



Treatment of osteonecrosis of the femoral head with free vascularized fibular grafting: results of 7.6-year follow-up

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Objective: The aim of this study was to determine long-term follow-up results of patients with femoral head osteonecrosis who were treated with free vascularized fibular grafting (FVFG).

Methods: The results of 28 hips of 21 patients (16 male, 5 female) who underwent FVFG for treatment of osteonecrosis of the femoral head were retrospectively reviewed. Mean age of patients at time of surgery was 30.7 years (range: 15–53 years). Mean follow-up duration was 7.6 years (range: 5–9.2 years).

Results: During follow-up, 1 patient died because of leukemia, and 1 patient was lost. The remaining 26 hips of 19 patients were evaluated. According to Ficat classification, at time of surgery, 17 hips were grade II, and 9 hips were grade III, 3 hips underwent total hip arthroplasty. Postoperative Harris Hip Score (HHS) in grade II disease was excellent in 12 patients, good in 3 patients, and fair in 1 patient. In grade III disease, 1 patient was excellent, 5 patients were good, and 1 patient was fair. There was a significant increase in HHS scores from preoperatively to postoperatively (61 ± 9.7 vs 84 ± 17.8 , $p < 0.001$).

Conclusion: FVFG yields extremely good results, particularly in pre-collapse stages of the disease in young patients. The operation time does not markedly increase if the surgical team is knowledgeable of the procedure and the residual fibular defect of the donor site does not impair functions of daily living.

Keywords: Free vascularized fibular grafting; osteonecrosis of the femoral head.

Level of Evidence: Level IV, Therapeutic Study.

Osteonecrosis of the femoral head is a disabling disease that frequently affects adults aged 20–50 years old.^[1] Regardless of etiology, the disease often progresses to femoral head collapse and hip joint arthritis if left untreated.

^[2] Treatment options for the disease mainly depend upon the stage and age of the patient. According to many studies, the etiology of the disease is not a determinant for a particular modality of treatment.^[3,4] Older age, se-

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verely collapsed femoral head, and arthritic patients are accepted as candidates for arthroplasty. Treatment options before collapse of the femoral head are intended to achieve regeneration of the subchondral necrotic bone to prevent collapse and preserve sphericity of the femoral head. Core decompression with or without cancellous bone grafting, non-vascularized strut grafts, tantalum rods, electrode insertions, different type of osteotomies, and free or muscle pedicled viable bone grafts have been presented for this purpose.^[5-7] Among these techniques, core decompression with vascularized fibular grafting technique removes all necrotic bone and fills the remaining cavity with vascularized bone graft and spongyous graft that contains both osteoinductive and osteoconductive properties. While the procedure is not new, most of the reports in the literature are from a few pioneering clinics utilizing the free vascularized fibular grafting (FVFG) technique. In this study, we presented our experience in treatment with FVFG in pre- and post-collapse stages of the disease, reporting medium-term (mean: 7.6 years) follow-up results.

Patients and methods

In this study, 28 hips of 21 patients (16 male, 5 female) who underwent FVFG for treatment of osteonecrosis of the femoral head between 2005 and 2009 were retrospectively reviewed. Mean age of the patients at time of surgery was 30.7 years (range: 15–53 years). Seven patients who had bilateral hip involvement were operated on in 5- to 8-month intervals. The etiologies were collum femoris fracture in 2 hips (7.1%), steroid use in 18 hips (64.3%), and idiopathic in 8 hips (28.5%). The osteonecrosis of patients was diagnosed and staged according to Ficat classification by evaluation of plain roentgenogram and magnetic resonance imaging (MRI) findings. Mean follow-up duration of patients was 7.6 years (range: 5–9.2 years). Due to less than 10-year follow-up, conversion to total hip arthroplasty (THA) was accepted as failure of the procedure. Radiologic progress of treatment was followed with plain roentgenograms taken in 3-month intervals for the first year and once yearly thereafter. Radiographs of patients were evaluated for a trabecular bone appearance at the tip of the vascularized fibular graft, indicating new bone formation. Preservation of spherical femoral head and loss of subchondral cystic lesions and crescent sign were also accepted as part of the healing of the lesion. Loss of sphericity and decrease in the joint space indicated progression of the disease. Functional outcomes of survived hips were evaluated using the Harris Hip Score (HHS) system. Scores greater than 90 points were accepted as

