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J Bone Joint Surg Am. 2004;86:87-101.

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Surgical Technique

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The original scientific article in which the surgical technique was presented was published in JBJS Vol. 85-A, pp. 987-993, June 2003

SURGICAL TECHNIQUE

Overview

In its early stages, free vascularized fibular grafting of the femoral head required two teams of surgeons and an operative time of six hours or more. Today, thanks in large part to the development of technical shortcuts, customized instrumentation, and an operative support staff familiar with the nuances of the surgery, free vascularized fibular grafting of the femoral head can easily be performed in between two and one-half and three hours, with two surgeons and one scrub nurse.

The procedure is performed with the patient under general anesthesia, with the adjunct of an epidural block, which remains in place for twenty-four to forty-eight hours postoperatively. The patient is placed in the lateral decubitus position and is supported by a pegboard. Pegs are placed at the level of the sacral ala posteriorly and the pubic symphysis anteriorly. Careful attention is paid to padding all osseous prominences, and the placement of an axillary pad is standard. The entire lower extremity to the level of the iliac crest proximally is prepared and draped. The lower limb is covered with an impervious stocking up to the midpart of the thigh, and a sterile tourniquet is placed over the stocking (just proximal to the knee), to be used during the fibular graft harvest. A Betadine-impregnated occlusive drape is used for both the hip and leg. The operative procedure on the hip and the harvest of the fibular graft are performed at the same time, and, as such, cooperation between the surgeons is required.

ABSTRACT

BACKGROUND:
Osteonecrosis of the femoral head, a disease primarily affecting young adults, is often associated with collapse of the articular surface and subsequent arthrosis. Free vascularized fibular grafting has been reported to be successful for patients with early stages of osteonecrosis, but little is known about its efficacy after the femoral head has collapsed.

METHODS:
We retrospectively reviewed the results in a consecutive series of 188 patients (224 hips) who had undergone free vascularized fibular grafting, between 1989 and 1999, for the treatment of osteonecrosis of the hip that had led to collapse of the femoral-head but not to arthrosis. The

continued

ABSTRACT | continued

average duration of follow-up was 4.3 years (range, two to twelve years). We defined conversion to total hip arthroplasty as the failure end point, and we analyzed the contribution, to failure, of the size of the lesion, amount of preoperative collapse of the femoral head, etiology of the osteonecrosis, age of the patient, and bilaterality of the lesion. We used the Harris hip score to evaluate clinical status preoperatively and at the time of the most recent follow-up.

RESULTS:
The overall rate of survival was 67.4% for the hips followed for a minimum of two years and 64.5% for those followed for a minimum of five years. The mean preoperative Harris hip score was 54.5 points, and it increased to 81 points for the patients in whom the surgery succeeded; 63% of the patients in that group had a good or excellent result. There was a significant relationship between the outcome of the grafting procedure and the etiology of the osteonecrosis (p = 0.017). Patients in whom the osteonecrosis was idiopathic, associated with alcohol abuse, or posttraumatic fared worse than did those with other causes, including steroid use. Survival of the joint was not significantly related to the size of the femoral head lesion, but there was an increased relative risk of conversion to total hip arthroplasty with increasing lesion size and amount of collapse. Neither patient age nor bilaterality significantly affected outcome.

CONCLUSIONS:
Patients with postcollapse, predegenerative osteonecrosis of the femoral head appear to benefit from free vascularized fibular grafting, with good overall survival of the joint and significant improvement in the Harris hip score. The results of this femoral head-preserving procedure in patients with postcollapse osteonecrosis are superior to those of core decompression and nonoperative treatment, as reported in the literature. Patients with larger lesions and certain diagnoses, such as idiopathic and alcohol-related osteonecrosis, have worse outcomes.

Fibular Graft Harvest

The lower extremity is exsanguinated with an Esmarch bandage, and the tourniquet is inflated to 350 mm Hg. A straight lateral 15-cm longitudinal incision is made coincident with the natural sulcus between the lateral and posterior compartments of the leg. The incision is begun 10 cm distal to the fibular head and ends 10 cm proximal to the lateral malleolus (Fig. 1). With maintenance of full-thickness flaps, the fascia of the lateral compartment is readily visualized and is incised in line with the skin incision. In an anterior direction, the peroneal muscles are reflected bluntly off the posterior intermuscular septum up to the level of the fibula, which is readily palpated. Two Gelpi self-retaining retractors are then placed at both extents of the wound to assist in anterior elevation of the lateral musculature. The peroneals are then sharply reflected off the lateral aspect of the fibula, with the surgeon working from posterior to anterior and stopping when the anterior intermuscular septum is completely visualized along the anticipated 15-cm segment of fibula to be removed. Because preservation of the periosteum is paramount to the success of the vascularized graft, we recommend retaining a thin (1 to 2-mm) layer of muscle. This "marbleizing" technique results in a cobblestone appearance to the fibular periosteum (Fig. 2).

The anterior intermuscular septum is then divided, exposing the anterior musculature, which is reflected off the fibula with the use of a right-angle clamp and Metzenbaum scissors. Small vascular perforators are controlled with bipolar electrocautery and vascular clips. At this point, the interosseous membrane is easily visualized and the adjacent anterior musculature and accompanying deep peroneal nerve and anterior tibial artery are gently swept off the interosseous membrane away from the fibula. With the use of a specially designed right-angle Beaver blade, the interosseous membrane is divided close to its fibular attachment along the entire length of the proposed fibular graft (Fig. 3). Palpation between the tibia and fibula reveals whether the release of the interosseous membrane has been completed. The posterior intermuscular septum is

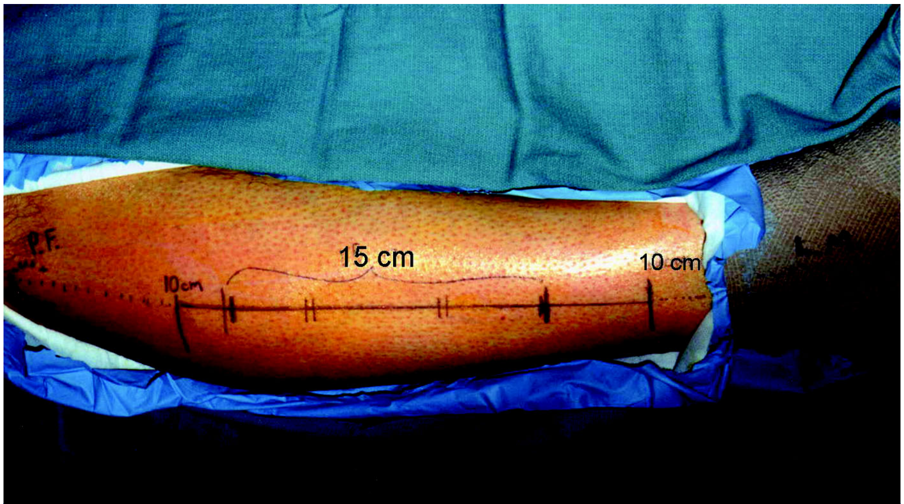

FIG. 1

A 15-cm incision is made on the lateral aspect of the leg between the lateral and posterior compartments. The incision is begun 10 cm distal to the fibular head (PF) and ends 10 cm proximal to the tip of the lateral malleolus (LM).

then divided, exposing the posterior muscles (the soleus proximally and the flexor hallucis longus distally).

