Surgical Technique: Free Vascularized Fibula Graft for Avascular Necrosis

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Abstract

Avascular necrosis (AVN) or osteonecrosis of the femoral head (ONFH) is a common cause of hip pain and disability in a young patient demographic with an average age of mid-30s. If left untreated, approximately 80 % of cases of ONFH will result in femoral head collapse and hip degeneration necessitating total hip arthroplasty (THA) in a mean of 2 years. The relatively poor outcomes and requisite lifestyle changes associated with THA in this patient population have challenged surgeons to seek alternative treatment options. Vascularized bone grafts have been shown to have better radiographical and clinical results compared to nonvascularized bone grafts. Of these options, free vascularized fibular graft (FVFG) is the treatment of choice for its structural and vascular support within the femoral head. Improved technique has led to complication rates, including donor-site morbidity, statistically similar to that of nonvascular fibular grafts. When used in young patients with precollapse ONFH, FVFG can greatly improve patient outcome, with lower rates of conversion to THA than other treatment modalities.

Introduction

Avascular necrosis (AVN) or osteonecrosis (ON) of the femoral head is a common cause of hip pain and disability. As many as 18 % of total hip

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arthroplasties (THA) are performed for osteonecrosis and this remains an excellent treatment option for older patients [1, 2]. However, the majority of patients with osteonecrosis of the femoral head (ONFH) are young, with an average age of mid-30s [3, 4]. If left untreated, approximately 80 % of cases of ONFH will result in femoral head collapse and hip degeneration necessitating THA in a mean of 2 years [3, 5, 6]. The relatively poor outcomes and requisite lifestyle changes associated with THA in this patient population have challenged surgeons to seek alternative treatment options.

Presentation and Imaging

Early stages of the disease may present without pain, but ultimately the physical exam will show painful and limited range of motion that will eventually include restricted passive range of motion [3]. Plain radiographs are necessary for the diagnosis of ONFH; however, findings are often limited or absent in the early stages of the disease. Plain radiographs only pick up bone density changes associated with remodeling or disuse and therefore may only detect changes months or even years after the disease starts [7]. The Ficat-Arlet (FA) staging system is the most common and stages hips based on the four parameters of collapse, size, femoral head depression, and acetabular involvement. In cases of suspected ONFH without signs on plain radiographs, magnetic resonance imaging (MRI) should be considered. MRI is the most sensitive imaging study for the diagnosis of ONFH, especially for asymptomatic or early-stage cases [7–9].

Management

For young patients with symptomatic disease, there appears to be very little benefit to nonoperative management. Evidence from a meta-analysis including over 800 hips shows that 76 % of hips treated solely with restrictive weight-bearing required an arthroplasty or salvage procedure [10]. The results from this and similar studies show universal agreement that restrictive weight-bearing as sole treatment is inappropriate [11]. Operative management is largely determined by the stage of the lesion, with femoral head collapse being the most important factor in management. Larger and more advanced lesions become progressively more difficult to treat. For small, precollapse lesions, core decompression has been widely used. First coined by Hungerford, Ficat and Arlet, core decompression is thought to relieve pain by lowering interosseus pressure and stimulating neovascularization of the femoral head and neck [12, 13]. This procedure is favored for its technical ease, short operative time, and allowance for any number of various subsequent surgical options. The efficacy of core decompression in more advanced ON lesions has not been demonstrated.

Larger and more advanced lesions have historically been treated by a variety of surgical options to attempt hip preservation in younger patients. Osteotomies have been used but concern remains over the potential for disruption of the blood supply to the femoral head and the difficulty in converting these hips to an arthroplasty as a salvage procedure. Conventional bone grafting has been reported either through a trapdoor [14] in the articular cartilage or through a cortical window in the femoral neck [15, 16]. Both of these procedures are performed with intracapsular dissection and risk the vascularity to the femoral head. In the late 1970s, several potential vascularized bone graft techniques were used in hopes of aiding the biology of bone healing within the femoral head. Vascularized bone grafting and its subtypes share the goal of lesion decompression via the removal of necrotic bone and the placement of bone graft with a vascular source to provide osteoinductive progenitor cells for healing. Local pedicled bone grafts, most commonly a muscle-pedicle-bone graft from either the quadratus femoris or the tensor fascia lata, have been reported with superior results as compared to conventional nonvascularized bone grafts [17–22]. This technique is dependent upon muscular metaplasia to be successful. This, combined with the lack of structural bone graft provided by these grafts, led some authors to consider other sources of vascularized bone graft.