excellent, scores between 80 and 89 points were good, scores between 70 and 79 points were fair, and scores less than 70 points were poor. The original technique described by Urbaniak and Aldridge et al. was used in all patients.^[8] All patients were operated under general anesthesia in the lateral decubitus position by the same surgical team, who were experienced in microsurgery. To reduce operation time, preparation of the hip and harvesting of fibular graft were performed concurrently with 2 teams (Figure 1). Preoperatively, the extent and spatial localization of the lesion was studied on magnetic resonance images. Intraoperative C-arm fluoroscope was used for anteroposterior and frog-leg lateral views (Figure 2). Prior to placement of the fibular graft, bone graft mixture composed of cancellous autografts harvested from the greater trochanter and 5–10 cc demineralized bone matrix (DBM) allograft (Osteoplast Activagen Injectable Paste OGS-ACI5, Bioteck S.p.A.,



Fig. 1. Completely scrubbed lower extremity; sterile tourniquet used. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]



Fig. 2. Debridement of osteonecrosis field and evaluation of cavity formed by contrast agent. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

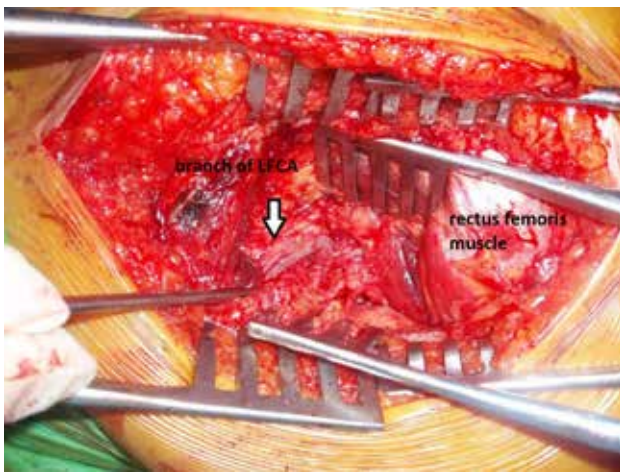


Fig. 3. View of lateral femoral circumflex artery in fatty tissue over the vastus intermedius muscle. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

Arcugnano, Italy) was used in all patients. The ascending branch of the lateral femoral circumflex artery and accompanying veins were used as recipient vessels (Figure 3).

Patients were treated with low-molecular weight heparin (20 mg enoxaparin subcutaneous/day) for 3 weeks postoperatively and intravenous antibiotic prophylaxis during hospitalization. All patients were kept in absolute bed rest for 5 days and mobilized with crutches without weight bearing on the affected side on the sixth day. Weight bearing was prohibited until the third month, after which partial weight bearing (20–25 kg) was initiated using a single Canadian-type crutch for the affected side for 45 days and gradually increased until full weight bearing was gained in the sixth month. Patients were informed about thumb flexion contractures and were encouraged to stretch to extension.

Categorical variables were presented as a percentage in a number of cases, with continuous variables as mean \pm standard deviation. Normal distribution was tested with skewness and kurtosis. A paired t-test was used to compare the changes in each patient's pre- and postoperative HHS scores. A p-value of <0.05 was considered significant for all tests. SPSS software (version 11.0, SPSS Inc., Chicago, IL, USA) was used.



Fig. 4. Roentgenogram of both hips of patient which were operated at stage II at sixth postoperative year. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]



Fig. 5. Roentgenogram of both hips of patient which were operated at stage III at seventh and eighth postoperative years. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

Results

During follow-up, 1 patient died because of leukemia, and 1 patient was lost. The remaining 26 hips of 19 patients were evaluated. According to Ficat classification, 17 hips were grade II, and 9 hips were grade III at time of surgery. At final follow-up, the disease had progressed and eventually had been treated with THA in 3 hips. No complications related to surgery—such as infection, deep venous thrombosis, femoral neck fracture, subtrochanteric fracture, peroneal nerve palsy, or severe flexion contracture of the great toe—were seen. Postoperative HHS scores in grade II disease were excellent in 12 patients, good in 3 patients, and fair in 1 patient. In grade III disease, 1 patient was excellent, 5 patients were good, and 1 patient was fair. There was a significant increase in HHS scores from preoperatively to postoperatively (61 ± 9.7 vs 84 ± 17.8 , $p < 0.001$). Radiographic trabecular bone formation at the tip of the fibular graft was detected in all patients with stage II and stage III disease. There was no sign of collapse or joint narrowing in patients who had HHS greater than 90 points (Figure 4). In 6 patients, the progress of collapse and joint narrowing was observed on plain X-rays (Figure 5). The degree of collapse and joint narrowing were directly correlated with HHS score.