Fibular Osteotomy

Directly beneath the distal aspect of the flexor hallucis longus muscle, the distal pedicle of the peroneal vessels is identified and, under direct vision, a right-angle clamp is passed along the posterior aspect of the fibula, just anterior to and away from the vascular pedicle. With the clamp interposed between the fibula and the vessels, a malleable retractor is passed between the clamp and bone. Approaching from the opposite side, another, larger malleable retractor is placed between the first malleable retractor and the fibula (Fig. 4). Diligent care is critical during placement of the retractors to ensure protection of the pedicle during the osteotomy.

After the surgeon rechecks to ensure that the planned osteotomy is at least 10 cm proximal to the lateral malleolus, an oscillating saw is used to cut the fibula (Fig. 4). Simultaneously, irrigation is used to prevent thermal osteonecrosis. The proximal pedicle is next identified deep to the soleus muscle along the posterior aspect of the fibula. It is protected, and the proximal fibular osteotomy is performed in a manner similar to the distal osteotomy. The fibular cuts are made 15 cm apart, to ensure an adequate pedicle length. When performing the proximal osteotomy, it is important to identify and protect the superficial peroneal nerve, which is exposed proximally on the deep surface of the peroneus longus muscle.

Once the fibula has been cut both proximally and distally, a bone clamp is placed around it to allow better control and easier rotation during the delicate pedicle dissection. Starting distally,

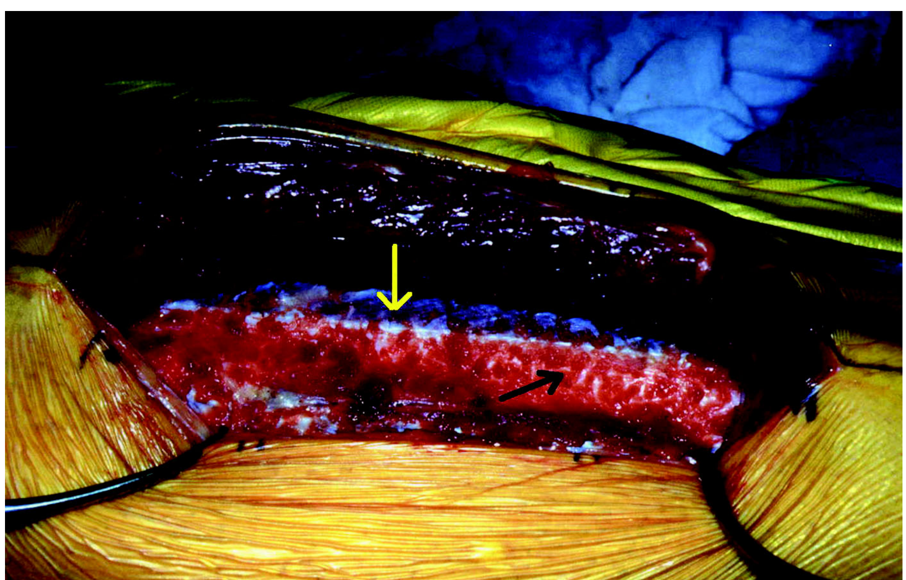

FIG. 2

The yellow arrow is pointing to the anterior intermuscular septum. The black arrow is pointing to the fibula, on which a small cuff of muscle and periosteum has been preserved—the so-called marbleizing technique.

CRITICAL CONCEPTS

INDICATIONS:

Symptomatic patients younger than fifty years of age with stage-II, III, or IV osteonecrosis of the femoral head according to the classification of Urbaniak et al.[1] are candidates for free vascularized fibular grafting of the femoral head. Patients younger than twenty years of age who have stage-V disease and a good range of motion of the hip are also eligible for the procedure.

CONTRAINDICATIONS:

Total hip replacement is recommended for patients over the age of fifty years who have any degree of symptomatic osteonecrosis or patients over the age of forty years who have advanced stage-IV disease or involvement of >50% of the femoral head with limited hip motion. Currently, we do not operate on patients with asymptomatic hips; instead, we observe them closely and recommend free vascularized fibular grafting of the femoral head when clinical symptoms or radiographic signs of progression develop. However, because of the high rate of disease progression in untreated patients, we are currently giving some consideration to revising these treatment guidelines.

the peroneal vessels are again identified, isolated, and divided with the aid of hemostatic clips. The now free distal pedicle is attached to the distal aspect of the fibula with a hemoclip to ensure that the peroneal vessels and any nutrient branches to the bone are not avulsed from the fibula during the remainder of the harvest.

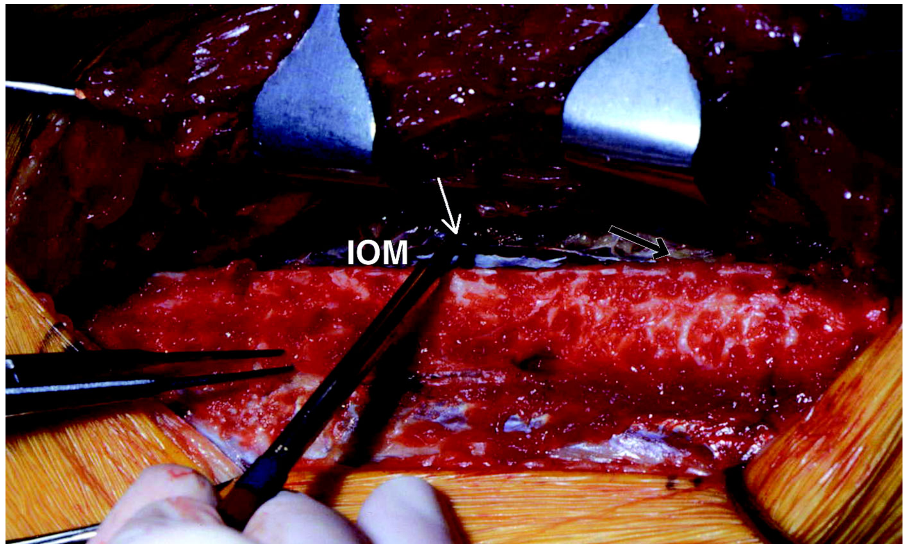

FIG. 3

The interosseous membrane (IOM) is divided with a specially designed right-angle Beaver blade (white arrow). The close proximity of the deep peroneal nerve and anterior tibial artery (black arrow) can be seen in this photograph.