More distant donor sites that provided structural support for ON lesions and did not depend upon muscular metaplasia became possible with the development of the operating microscope and improved microsurgical techniques for free vascularized bone grafts. In the late 1970s, Urbaniak [23], Brunelli and Brunelli [24], and Judet and Gilbert [25] began using the free vascularized fibular graft (FVFG) to treat ON of the femoral head. The fibula provides a large corticocancellous bone graft that can be placed from an extracapsular entry point. It has a reliable vascular pedicle and when performed correctly has a low donor-site morbidity. Free vascularized fibular grafts have been compared to nonvascularized fibular grafts and demonstrate superior results in larger and more advanced ON lesions [26]. Several studies have cited vascularized fibular bone grafts as being radiographically and clinically superior to nonvascularized bone grafts in terms of progression to the next stage of disease [6, 27]. Harris hip scores (HHS) improved in 70 % of hips using fibular vascularized and 36 % using nonvascularized grafts. The rate of survival for stage I and II precollapse lesions at 7 years was 86 % for FVFG and 30 % for nonvascularized fibular grafts (NVFG) [6, 27].

Often cited drawbacks from using vascularized bone grafts include increased surgical difficulty of vascular grafting as well as donor-site morbidity [11]. However, donor-site morbidity is debated, with previous research showing anywhere from nearly no morbidity to 10 % [15, 28]. A recent meta-analysis vascularized fibular grafts (VFG) was compared to other treatment methods including core decompression, NVFG, and vascularized iliac grafts and found that 122/740 (16 %) of VFGs while 104/244 (42.6 %) of other methods resulted in failure (i.e., THA) [29]. A weighted test of the complication rate between VFG and other treatment methods showed no statistically significant difference. However, there has yet to be a prospective randomized control trial comparing VFG to other methods.

As a whole, hips treated with free vascularized fibular grafts demonstrated less radiographic progression, less femoral head collapse, and improved HHS. The authors have used this technique successfully for the management of this challenging clinical problem in young patients.

The free vascularized fibular graft remains the transfer of choice for osteonecrosis of the femoral head. The FVFG provides a large stock of corticocancellous bone graft for biological and structural support with a reliable vascular pedicle in the peroneal artery and veins. The graft can be harvested with a skin paddle for flap surveillance; however, there is a lack of consensus regarding the necessity of this [30].

Patient Population

The ideal patient for free vascularized fibular grafting for ON of the femoral head is a young, active patient with a symptomatic precollapse lesion (FA Stage I and II). Age, activity level, comorbidities, etiology, stage of disease, and radiographic findings are all considered when determining the appropriate management of each patient with ON of the femoral head.

There is no age limit for treatment of ON with FVFG; however, with increasing age there is an increased likelihood that arthroplasty will provide a successful management option for the patient. In general, patients older than 50 years are best treated by total hip arthroplasty. Because arthroplasty is associated with activity restrictions, patients younger than 50 years of age are evaluated on an individual basis for activity level and lifestyle so that an appropriate treatment option can be selected. Younger patients with an active lifestyle are typically best managed with FVFG.

Comorbidities and etiology are also considered when evaluating a patient's candidacy for FVFG. Alcohol and corticosteroid use are two common associated factors in the development of ON of the femoral head. While some centers consider current corticosteroid use as a contraindication to FVFG, the authors routinely offer FVFG to these patients with noted success. Active alcohol abuse should be considered a relative contraindication as both the pathophysiology of alcohol abuse and the potential noncompliance of postoperative weight-bearing restrictions can compromise outcomes.