Discussion

If the osteonecrotic lesion at the femoral head is large and involves the lateral pillar, the progress to collapse is inevitable; the time of progress to collapse is usually less than 3 years, according to the study of Ohzono, which observed the natural progress of 115 untreated hips.^[9] Many treatment modalities have been proposed for this disease. Osteotomies of the proximal femur, including the femoral neck and intertrochanteric region, have been recommended to replace the osteonecrotic lesion area under the stress of body weight with an unaffected viable healthy portion of the femoral head. Rotation, varus, flexion, extension and medializing-type osteotomies have been proposed for this purpose.^[2] The rotational osteotomy described by Sugioka is a very demanding procedure, with regards to both the planning required and the need to preserve the branches of the medial femoral circumflex artery during the procedure.^[5] Osteotomies also distort the anatomy and biomechanics of the hip joint. In a study of 115 osteotomies performed by Schneider et. al., all osteotomies were associated with a high incidence of complications and a low survival rate, and the benefits provided were only temporary.^[10] Core decompression alone may be accepted, similar to the first generation of intralesional surgical interventions. Arlet

and Ficat proposed the cause of osteonecrosis as the increase in intraosseous hypertension, intramedullary venous stasis, and edema due to distortion of blood supply to the femoral head.^[11] It was believed that the procedure would diminish intraosseous pressure and allow restoration of blood flow in the hypoxic femoral head. According to the results of a large series, core decompression may be effective in small lesions and early stages (stage I) of the disease, but without mechanical and osteogenetic support of bone grafts, the treatment will eventually fail in large lesions and advanced stages of the disease.^[6] According to a meta-analysis by Castro et al., further surgical interventions were necessary in 16%, 37%, and 71% of cases after core decompression of osteonecrosis at Steinberg stages I, II, and III, respectively.^[12] Combining core decompression with porous tantalum implants was proposed as structural support to the subchondral bone required for prevention of collapse, without leading to donor-site morbidity of the fibular graft. According to a meta-analysis of 6 randomized controlled trials including 256 cases, this treatment option is recommended for young patients with early-stage small lesions. Large lesions and advanced stages of the disease were associated with poor results.^[7] Vascularized iliac bone grafting was also combined with tantalum rods to achieve better results in large lesions and advanced stages of the disease.^[13] The FVFG technique described by Urbaniak and Aldridge contains unique steps for treatment of osteonecrosis of the femoral head. Adequate curettage of lesions shortens the healing period by removing all dead bone that would require additional time to replace with new bone formation if the lesion were to heal without treatment. Control scans of a contrast-filled cavity during the procedure ensure complete removal of necrotic bone.^[8] Filling the remaining cavity with cancellous autologous bone grafts with osteoinductive and osteoconductive properties provides the scaffold for new bone formation. We believe that grafting the cavity properly is important for new bone formation. In the present study, specially designed instruments were used for implantation of grafts into the cavity (Figure 6). DBM allograft was also used as a bone graft extender and mixed with autologous cancellous grafts in all lesions. Adding DBM allografts extends the amount of grafts to properly fill the cavity. In large lesions particularly, the cancellous graft harvested from a trochanteric region may be insufficient for the amount, and emptying the trochanteric region may cause iatrogenic fracture. Furthermore, it was shown that DBM allograft extenders enhanced the consolidation of spinal fusions.^[14] Therefore, high survival rates in large lesions may be related to the use of DBM allografts in our patients. Following cancellous graft placement, in-



Fig. 6. (a) Straight reamers in increasing size provide a tunnel size matching with fibula. Ball-tipped reamers (b) and reverse cutters (c) are used inside the lesion. Graft impactor composed of a drill with large helix angle inside the metal tube with distal openings. The grafts are first placed in the tube and then the drill is advanced through. (d) Clockwise spinning of the drill impacts the grafts inside the cavity. Removal of the tube leaves a space to inset the fibular graft. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