The fibula and adjoining peroneal vessels are then dissected from the surrounding flexor hallucis longus, posterior tibialis, and soleus muscles. Dissection is best performed with a clockwise-counterclockwise, back-and-forth motion of the fibula, with the surgeon standing at the patient's foot looking down the long axis of the leg. This allows constant visualization of the pedicle and easier access to vascular perforators. Attempts

FIG. 4

The fibular osteotomy is performed once the pedicle has been isolated distally and proximally and protected with malleable retractors.

FIG. 5

The proximal stump of the peroneal artery is ligated with the hemostatic clips (arrow) just as it branches from the posterior tibial artery, ensuring at least a 4 to 5-cm pedicle.

should be made to free and protect any nerve branches to the flexor hallucis longus. This nerve invariably runs with the peroneal vessels and can be teased rather easily away from the main pedicle, preserving its integrity. With that said, in our experience, sacrificing this nerve has not appeared to affect the clinical outcome.

As the dissection proceeds in a proximal direction, large perforators to the soleus are encountered, typically at the level of the proximal osteotomy. These vessels are best managed with hemostatic clips. The fibula is elevated until it is tethered only by the proximal vascular pedicle. Once 4 to 5 cm of pedicle length has been established, the pedicle is ligated with two large hemostatic clips (Fig. 5) and is divided just distal to its origin from the posterior tibial vessels. An illustration of the harvested fibula and accompanying vessels is shown in Figure 6. The tourniquet is then deflated, the wound is copiously irrigated, and any persistent bleeding is addressed. The fibular graft is carefully passed to a back table for implant preparation. Because the procurement of the fibular graft either coincides with or precedes the work on the femoral head, the leg wound is not closed at this time but is packed with saline-solution-soaked gauze and wrapped firmly with a sterile towel, which is secured with two towel-clips. This allows the hip surgeon to manipulate the leg without delay when obtaining fluoroscopic views of the hip, particularly the frog-leg lateral views of the hip. The leg wound is closed a short time later, during the vascular anastomosis at the hip. The deep fascial layers of the leg are not closed for fear of a compartment syndrome. The subcutaneous layer and the skin are closed over a drain, and the leg is wrapped in a soft bulky dressing.

Preparation of the Fibular Graft

On a back table, the fibular graft is placed on a sterile saline-solution-soaked operative sponge in a basin. It is here that the artery and two veins of the pedicle are delineated from one another and separated with use of microscissors and jewelers'

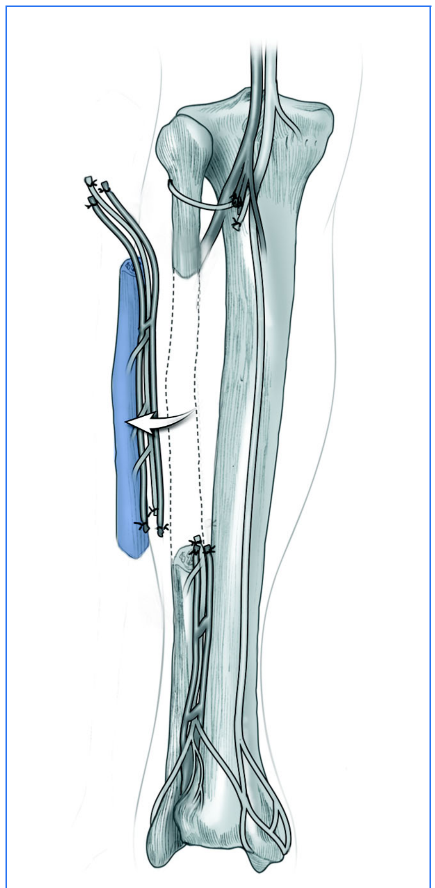

FIG. 6

The harvested fibula and accompanying pedicle of the peroneal vascular system are demonstrated.

CRITICAL CONCEPTS | continued

PITFALLS:

The development of a flexor hallucis longus contracture causes substantial morbidity, but it is easily avoided by initiating a strict passive-stretching program immediately following surgery.

Subtrochanteric fractures were more of a concern when cancellous bone graft was harvested from both the greater and the lesser trochanteric region, but since we stopped using that approach and began curetting bone only from the greater trochanter, the rate of postoperative subtrochanteric fractures has declined. For this reason, we recommend harvesting cancellous graft from only the greater trochanter.

Another pitfall, which places the onus largely on the patient, relates to compliance with restricted weight-bearing. Premature weight-bearing on the affected side can lead to femoral head collapse and fracture, among other complications.

Attention to detail is important at every step of this technically demanding procedure, but it is especially vital when ensuring adequate pedicle length. A short pedicle on either the donor or the recipient side will jeopardize the creation of a tension-free anastomosis and thus necessitate the use of a vein graft.

An uncommon problem that we have encountered is a patient with an allergy to the radiographic contrast medium, which limits our ability to assess the adequacy of the reaming of the necrotic bone. In these cases, we recommend using only air,

continued

FIG. 7

Skin markings for planning the hip incision. The anterior superior iliac spine (ASIS) is identified. A line is drawn 10 cm distally, from which a line tangential to the longitudinal axis of the femur is drawn. This corresponds to the location of the donor vessels (the ascending branch of the lateral femoral circumflex artery). The vastus ridge (VR) is readily palpated in most patients. Typically, one-third of the incision is placed superior to the vastus ridge and two-thirds is placed inferior to the vastus ridge.

forceps. All three vessels are then irrigated with heparin-impregnated lactated Ringer solution. Each vessel is visually inspected for any major leaks. Neither vein will fill over its entire length of the graft because of its valves, but the artery should insufflate throughout its entire course during injection of the heparin solution. Some oozing from the attached muscle and periosteum is anticipated and considered normal; however, we consider any leaks from the main vessels that form a stream to be major and worthy of repair with either 8-0 suture or micro-hemostatic clips. Such attention to detail is imperative to minimize the risk of the development of a vascular steal and thus ensure adequate endosteal blood flow following the anastomosis. One vein is chosen as the recipient, while the other is ligated with a hemostatic clip. The diameter of the fibula is measured and is reported to the hip surgeon to direct the end point for core reaming of the hip (as discussed in detail below). Generally, the diameter of the fibula from children, women, and men measures 13, 16, and 19 mm, respectively. Next, the proximal pedicle is reflected in a subperiosteal fashion from the fibula until a nutrient vessel is seen entering the cortex. The length of the pedicle at this point should be approximately 4 to 5 cm. The