Fig. 1 The patient is positioned as distal on the table as allowable to facilitate two teams, one approaching and preparing the hip and one harvesting the fibula

The stage of the ON lesion is given great weight when choosing the appropriate treatment. Asymptomatic hips are not treated with FVFG as some of these early-stage lesions will remain asymptomatic. Knowledge of the progression of ON in silent hips is limited to the evaluation of patients with contralateral disease. When ON is diagnosed on one side, Hungerford and Zizic found that 67 % of patients will develop collapse of the femoral head on the opposite side [31]. In the authors' experience, only 6 % of patients without evidence of ON in the silent hip progressed to symptomatic disease, but 72 % of patients with asymptomatic lesions present progressed [32].

Patients with precollapse lesions with maintenance of a spherical femoral head have the most to gain by an attempt at biological preservation of the femoral head. ON lesions that demonstrate some mild collapse on radiographs are considered for FVFG in younger patients with good mobility of the hip and an active lifestyle. For these patients, the questionable long-term survival of an arthroplasty procedure makes the FVFG a more attractive option.

Surgical Approach and Technique

The patient is positioned in a lateral decubitus position on a pegboard with the lower leg on a padded Mayo stand. Because of the duration of the procedure, all bony prominences should be well padded and an axillary roll should be placed to avoid positioning complications. Before prepping and draping the patient, confirm that the patient is positioned as distal on the operating table as allowable. With the patient's foot at the distal end of the table, the surgeon harvesting the fibula will minimize reach and strain while operating from the foot of the bed (Fig. 1). Furthermore, confirm that the pegs placed for patient positioning are out of the anticipated radiographic field of the femoral head.

The hip is approached through a curvilinear incision over the lateral aspect of the affected hip. The incision is approximately 10–15 cm in length and is directed convex anterior. This incision is placed such that the lateral femoral circumflex vessels are centered proximal to distal. These donor vessels are located approximately 10 cm distal to the anterior superior iliac spine (Fig. 2). With respect to anteroposterior placement of the incision, it must be positioned such that the microvascular work (anterior) and the hip reaming (posterior) can be performed through the same incision. This requires surface identification of the anterior and posterior borders of the proximal femur and the vastus ridge. The anterior margin of the incision is placed approximately 2 cm anterior to the anterior border of the femur with one-third of the incision superior to the vastus ridge and two-thirds inferior. This incision can be easily

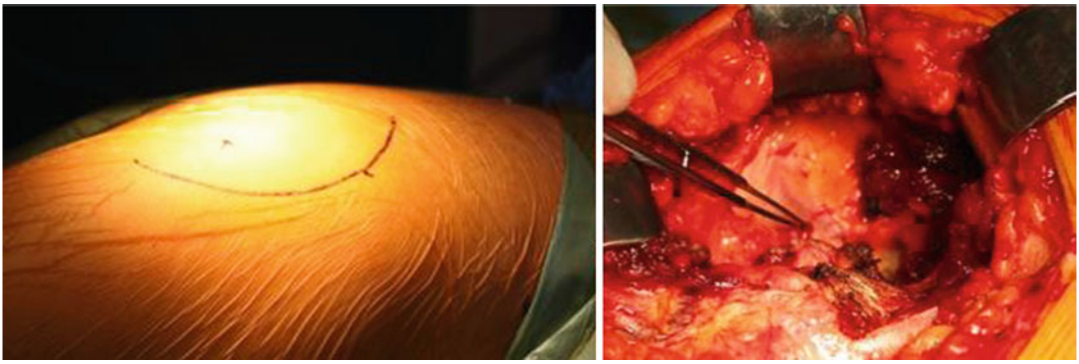

Fig. 2 The hip is approached through a 10–15 cm convex anterior curvilinear incision over the lateral aspect of the affected hip. The lateral femoral circumflex donor vessels are located approximately 10 cm distal to the anterior superior iliac spine

drawn by the operating surgeon placing his long finger on the vastus ridge with the tip of the finger 2 cm anterior to the anterior margin of the femur and the index finger superior. With the fingers maximally abducted, a line drawn connecting the fingertips corresponds with the desired skin incision [33].

