilised satisfactorily. Further limb lengthening may be carried out through a separate corticotomy of either the proximal or distal tibial remnant. The opposite limb is untouched. Based on our results we feel that IVFT is a satisfactory method of tibialisation of the fibula in patients with large segmental type-4 defects and a usable ipsilateral fibula. We do not recommend it for smaller segmental defects (types 1, 2 and 3) since other methods such as corticotomy with bone transport or lengthening are more effective.

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**References**