The Journal of Bone & Joint Surgery · Surgical Techniques | March 2004 · Volume 86-A · Supplement Number 1 · jbjs.org

proximal part of the fibula is then cut with an oscillating saw at the level of the most proximal nutrient vessel, with protection of the pedicle during the osteotomy. Again, copious irrigation should accompany all osteotomies to prevent thermal necrosis. Once the exact length of fibula required has been determined from preparation of the proximal part of the femur (see the description of the hip technique for further details), this length is measured and is marked on the fibular graft. A centimeter of periosteum is preserved distal to the mark, and this periosteal cuff is evaginated back to the level of the mark, after which the final bone cut is made. The distal pedicle and evaginated periosteum are secured to the distal extent of the fibula with a 4-0 absorbable suture in order to prevent stripping of the pedicle and periosteum during insertion into the femoral core.

Operative Procedure on the Hip

Before the skin is incised, the location of the donor vessels is estimated and is marked on the skin, approximately 10 cm distal to the anterior superior iliac spine (Fig. 7). The proximal part of the femur is approached through a 10 to 15-cm curved (convex anterior) anterolateral skin incision, with one-third of the incision superior to the tip of the greater trochanter and two-thirds inferior to the greater trochanter. The skin incision is followed by a variation of the Watson-Jones approach to the hip, exploiting the interval between the tensor fasciae latae and the gluteus medius. The tensor fasciae latae is incised in a curvilinear fashion (convex posterior) to allow access to the greater trochanter (Fig. 8). The vastus lateralis is

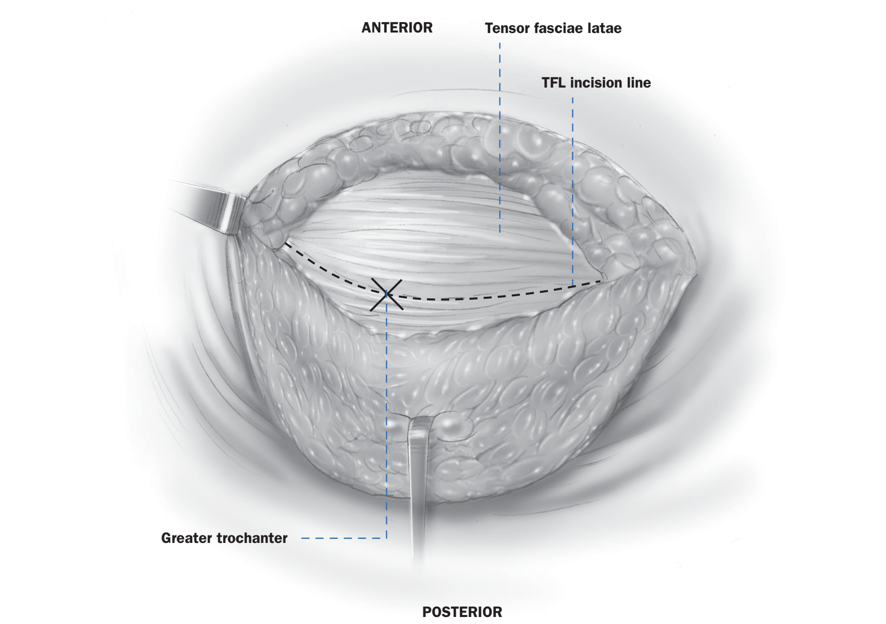

FIG. 8

The tensor fasciae latae (TFL) is incised in a convex posterior manner to allow ease of access to the proximal part of the femur. This tensor fasciae latae flap is reflected anteriorly, providing good visibility for the anteriorly placed anastomosis.

CRITICAL CONCEPTS | continued

PITFALLS (continued):

which will demonstrate, albeit less dramatically, the adequacy of the grafting.

For skeletally immature patients (those with open physes and more than two years of growth potential remaining), we place a single 3.5-mm fully threaded syndesmosis screw through the distal parts of the tibia and fibula, crossing three cortices, 2 cm proximal to and parallel with the ankle mortise. This screw can be removed around the time that full weight-bearing is allowed (at six months).

Once the vessels in the hip have been dissected free, the suction should not be placed into the wound because of the risk of avulsing or otherwise damaging the vessels.

Fifteen percent of patients experience dextran-induced headaches. We discontinue the dextran treatment at the first sign of the headaches and begin treating the patients with aspirin. In our experience, doing so has not appeared to affect the outcome.

Neither an excessive amount of fibula nor a prominent pin should protrude laterally at the hip as either can cause trochanteric bursitis.

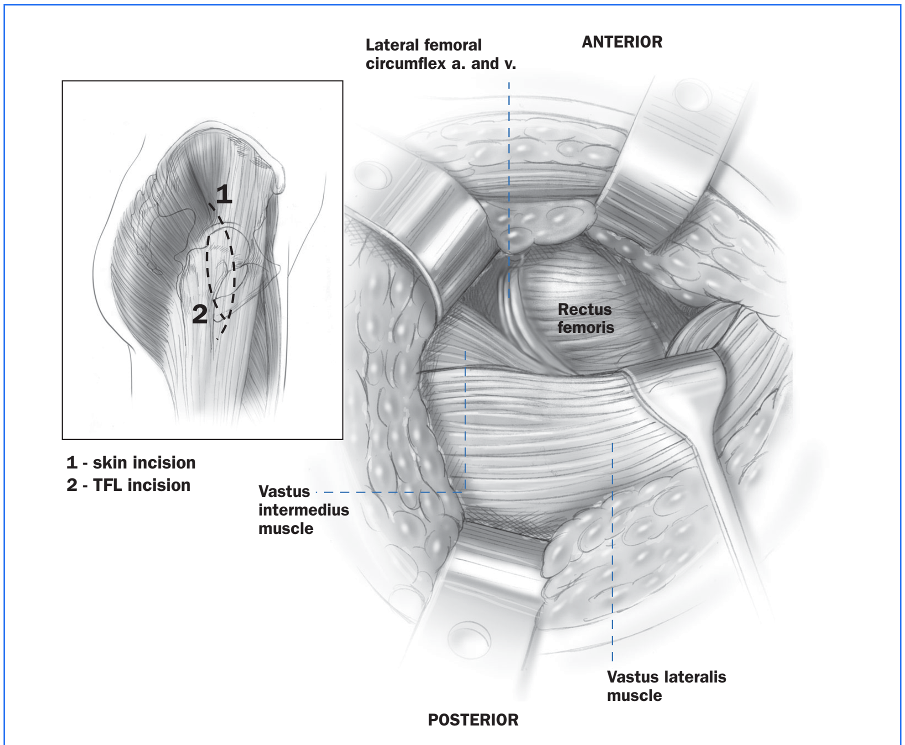

FIG. 9

The donor vessels are visualized before the vastus lateralis and intermedius are reflected. In this drawing, the vessels can be seen lying beneath a fat pad (which has been swept away), ascending into the falx of the rectus femoris. TFL = tensor fasciae latae.