After the skin incision, a variation of the Watson-Jones approach to the hip is used with dissection continuing in the interval between the tensor fascia latae and the gluteus medius. The fascia is incised in a curvilinear fashion directed convex posterior. A four-quadrant retractor is placed to assist with visualization of the deep structures. The anterior and posterior limbs are placed over the cut edges of the fascia, the superior limb is placed around the substance of gluteus medius, and the inferior limb is placed on the skin. The vastus lateralis and vastus intermedius are identified originating from the vastus ridge. The donor vessels can now be visualized anterior to the vastus intermedius in the interval between vastus intermedius and rectus femoris. The ascending branch of the lateral femoral circumflex artery and its two veins typically run obliquely cephalad at a 45° angle at a distance of 10 cm distal to the anterior superior iliac spine (Fig. 2).

Once the donor vessels are identified and can be appropriately protected, the vastus lateralis is sharply elevated to expose the lateral aspect of the proximal femur. An L-shaped incision is used with a longitudinal limb posteriorly and a transverse limb at the level of the vastus ridge. As the vastus intermedius is encountered anteriorly, a right-angle clamp and Metzenbaum scissors are used to safely release its attachments from the proximal femur and to avoid injury to the donor vessels. The complete reflection of the vastus intermedius provides a trough for the donor vessels during the later microvascular anastomosis. The vastus lateralis and vastus intermedius muscles are then secured to the anterior skin edge and placed deep to the inferior limb of the four-quadrant retractor.

The donor vessels can now be clearly seen lying within the aponeurotic falx of the rectus femoris anteriorly. The ascending branch of the lateral femoral circumflex artery and its two veins are carefully dissected out under loupe magnification. The smaller side branches of the vessels are ligated with small vascular clips such that a pedicle of at least 4 cm is obtained for later anastomosis. Typically, there is sufficient pedicle length if the vessels reach halfway up to the anticipated entry site of the fibula. The hip wound is copiously irrigated and the four-quadrant retractor is removed for preparation of the femoral head.

Preparation of the femoral head is done with the aid of c-arm fluoroscopy. The c-arm fluoroscope is draped sterilely and positioned over the patient like an arch. It is canted cephalad slightly to allow the surgeon a greater working space. The ability to obtain true anteroposterior (AP) and frog-leg lateral views is confirmed prior to

