Abstract: The purpose of this study was to examine our experience with this flap for the treatment of recalcitrant nonunions of the extremities. A retrospective chart review was performed on 11 consecutive patients treated with the medial femoral periosteal bone flap from June 2003 to March 2005. Patient demographics, nonunion characteristics, complications, and long-term outcome based on radiographic and clinical parameters were analyzed. Nine free transfers and 3 pedicled flaps were used for a total of 12 nonunion sites in 11 patients. The average age of the patient population was 49 years (21–64 years). The location of the nonunion sites were femur (n = 4), tibia (n = 2), humerus (n = 3), clavicle (n = 2), and radius (n = 1). The nonunion sites were secondary to traumatic fractures complicated by osteomyelitis (n = 10) and tumor extirpation (n = 2). The time period of nonunion prior to the use of vascularized periosteal bone graft ranged from 10 months to 23 years (median = 23 months). All patients had previous attempts at debridement with or without antibiotic bead placement, and all underwent rigid fixation with or without nonvascularized bone grafts prior to vascularized grafting. Following flap placement, 9 (75%) of the nonunion sites healed primarily without complication at an average period of 3.8 months (2–7 months). Two nonunions healed secondarily following hardware modification. There was only 1 flap failure secondary to arterial thrombosis, resulting in a below-knee amputation. The rate of limb salvage was 91%. Donor-site morbidity was minimal, with postoperative seromas occurring in 3 patients.

Key Words: periosteal bone flap, nonunion, medial femoral condyle

Bone nonunions can pose significant problems to the reconstructive surgeon. Nonunion sites in the presence of preexisting infection or radiation may be unamenable to classic cancellous or autologous cortical grafts despite gaps of less than 5 cm. For such situations, vascularized bone grafts have become the standard of care.1,2

The benefits of vascularized bone grafts include preservation of osteocytes,3 which results in accelerated graft consolidation without the need for creeping substitution into areas of necrotic bone.1,4,5 Vascularized bone grafts have been noted to have increased bone mass with diminished osteopenia after transfer compared with nonvascular graft.6 Finally, multiple studies have demonstrated that vascular bone grafts offer superior biologic and mechanical properties over nonvascular bone graft.7–9

For defects less than 5 cm, a large vascularized bone flap, such as a fibular flap, may be unnecessary. Smaller vascularized grafts like the iliac crest flap have been described as an alternative; however, both flaps can be associated with donor-site morbidity and extensive soft-tissue dissection.10–12 Another option for smaller recalcitrant nonunions is the medial femoral condyle periosteal flap.13–21 This flap provides vascularized periosteum, in addition to cortical and cancellous bone.

The advantage of this particular flap has been its smaller size and periosteal flexibility. The periosteum may be wrapped to cover tubular bones, making it an ideal flap to conform to the area of nonunion in the extremities. It is especially useful in situations in which the classic fibular flap is not ideal based on the size of the defect. An additional advantage of this flap is its limited donor defect. We present our experience with 11 consecutive patients who had recalcitrant nonunion resistant to all the conventional means of therapy.

PATIENTS AND METHODS

A retrospective chart review was performed on all patients who underwent vascularized medial femoral condylar periosteal bone grafts from June 2003 to March 2005 by the senior author. All the flaps were done exclusively for the treatment of bony nonunions. Patient demographics, area of nonunion, treatment history, type of flap used, time to union, complications, and follow-up data were collected. Institutional review board approval was obtained. The nonunion time period was defined as the time from the injury to the use of the vascularized medial femoral periosteal bone graft. Preexisting osteomyelitis was documented by the presence of positive bone cultures and bone erosion or sequestrum formation noted on radiographs. Union was complete when there was trabecular bridging or callus visualized at the...
fracture site, with return to normal activities (weight bearing, range of motion, exercising.).

Both free-tissue transfers and pedicled flaps were included. Each nonunion site was studied independently. There were a total of 11 patients included in the study, with 12 nonunion sites. Patient 5 (Table 1) had a tumor removed from the femur, with an allograft interposition performed. Both the distal and proximal ends went onto nonunion. Therefore, these were counted as 2 separate nonunion sites. There were 6 males and 5 females treated. The average age of the patient population was 49 years (21–64 years).