then encountered, and the donor vessels (the ascending branch of the lateral femoral circumflex artery and its accompanying two veins) are identified as they lie between the rectus femoris and the vastus intermedius (Fig. 9). Once the donor vessels are visualized, the origin of the vastus lateralis is reflected sharply from the vastus ridge, and the posterior attachments of the vastus lateralis are reflected approximately 5 cm from the linea aspera to expose the lateral aspect of the femur. The origin of the vastus intermedius is then carefully detached with a right-angle clamp and knife from its anterior position on the proximal part of the femur. All fibers from the vastus intermedius should be taken down to provide a trough for the ascending vessels and thus ensure a tension-free vascular anastomosis. The reflected vastus intermedius and vastus lateralis muscles are secured to the anterior wound edge with a 0-Vicryl stitch for retraction. A four-quadrant retractor is then introduced to provide better visibility for the dissection of donor vessels.

Isolation of the Vascular Pedicle

With the vastus intermedius reflected from its origin, the falx or aponeurotic bridge spanning from the anterolateral aspect of the femur to the rectus femoris can be seen anteriorly. With use of sponge sticks, the adjacent deep fat pad is swept away to expose clearly the ascending

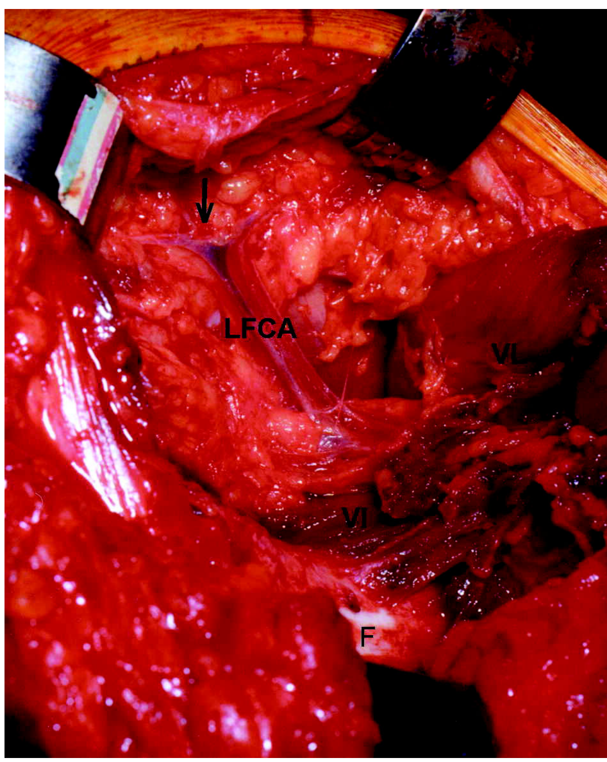

FIG. 10

With the vastus lateralis (VL) and intermedius (VI) reflected, the ascending branch of the lateral femoral circumflex artery (LFCA) and accompanying veins can be seen. These vessels need only be taken down at their first bifurcation (arrow). F = femur.

branch of the lateral femoral circumflex artery and its two accompanying veins (Fig. 10). Under loupe magnification, the pedicle is carefully dissected out. A tension-free anastomosis can be performed with a minimum pedicle length of 4 cm, which is obtainable if the ascending branch off the lateral femoral circumflex artery is ligated at its first major division. Any small branches are ligated with small hemostatic clips or are cauterized. After the artery and the two veins are dissected free and a length of at least 4 cm has been established, each is divided and is clamped with a small hemostatic clip. The wound is irrigated with warm saline solution, and the four-quadrant retractor is removed for preparation of the proximal part of the femur.

FIG. 11-A

Intraoperative fluoroscopic image showing correct guide-pin placement on the anteroposterior view. This superior pin placement is typical, as osteonecrosis is predominantly located in this area.

FIG. 11-B

Intraoperative fluoroscopic image showing correct guide-pin placement on the frog-leg lateral view. The pin is typically placed anteriorly, as is demonstrated on this image.

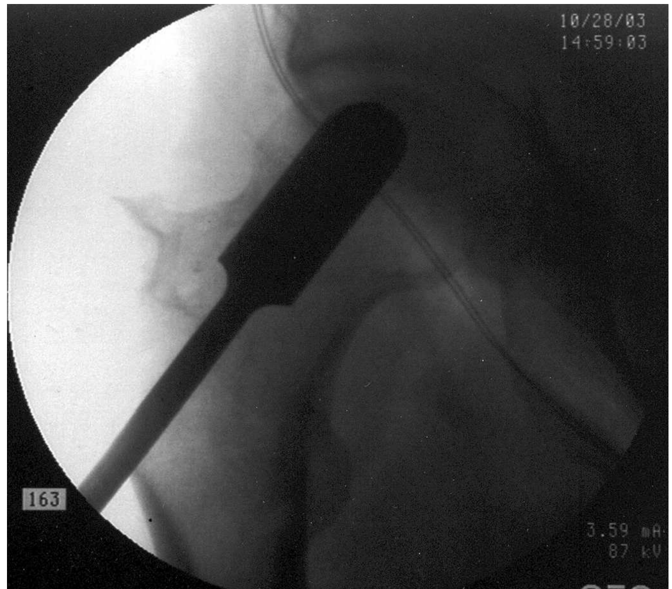

FIG. 12

Intraoperative fluoroscopic image demonstrating passage of the straight reamer between the cortices of the femoral neck and into the necrotic region within the femoral head.