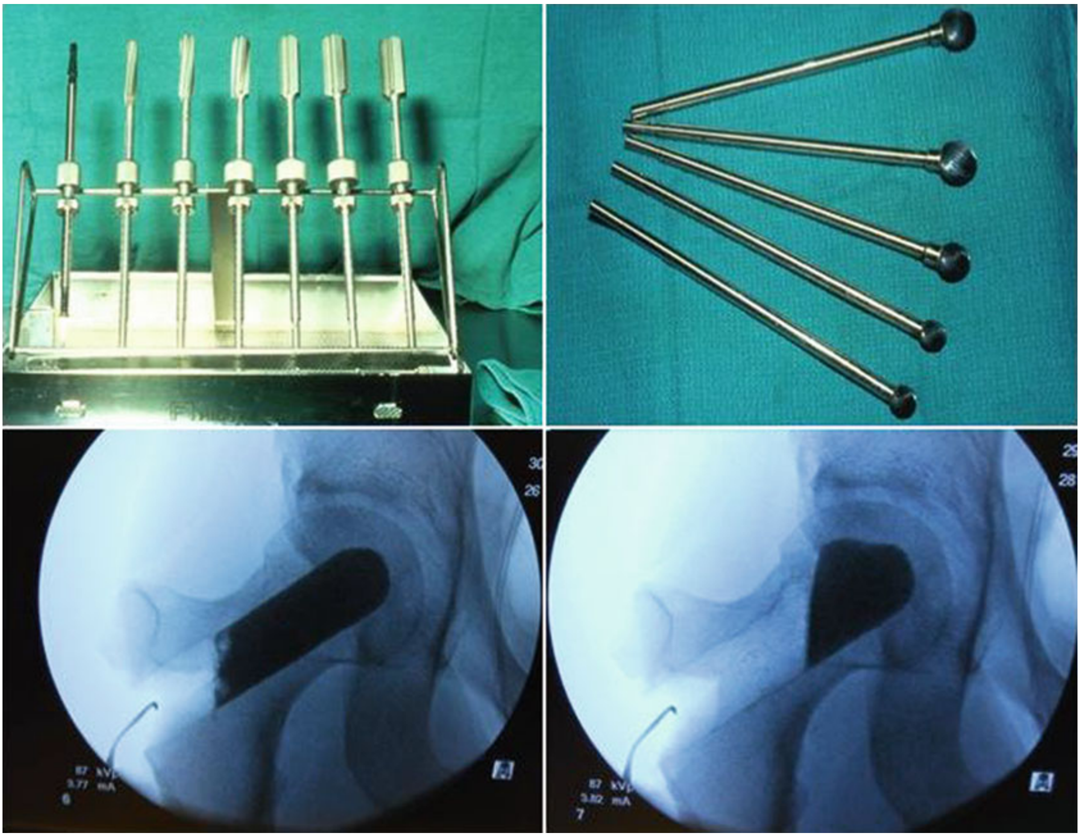

Fig. 3 Straight and ball-tipped reamers are used to remove necrotic bone. Radiographic contrast is used to evaluate the adequacy of the excavation of the osteonecrotic lesion

beginning preparation of the femoral head. With fluoroscopic guidance, a 3 mm sharp-tipped guide pin is placed into the center of the ON lesion. The starting point for this pin is approximately 2 cm distal to the vastus ridge at the junction of the middle and posterior thirds of the proximal femur. Care is taken to avoid making the entry point too distal as encroachment on the high-stress subtrochanteric region will increase the risk of fracture.

Once correct pin placement is confirmed on AP and lateral fluoroscopic views, the guide pin is overdrilled with a cannulated 8 mm drill bit. The sharp-tipped guide pin is exchanged for a blunt-tipped guide pin that is sequentially over-reamed with a series of specialized straight reamers beginning at 10 mm in diameter. These reamers are available in 13, 16, 17.5, 19, and 21 mm and they are sequentially used up to the size of the harvested fibula. The reaming is performed up to 4 mm from the subchondral plate using live fluoroscopy. The healthy bone that is collected in the flutes of the reamer is saved for later bone grafting while obviously necrotic bone is discarded. Similarly, a filtered suction device is used to collect bone fragments generated by the reaming from the core. The scrub nurse fashions this collected bone into "bullets" on the back table for later grafting.

After the final size-matched straight reamer is used, the guide pin is removed and a ball-tipped reamer is placed to remove the remaining area of necrotic bone. These reamers allow the creation of a bulbous cavity and are best used with the assistance of fluoroscopy. Radiographic contrast is used to evaluate the adequacy of the excavation of the ON lesion (Fig. 3).