### Vascular Anatomy

The medial femoral periosteal bone flap is based on the descending genicular artery (DGA), a medial branch of the superficial femoral artery (SFA), and on the superomedial genicular artery, a medial branch of the popliteal artery (Fig. 1).

![Vascular Anatomy Diagram](image)

**FIGURE 1.** Vascular anatomy of the medial femoral condyle periosteal flap. The major blood supply to the flap comes from the descending genicular artery (DGA), a branch of the femoral artery. Alternatively, the superior medial genicular artery (SGA) may be used if the DGA is of inadequate caliber. The SGA has a shorter pedicle length. By permission of Mayo Foundation for Medical Education and Research. All rights reserved. (Fuchs B, Steinmann SP, Bishop AT. Free vascularized corticoperiosteal bone graft for the treatment of persistent nonunion of the clavicle. *J Shoulder Elbow Surg* 2005;14:264–268).
gives access to the medial knee and distal thigh. A midaxial incision is made directly over the medial femoral condyle, extending from the midthigh to the level of the patella. The skin perforator is identified with a handheld Doppler probe prior to making the skin incision. The perforator is usually located posterior to the midlateral line in the distal third of the thigh, just proximal to the condyle. Dissection is carried down to the fascia of the vastus medialis, which is incised. By retracting it anteriorly, the descending genicular vessels are identified as they emerge from the adductor magnus prior to their entry into Hunter canal (adductor hiatus). The branches are dissected until they are identified entering the periosteum. Occasionally, the DGA will be less than 1 mm. In such cases, the superomedial genicular vessels are used as an alternate pedicle. The required size of graft is drawn on the condyle of the femur. The articular surface and the medial collateral ligament are protected during harvest. The graft is then carefully chiseled out, taking measures not to destroy the periosteal branches (Fig. 2). If desired, the saphenous branch is followed to its subcutaneous level, and an ellipse of skin from the medial knee and thigh can be taken, along with the flap. In cases where the saphenous branch is a branch directly off of the SFA, the skin superficial to the articular branch of the DGA may be taken instead.

The flap is then inset at the recipient site after a microvascular anastomosis is performed, or for defects involving the middle and distal third of the femur, the graft may be pedicled on the DGA. Flaps are tailored to fit bony defects with the use of a fine rongeur. A large periosteal flap is preserved to wrap around the native long bone site both proximal and distal to the nonunion site to promote healing (Fig. 3). Grafts may be held with K-wires, screws, or suture anchors. After harvesting the flap, hemostasis is ensured, a suction drain is placed in the thigh, and the donor site is closed directly. Flaps are monitored by examination of the skin paddle or implanted Doppler probes. Postoperatively, weight bearing is allowed as tolerated. A supplemental knee brace is used for 2 weeks.

CASE REPORT

A 46-year-old woman presented after being treated elsewhere for a closed, extra-articular fracture of the distal humerus 4 weeks previously. She had undergone internal fixation and bone grafting twice at another institution. Radiographs on presentation showed a very distinct fracture line, with no evidence of callus formation, and she was admitted for further treatment. Initially, all hardware was replaced and she underwent additional bone grafting. Multiple intraoperative cultures were negative; however,
the fracture showed no clinical or radiographic signs of union at 6 months, and she therefore underwent further iliac crest and OP-1 bone grafting and continued to use a bone stimulator postoperatively.

Nine months later, the fracture remained ununited (Fig. 4), and she underwent vascularized bone grafting with a corticoperiosteal, medial femoral, condyle free flap. The flap was harvested on the DGA as described, and an end-to-side anastomosis into the brachial artery was performed. The patient was followed up with serial radiographs (Fig. 5), which showed progressive callus formation, confirming the notable clinical improvement.