Preparation of the Femoral Head

A c-arm fluoroscope is draped with a sterile sleeve and is then positioned over the hip region like an arch. This allows anteroposterior and frog-leg lateral views of the proximal part of the femur to be obtained with relative ease. Starting approximately 2 cm distal to the vastus ridge and at the junction of the middle and posterior thirds of the lateral aspect of the femur, a 3-mm guide pin is inserted under fluoroscopic control into the center of the necrotic nidus within the femoral head. The position of the pin must be checked on both the anteroposterior and

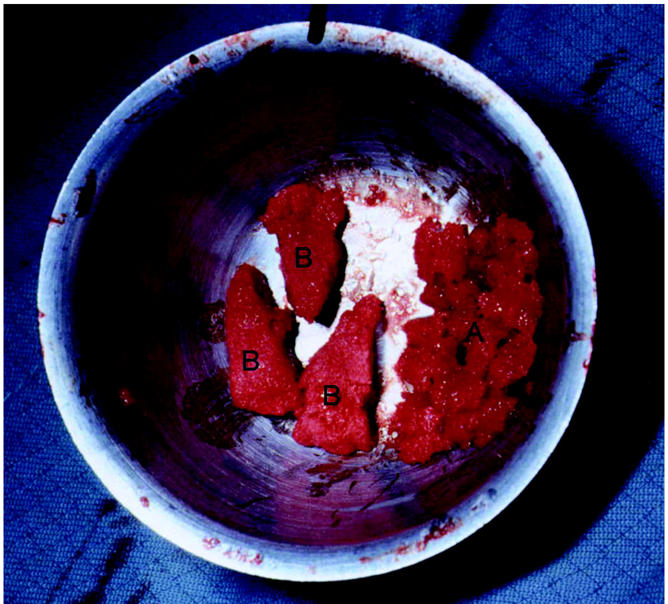

FIG. 13

The bone graft cup with the "bullets" (B) fashioned from the bone reamed from the femoral core as well as the cancellous bone taken from the greater trochanter (A). Both bone grafts are used to fill the excavated region of the femoral head.

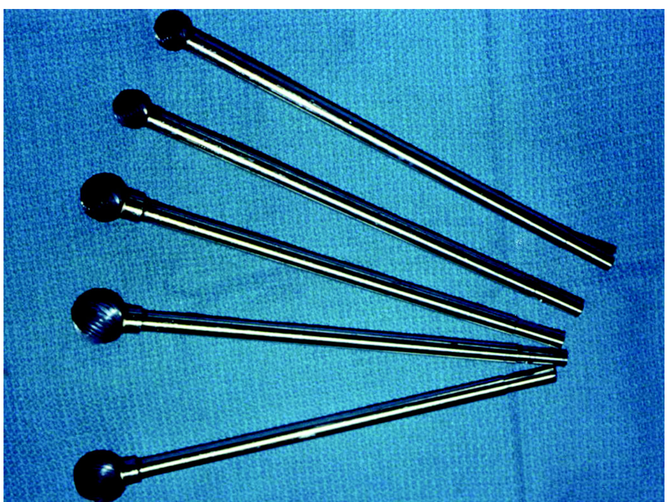

FIG. 14

The ball-tip reamers used to remove areas of necrotic bone that are not reached by the straight reamers.

the lateral view (Figs. 11-A and 11-B). The pin not only must be positioned within the center of the necrotic bone but also must be spaced appropriately between the cortices of the femoral neck to allow the passage of a 19 to 21-mm reamer if necessary. With correct pin placement confirmed by fluoroscopy, sequential reaming is performed over the guide pin, starting with a 10-mm reamer and increasing in size to 13, 16, 19, and 21-mm straight reamers. The end point of reaming is the diameter of the harvested fibula. The reaming should extend within 3 to 5 mm of the subchondral plate of the femoral head. This portion of the reaming is best done under live fluoroscopic guidance (Fig. 12). With each pass, the reamer is removed and its flutes are freed of any bone. Obviously, necrotic bone is discarded, while healthy-appearing bone is saved for later grafting. Additional bone is captured with a filtered suction tip (KAM Super Sucker; Anspach, Palm Beach Gardens, Florida) during the reaming process when a bone slurry is expressed from the core. Periodically, bone from the sucker tip is emptied onto a surgical sponge, dried, and fashioned by the scrub nurse into rectangular "bullets" to be used later for grafting (Fig. 13). After the passage of the final straight reamer, the guide pin is removed and a special ball-tip reamer (Fig. 14) is introduced. Under fluoro-

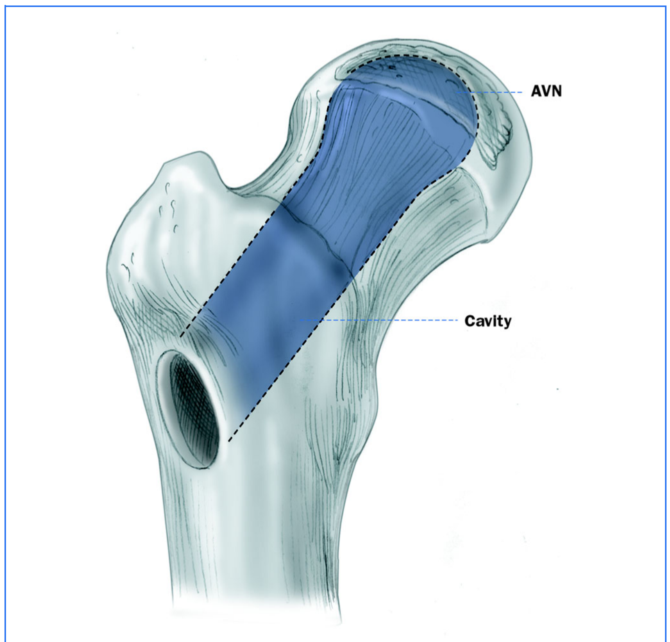

FIG. 15

A drawing showing the core decompression of the femoral neck and head and the bulbous cavity left in the femoral head as a result of the additional ball reaming. The area of necrotic bone (AVN) removed by the reaming is shown.

scopic control, additional necrotic bone is excavated from the femoral head, creating a bulbous cavity, usually in the anterior and superior quadrants of the head (Fig. 15). Ball reaming is rarely needed for lesions that involve <25% of the femoral head.

Next a water-soluble radiographic contrast medium is injected into the femoral core to document the adequacy and amount of the necrotic bone removed (Fig. 16-A). Then, with the use of a large curet, cancellous bone is taken from the greater trochanteric region, with use of the proximal femoral core as an access point. Some of the cancellous graft is then placed into the femoral head cavity with DeBakey forceps and is impacted with the use of a custom-made cancellous-bone-impaction instrument. The impactor is a tubular device, sealed at one end to push the cancellous graft farther into the head. It is particularly helpful for elevating the sunken subchondral floor in cases of femoral head collapse. At its inserted end, the device has several windows, through which additional cancellous bone is extruded, thus filling voids in the subchondral bone. A specialized drill bit is passed down the impactor, forcing the bone out through the windows into the femoral head (Fig. 17). The impactor is fully inserted and gently seated with a mallet, and its position is confirmed under fluoroscopy. The length of the fibular graft is determined at this point by reading the circumferential markings (units in millimeters) on the impactor's side at the 3 o'clock and 9 o'clock positions. After the cancellous bone is inserted, the bone "bullets," created from the reamed bone, are inserted and extruded likewise into the femoral head cavity. Finally, contrast material is reinjected to confirm adequate filling of the subchondral voids in the femoral head (Fig. 16-B).