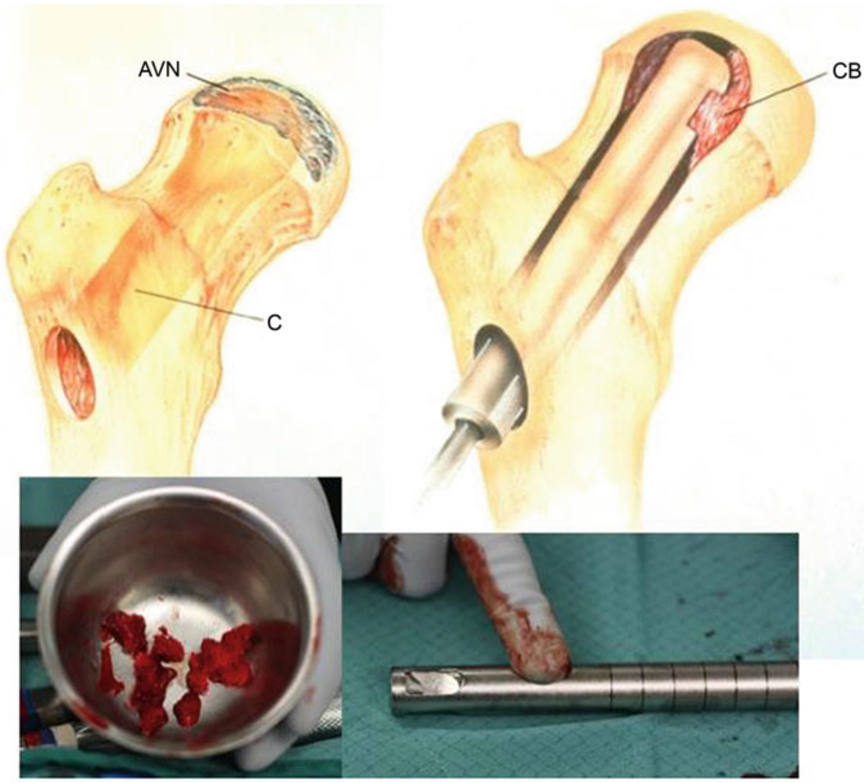

Fig. 4 Cancellous bone graft and *bullets* are placed within the core of the custom-made bone impactor, which disperses the graft within the cavity [34]

Cancellous bone is harvested from the greater trochanter through the lateral entry point using a large curet. This bone is kept separate from the bone graft obtained from the reamings. Long DeBakey forceps are used to place this bone graft into the cavity created within the femoral head. The Urbanipactor, a specialized impaction instrument designed for this procedure, is used to impact the bone graft. After placing the cancellous bone graft within the cavity, the Urbanipactor is fully inserted and its position is verified with fluoroscopy. The remaining cancellous bone graft and the bullets are placed within the core of the Urbanipactor and the specialized drill bit is used to disperse the graft within the cavity (Fig. 4). Graduated circumferential markings on the outside of the Urbanipactor are utilized to measure the depth of the core to determine the length of the fibular graft. The Urbanipactor is then removed and radiographic contrast medium is reinjected to confirm adequate bone grafting of the cavitary defect (Fig. 5).

The fibular graft is harvested at the same time as the hip preparation. The lower extremity is exsanguinated with an Esmarch bandage and a thigh tourniquet is inflated to 350 mmHg. A line is marked on the skin connecting the fibular head with the lateral malleolus. The proximal and distal 10 cm of fibula are marked and care is taken to preserve both the proximal and distal tibiofibular joints over this distance. Typically, this leaves approximately 15 cm of the central portion of the fibula available for harvest. The skin is incised over the sulcus between the lateral and posterior compartments of the leg with maintenance of full-thickness skin flaps. The fascia of the lateral compartment is incised longitudinally in line with the peroneal tendon with care to protect the superficial peroneal nerve. The peroneal muscles are

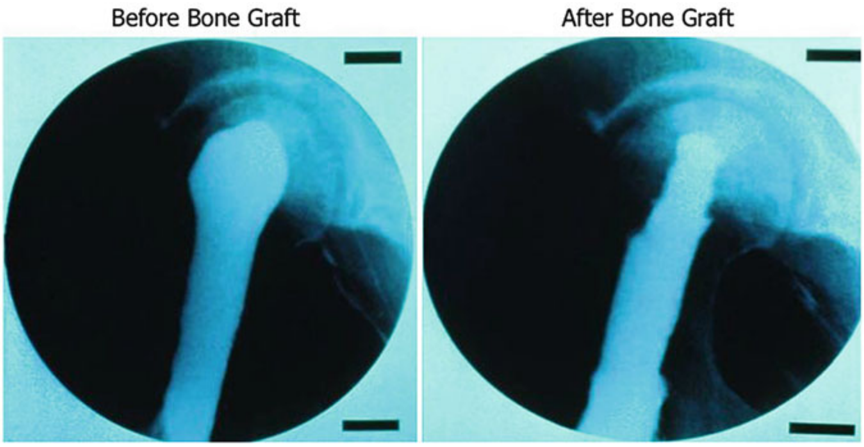

Fig. 5 Radiographic contrast medium is reinjected to confirm adequate bone grafting of the cavitary defect