**RESULTS**

A total of 9 free-tissue transfers and 3 pedicled flaps were performed. The 12 nonunion sites treated included femur (n = 4), tibia (n = 2), humerus (n = 3), clavicle (n = 2), and radius (n = 1). The etiologies of the nonunion sites were traumatic fractures complicated by osteomyelitis (n = 10) and tumor extirpation with nonunion of the interposition allograft (n = 2). The nonunion time periods ranged from 10 months to 23 years (median: 23 months) (Table 1). All cases had some form of conventional treatment of the nonunions, which included autologous cancellous graft, bone stimulator, and cadaveric grafting (Table 1). Both cases of tibial nonunions required concomitant free latissimus muscle transfers, in addition to nonunion repair with the periosteal flap, for soft-tissue deficits.

Nine nonunion sites (75%) healed primarily, without complication, at an average time period of 3.8 months (2–7 months) (Table 2). Two nonunion sites ultimately failed to heal primarily, despite viable vascularized flaps. The first of these (case 3) did not achieve primary union, due to hardware failure and recurrent fungal infection at the nonunion site. This case was salvaged with removal of hardware and placement of an intramedullary rod. At the time of hardware removal, the flap had incorporated into the medial and anterior portion of the femoral shaft. The second failure (case 5) was attributed to complications secondary to chemotherapy and inadequate bony fixation. Secondary union was obtained with a free fibular graft and hardware exchange. At reexploration in this case, the periosteal grafts had incorporated into the native bone but not the allograft. In addition, significant motion was noted at the fracture site.

There was 1 flap failure (case 2) secondary to an arterial thrombosis. This case involved a simultaneous free latissimus and medial femoral condylar periosteal graft anastomosed into a bypass graft in a patient with significant peripheral vascular disease and osteomyelitis. Despite reexploration and reanastomosis, the flap was not salvaged, and this ultimately led to a below-knee amputation.

Donor-site complications occurred in 3 patients (25%). The 3 complications were all due to seroma formation, which developed at the medial thigh incision. All cases resolved with conservative treatment. There were no cases of knee instability, femoral fractures, or knee pain at final follow-up.

Overall limb salvage was 91%. The functional outcome of all limbs that went on to heal primarily was excellent. All patients with lower-extremity reconstructions are pain free and have returned to ambulation. Upper-extremity patients have returned to regular activity and are using the limb normally.

**DISCUSSION**

Fracture nonunion in the absence of major skeletal loss is an uncommon but serious complication. The rates of healing of nonunions by traditional means of internal fixation with bone graft range from 70% to 92%. However, in those cases of infection, poorly vascularized beds, and open, segmental, or severely comminuted fractures, secondary bony healing may still be compromised. In such cases, secondary bony revision rates may reach 30%, while amputation and limb loss rates may be as high as 40%. It is important for the plastic surgeon to be able to provide limb-salvage options in such circumstances.

Vascularized periosteal bone flaps from the iliac crest, distal humerus, 10th rib, and distal femur have been described previously in the treatment of bony nonunions, avascular necrosis, osteoradionecrosis, osteomyelitis, and reconstruction of
bone defects; however, their success in treating nonunions of the femur and tibia has not previously been reported. To our knowledge, this is one of the largest series of femoral condylar periosteal grafts used for the treatment of recalcitrant nonunions within the upper and lower extremities.

Sakai and Finley have shown that the periosteum is osteogenic; however, others have found periosteal grafts to be unreliable when harvested without cortical components. The proposed reason for this unreliability when harvested as an isolated graft is the injury to the cambium layer, which lies between the periosteum and cortex of the bone. Doi and Sakai described elevating the periosteum along with a thin strip of cortex, thus protecting the delicate and vital cambium layer.

The anatomic descriptions and clinical applications of the medial femoral condylar flap have been previously described. Doi and Sakai successfully treated 8 of 11 (73%) patients with nonunion of the upper extremity with the help of this flap. Fuchs et al describe 3 cases of persistent nonunion of the clavicle that were ultimately healed by free vascularized corticoperiosteal bone grafts. Muramatsu et al successfully treated 10 humeral shaft

FIGURE 5. Serial postoperative radiographs after a medial femoral condyle periosteal flap was used to treat the fracture shown in Figure 4.
nonunions with the vascularized periosteal flap from the medial femoral condyle.