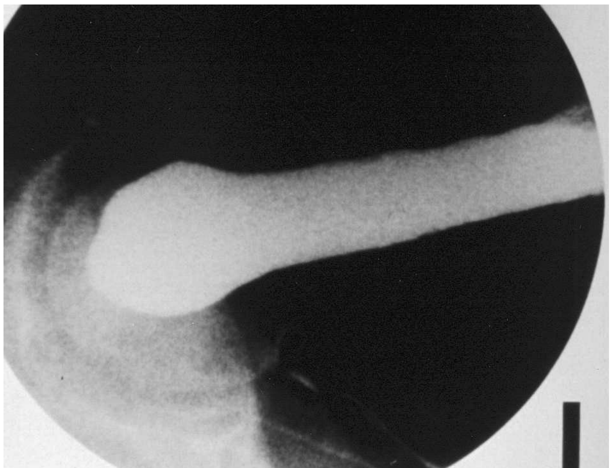

FIG. 16-A

The water-soluble radiographic contrast medium can be seen filling the cavity within the femoral head after reaming.

FIG. 16-B

Following the placement of bone graft within the femoral head cavity, radiographic contrast medium is again injected into the femoral head and core. The contrast image within the femoral head is now tapered, indicating an adequate amount and placement of healthy bone graft into the previously necrotic region of the femoral head.

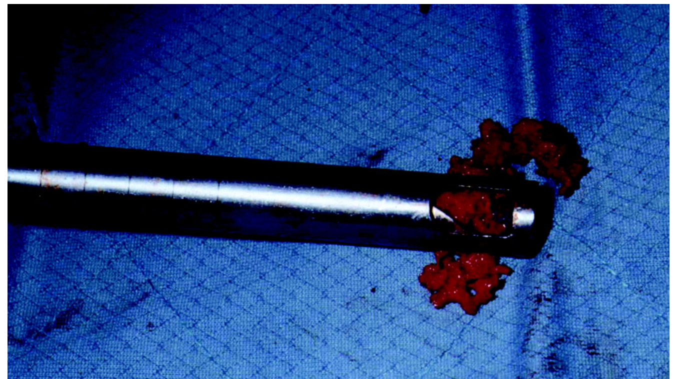

FIG. 17

The custom-made bone impactor. The windows allow controlled delivery of bone graft to the regions of the femoral head excavated by the ball-tip reamers.

The femoral head is now ready to receive the fibular graft.

Placement of the Fibular Graft

The pedicle coursing along the fibula is placed superiorly and anteriorly, usually resting in and protected by a natural fibular recess. To further protect the pedicle, the fibula is inserted along the posterior border of the femoral core, which should be capacious enough to accommodate the fibula without excessive compression of the pedicle. With use of a bone tamp, the graft is gently advanced farther into the cavity of the prepared femoral head. Its final position is confirmed with fluoroscopy. The graft is secured within the core by a 0.062-mm Kirschner wire that crosses both cortices of the fibula and the medial femoral cortex at the level of the lesser trochanter (Fig. 18). DeBakey forceps are used during placement of the Kirschner wire to push and maintain the graft in a posterior position within the core, thus preventing compression of the anteriorly placed pedicle. A wire guide is used to protect the pedicle from injury during placement of the Kirschner wire. The Kirschner wire is bent, cut short, twisted posteriorly, and buried in the fibers of the gluteus medius. At this point, the fluoroscopy unit can be removed from the operative field.

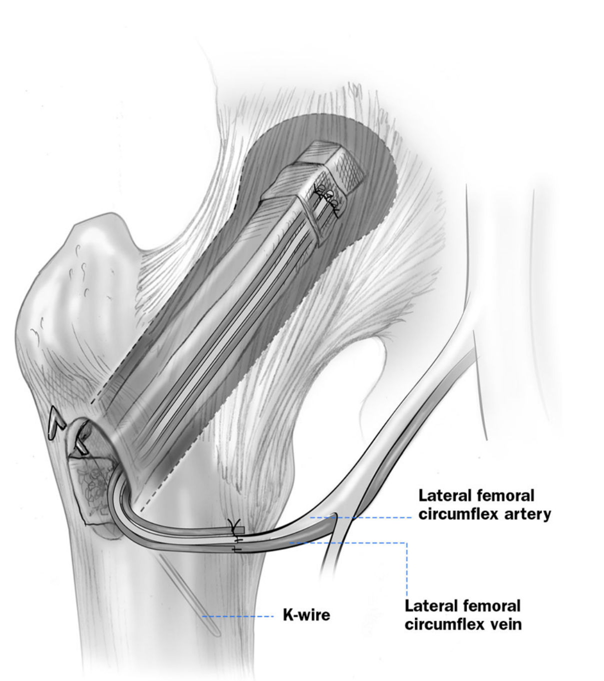

FIG. 18

A drawing of the final graft placement. Note the Kirschner (K) wire placed through three cortices to secure the fibula within the femoral core.

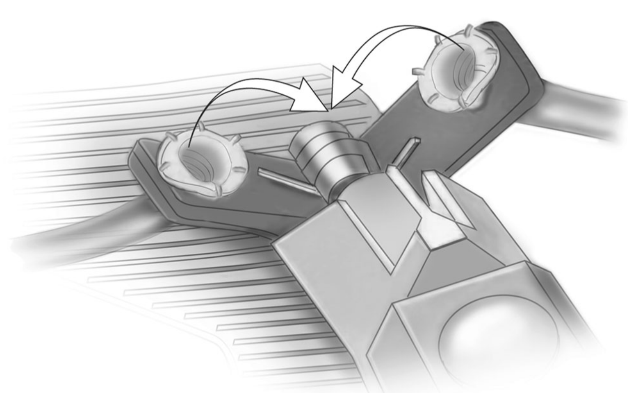

FIG. 19

The vein from the fibular pedicle and the donor vein are easily coapted with use of a venous coupler.