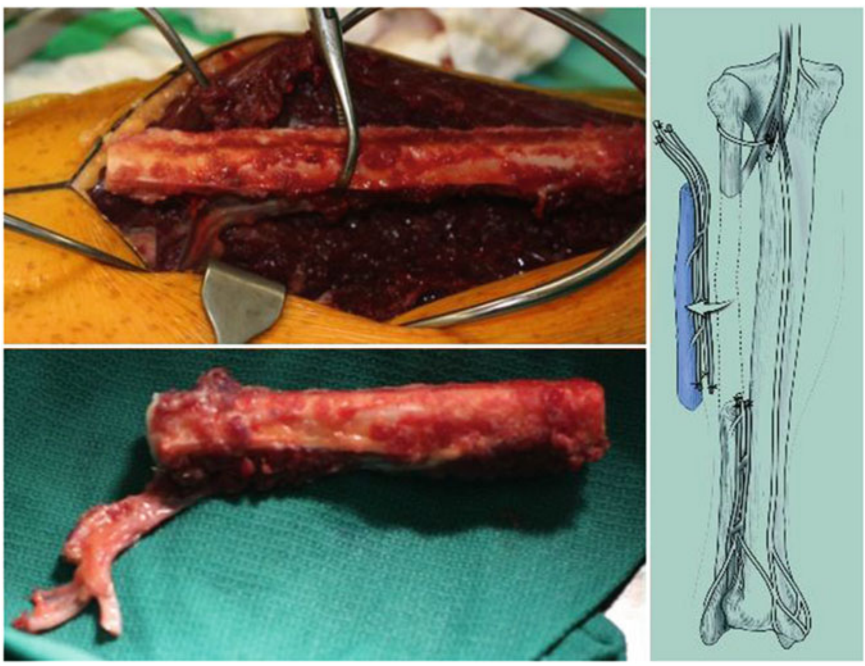

Fig. 6 Harvested fibular graft with peroneal vascular pedicle. During isolation, the neurovascular bundle is protected using a right-angle Beaver blade [34]

reflected anteriorly off the posterior intermuscular septum. The lateral aspect of the fibula is palpable deep to the peroneal muscles. Two large Gelpi retractors are placed to demonstrate this interval and maintain tension of the peroneal muscles as they are sharply reflected off of the fibula. A thin 1–2 mm layer or muscle is left with the fibula ("marble-izing") in order to preserve the periosteal blood supply to the fibula. Dissection is continued from posterior to anterior until the anterior intermuscular septum is encountered.

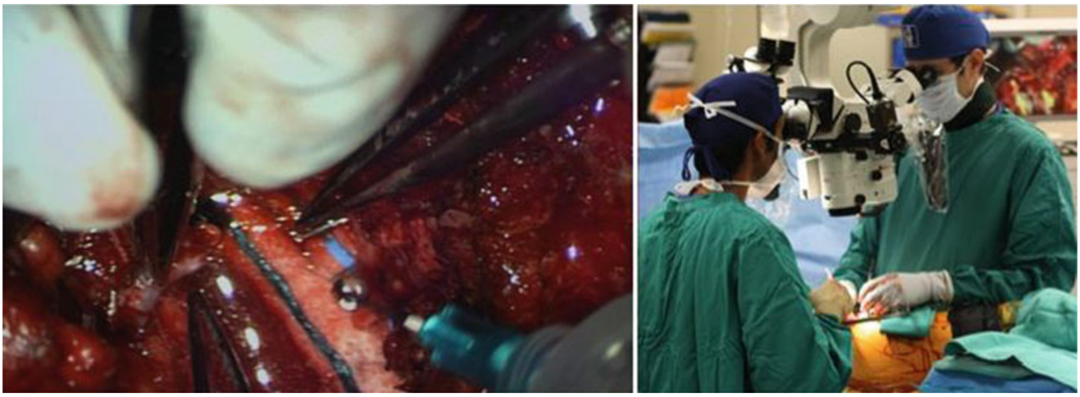

Fig. 7 The peroneal vessels and the ascending branch of the lateral femoral circumflex vessels are reliably present for anastomosis. Their orientation makes performing the microvascular anastomosis easiest from patient's posterior side