Our series similarly highlights the success of this flap in dire situations. We report a primary success rate of 75% with nonunions resistant to conventional therapy. Two of the 3 cases that initially failed to heal after the flap was placed went onto heal secondarily. In both these cases, the original periosteal flaps were well incorporated and contributed to ultimate successful union. Case 3 required eradication of a fungal superinfection, followed by hardware modification, to heal. Treatment of any underlying infection and making sure there is good apposition with rigid fixation is paramount. We feel that inadequate fixation and persistent infection led to initial failure in this case.

In case 5, reexploration identified inadequate fixation, with significant motion at the proximal allograft/bone junction. In addition, the patient underwent chemotherapy following graft placement. Chemotherapy has been reported in numerous studies to decrease bony remodeling in a dose-dependent manner. In addition to inhibiting revascularization, chemotherapy limits osteoclast and osteoblast activity and has been shown experimentally to affect bone healing and biomechanical stability even in vascularized bone flaps. In these patients, delaying periosteal grafting until after chemotherapy may improve overall outcomes. Alternatively, in cases of allograft failure associated with chemotherapy, consideration of an onlay free fibular graft may be more suitable; we have previously found this to be reliable in reconstructions compromised by chemotherapy.

The success of this flap in these situations is most likely due to a number of reasons. It is a vascular flap, making its viability more reliable. It induces angiogenesis, which aids in healing, as well as ability to fight infection in the area. It is osteogenic, which is vital for formation of new bone in nonunion. Its ability to conform to small, nonlinear defects allows it to be placed precisely, minimizing the need for bridging callus.

As opposed to a vascularized fibular graft, the medial femoral condylar periosteal flap is smaller and more flexible and may be easily tailored to irregular defects. This allows the flap to be effectively wrapped around tubular bones and placed within the

<table>
<thead>
<tr>
<th>Patient</th>
<th>Site of Nonunion</th>
<th>Type of Periosteal Flap</th>
<th>Outcome</th>
<th>Time to Union</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Tibia</td>
<td>Free + free latissimus</td>
<td>Primary union</td>
<td>4 mo</td>
</tr>
<tr>
<td>Case 2</td>
<td>Tibia</td>
<td>Free + free latissimus</td>
<td>Flap failure secondary to arterial thrombosis, BKA</td>
<td>N/A</td>
</tr>
<tr>
<td>Case 3</td>
<td>Femur</td>
<td>Pedicled</td>
<td>Secondary union following hardware change</td>
<td>8 mo</td>
</tr>
<tr>
<td>Case 4</td>
<td>Femur</td>
<td>Pedicled</td>
<td>Primary union</td>
<td>5 mo</td>
</tr>
<tr>
<td>Case 5</td>
<td>Proximal femur</td>
<td>Free</td>
<td>Secondary union following free fibula and hardware change</td>
<td>12 mo</td>
</tr>
<tr>
<td></td>
<td>Distal femur</td>
<td>Pedicled</td>
<td>Primary union</td>
<td>7 mo</td>
</tr>
<tr>
<td>Case 6</td>
<td>Humerus</td>
<td>Free</td>
<td>Primary union</td>
<td>4 mo</td>
</tr>
<tr>
<td>Case 7</td>
<td>Humerus</td>
<td>Free</td>
<td>Primary union</td>
<td>4 mo</td>
</tr>
<tr>
<td>Case 8</td>
<td>Clavicle</td>
<td>Free</td>
<td>Primary union</td>
<td>2 mo</td>
</tr>
<tr>
<td>Case 9</td>
<td>Clavicle</td>
<td>Free</td>
<td>Primary union</td>
<td>5 mo</td>
</tr>
<tr>
<td>Case 10</td>
<td>Humerus</td>
<td>Free</td>
<td>Primary union</td>
<td>2 mo</td>
</tr>
<tr>
<td>Case 11</td>
<td>Radius</td>
<td>Free</td>
<td>Primary union</td>
<td>2 mo</td>
</tr>
</tbody>
</table>

BKA, below-knee amputation.

FIGURE 6. Postoperative radiograph of femoral condyle donor site shows no significant defect.
CONCLUSIONS

Vascularized periosteal bone grafts harvested from the medial femoral condylar region are versatile, reliable, and effective flaps that are successful in healing cases of resistant, longstanding nonunion.

REFERENCES