Vessel Anastomosis

The four-quadrant hip retractor is replaced to optimize exposure of the harvested vessels (the ascending branch of the lateral femoral circumflex artery and the two veins). Attention is initially directed toward the venous anastomosis. We have continued to have success when performing our venous anastomoses with a coupling device (Microvascular Anastomotic Coupler System; Medical Companies Alliance, Homewood, Alabama [www.mca-mas.com]) (Fig. 19). This is done under loupe magnification. The device comes in sizes ranging from 1.0 to 3.0 mm (in 0.5-mm increments); however, we use either the 2.5 or the 3.0-mm coupler in the majority of cases. After this step, the microscope is brought into the surgical field, a blue microsurgical suction mat (PMT, Chanhassen, Minnesota) is placed as a backdrop, and the arterial anastomosis is completed with use of an 8-0 or 9-0 black nylon monofilament suture with a 100-μm needle (Sharpoint; Pearsalls, Taunton, Somerset, United Kingdom) (Fig. 20). We prefer to sew with simple interrupted stitches rather than a running stitch. The ends of both the donor and the pedicle arteries are stabilized with the assistance of a double occluder vessel Bear clamp (AROSurgical, Newport Beach, California). Following the anastomosis, the clamps are released and the repair site is observed for leaks. We often place a small local fat graft over minor leaks; the fat, through its thrombogenic properties, suffices as a patch. Larger leaks require additional suturing. Next, the exposed end of the fibular graft is observed for endosteal bleeding. Bleeding from the endosteal vessels is seen within five minutes after releasing the occluder clamps in >90% of cases. When flow is absent after five minutes, we recommend several steps. First, we check the patient's blood pressure and core body temperature. If either or both are low, elevation to normal levels often produces adequate flow. In addition, we irrigate the medullary canal of the exposed fibula with papavarin and heparin. If this does not improve flow, we recheck the anastomosis site for leaks and perform a patency test on both sides of the anastomosis. If flow is sluggish or absent on the femoral side of the anastomosis, we trace the artery back to its origin from the lateral femoral circumflex artery. The ascending branch can be either kinked or tethered anywhere along its course. If this is the case, removal of the aggravating tissue (most often the vastus intermedius) often allows adequate flow. If poor flow is localized to the fibular pedicle side, we check the vein that was not used for the venous anastomosis, as often this vein can have a small leak, which induces spasm throughout the vessels or causes a vascular steal. Any leaks are repaired with either 8-0 suture or micro-hemoclips. To address vessel spasm, we massage the vessels with forceps and irrigate the entire artery with papavarin. If none of these measures establishes adequate blood flow, we remove the Kirschner wire and extract the fibula from the core as far as the pedicle will allow, checking for vessel leaks along the fibula. Any vessel leak along the fibula should be occluded with a micro-hemoclip. Another consideration at this point is the size of the femoral core and the potential for vessel compression. The vessels usually can be decompressed by rotating the graft to provide more space. The graft rarely, if ever, has to be removed entirely for size adjustment, if accurate measurements have been made in the preparation of the core and of the fibular graft. If all else fails, the

CRITICAL CONCEPTS

AUTHOR UPDATE:

The surgical procedure has remained relatively unchanged since it was described by one of us (J.R.U.) and others[1-3]. No changes have been made since the original publication of our article in the June 2003 volume of *The Journal of Bone and Joint Surgery*[4]. The surgical technique is not altered according to the stage of the disease or the presence or absence of collapse. The exception to that statement is that we attempt to elevate the depressed articular segment intraoperatively, thus restoring sphericity to the femoral head, in patients with postcollapse osteonecrosis.

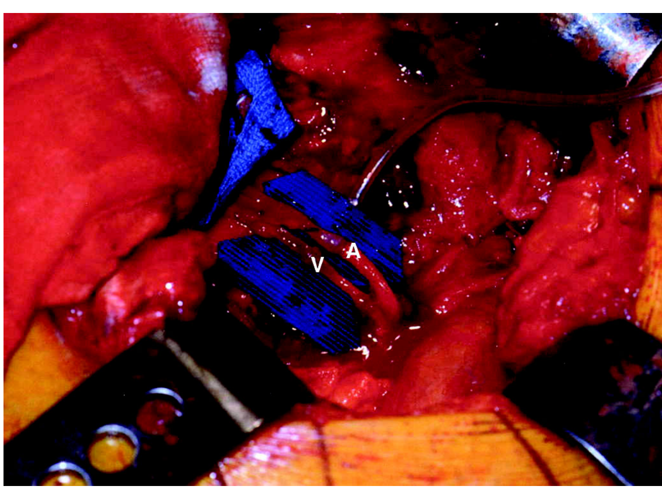

FIG. 20

Both the vein (V) and the artery (A) have been anastomosed and rest on the blue background. The arterial repair is checked by noting pulsatile flow on both sides of the repair and by demonstrating filling of the vein.

FIG. 21-A

Preoperative anteroposterior radiograph of a symptomatic left hip. An increased density is noted within the femoral head; however, the sphericity of the head and the joint space appear to be well preserved on this view.

FIG. 21-B

A frog-leg lateral radiograph of the left hip of the same patient shows subchondral collapse with subsequent loss of sphericity. The joint space shows no evidence of arthrosis.

FIG. 21-C

Magnetic resonance image of the same patient shows the classic serpiginous signal changes, diagnostic for osteonecrosis, within the left femoral head.

FIG. 21-D

The left hip two years after free vascularized fibular grafting, showing no progression of collapse and demonstrating incorporation of the fibular graft and preservation of the joint space.

anastomosis is redone and an interpositional vein graft is utilized if there is excessive tension.

The vastus lateralis and intermedius muscles are not reattached during closure because of the risk of constricting the vascular pedicle. The tensor fasciae latae and the iliotibial band are closed over a drain. The subcutaneous tissue and the skin are closed in the same manner as used for the leg wound.

Postoperative Care

Postoperatively, all patients are treated with intravenous infusion of dextran for three days, after which they are transitioned to an aspirin a day, which is taken for six weeks. The operative drains, Foley catheter, and epidural catheter are removed on the second postoperative day. Physical therapy is also initiated on that day. The average hospital stay is four days. Patients remain non-weight-bearing on the operative side for six weeks, after which time progressive weight-bearing is permitted. Full weight-bearing is achieved by six months. Patients are encouraged to begin early active and passive motion of the toes and ankle, with special emphasis on passive stretching of the great toe. The great toe is susceptible to a flexion contracture secondary to scarring of the flexor hallucis longus muscle, the origin of which was reflected off the fibula during the harvest. Follow-up radiographic and clinical examinations are performed at three months, six months, and yearly thereafter (Figs. 21-A through 21-D). If a second procedure is required for the contralateral hip, it is typically performed three months later.

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The authors did not receive grants or outside funding in support of their research or preparation of this manuscript. They did not receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

The line drawings in this article are the work of Jennifer Fairman (jfairman@fairmanstudios.com).

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