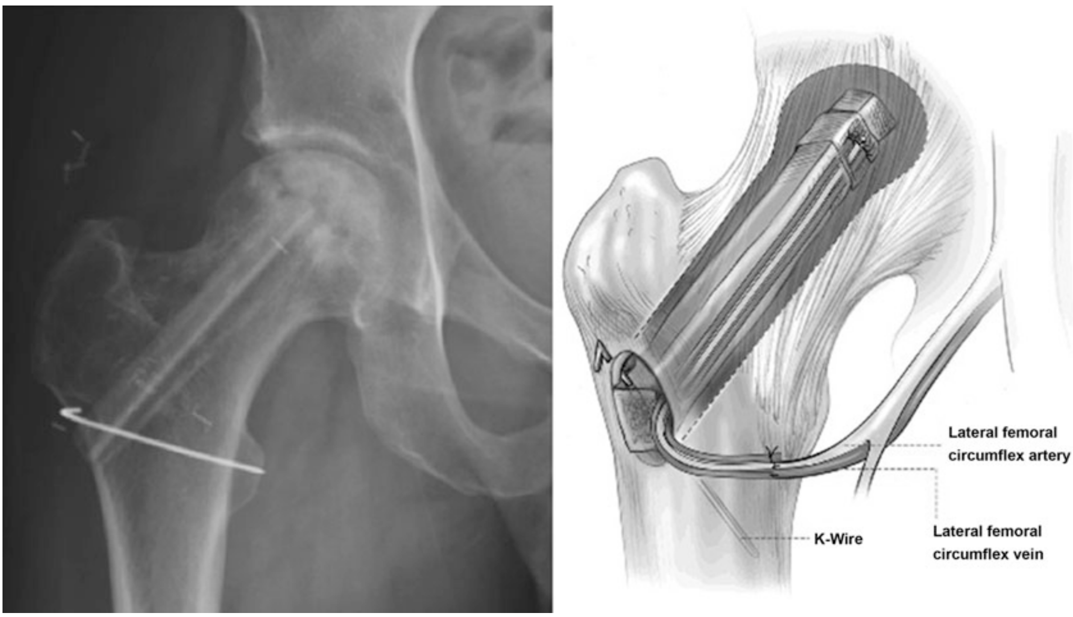

Fig. 8 A final schematic and 1-year anteroposterior postoperative radiograph [34]

A #15 scalpel is used to divide the anterior intermuscular septum approximately 1–2 mm off of the fibula. The anterior compartment musculature is then encountered and bluntly dissected off of the fibula with Metzenbaum scissors and DeBakey forceps. The interosseous membrane is then easily visualized as are the anterior tibial artery and the deep peroneal nerve. The neurovascular structures are protected while the interosseous membrane is released from the fibula with the use of a right-angle Beaver blade (Fig. 6).

The peroneal artery and the ascending branch of the lateral femoral circumflex artery are typically 1.5–2 mm in size and are reliably present. The concomitant veins are typically 2.5–4 mm in diameter. The vessels are oriented in an anteroposterior direction, which usually places the microsurgical field on a slight incline. For this reason, it is easiest for the surgeon performing the microvascular anastomosis to be standing on the patient's posterior side (Fig. 7). A final schematic and 1-year postoperative radiograph is seen in Fig. 8.

Summary

ONFH is a common cause of hip pain that can result in significant morbidity in a young adult patient demographic. Vascularized bone grafts have been shown to have better radiographical and clinical results compared to nonvascularized bone grafts. Of these options, free vascularized fibular graft is the treatment of choice for its structural and vascular support within the femoral head. Improved technique has led to complication rates, including donor-site morbidity, statistically similar to that of nonvascular fibular grafts. When used in young patients with precollapse ONFH, FVFG can greatly improve patient outcome, with lower rates of conversion to THA than other treatment modalities [29]. At 10-year follow-up, 75 % (49/65 hips) of FVFG were surviving. In those that were converted, the average conversion was at 8.3 years postoperatively [35]. As judged by Harris hip scores and SF-12 physical component summary scores, the function of THA and FVFG is similar; however, SF-12 mental component summary scores are higher in patients surviving FVFG [35]. Moreover, these patients also have a higher capacity to compete in athletic events, including impact sports, than their THA counterparts.

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