Introducing a strut graft is the theoretical approach to mechanically support an undermined subchondral cortex of the femoral head to prevent collapse. Nonvascularized strut cortical bone, autografts, and allografts have been used for this purpose.^[15] Besides mechanical support, the hypothesis governing the vascularization of a strut graft is to provide continuous osteoinductive support to impacted cancellous grafts for ossification. As described in the original technique, folding the periosteum at the tip of the fibula exposes the cambium layer, allowing it to benefit from the osteogenic effect (Figure 7).^[16] Supporting this theory, vascularized bone grafts yield better results than nonvascularized grafts.^[17,18] Several authors reported very consistent and satisfactory results with this procedure.^[19–21] Brunelli reported good-to-excellent results (average: 78%) with more than 5-year follow-up.^[19] Yoo et al. reported a 91% success rate in a follow-up interval of 3–10 years.^[20] Urbaniak et al. showed an 83% survival rate of the fibular graft in 646 procedures after follow-up of up to 17 years.^[21] They also reported the results of a prospective study of 103 consecutive hips treated with FVFG for symptomatic osteonecrosis of the femoral head.^[1] Age, etiology, size, location, and stage of the osteonecrotic lesion have all been proposed as factors influencing the outcome of vascularized fibular grafting for osteonecrosis of the femoral head. However, upon review of the literature, we found conflicting results regarding the effect of these factors on clinical outcomes. Higher survival rates in younger patients are a common finding of most reports.^[22,23] While some authors report the use of steroids as a poor prognostic factor, others associated idiopathic and alcohol-related osteonecrosis of the femoral head with worse prognoses.^[23,24] On the other hand, some reports present no relationship between outcomes and etiology.^[1] The extent of osteonecrotic lesions may be a determining factor for prognosis of FVFG treatment. According to Kerboul, the necrotic

angle, which shows the extent of the lesion, is calculated by adding the areas of osteonecrosis on the anteroposterior and frog lateral views.^[25] Lesions with an angle larger than 200° frequently experience poor results with femoral head-preserving procedures.^[23,26] Contrarily, according to a long-term (mean: 14.4 years) survival analysis of 65 hips, Eward et al. found no correlation between the size of lesion and conversion to THA. However, all patients in that study were at the pre-collapse stage.^[24] In the present study, patients were not classified according to lesion size.

Radiographic stage of the disease is another point of interest for predicting the prognosis of treatment. According to many reports, the probability of THA increases with advanced Steinberg stages, whereas it is 0–10% in stage II, 12–23% in stage III, 17–30% in stage IV, and 27–60% in stage V.^[20,27] Eward found no difference between Ficat stage I and stage II regarding conversion to THA.^[24] Marciniak also found no relationship

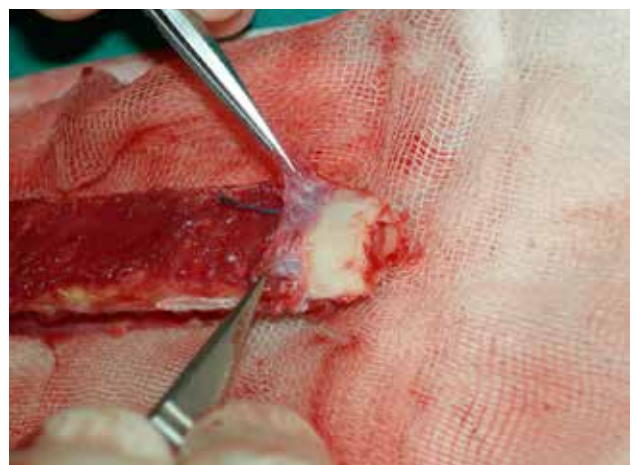


Fig. 7. Periosteum stripped and folded at the end of the fibula and view of the cambium layer. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

between initial radiographic stage and final clinical outcome or overall rate of graft survival.^[28] In the present series, 3 THAs (10.7%) were applied to 2 bilaterally involved patients, both hips of 1 patient at 5.5 years and 1 side of another patient at the sixth year. Both hips of the bilateral THA patient were stage III at time of primary surgery. The other patient's hip was stage II at time of surgery.

The patency of all microvascular anastomoses in the postoperative period is the subject of debate, particularly if no monitor-like skin paddle is present. To eliminate this doubt, some authors recommended to inset the fibular graft with a skin paddle.^[29] Although skin paddle shows the patency of anastomoses, it does not provide information regarding revascularization inside the femoral head. According to our experience, localization of the perforator of the skin paddle is not consistent and may lift and kink the pedicle of the graft when sutured to the skin. Bone scintigraphy using Technetium-99m methylene diphosphonate and single-photon emission computed tomography are effective methods in assessment of bone blood flow in the postoperative period. However, these 2 tests are usually performed within the first week following surgery (preferably within 72 hours) to rule out thrombus formation.^[30] According to Berggren et al., a positive bone scan a week or longer after surgery does not show patency of the vessels or bone viability, as a result of new bone formation at the surface of the graft due to creeping substitution. Thus, it has been recommended to perform bone scans at the week of surgery to avoid false-positive uptake.^[31,32] Dynamic contrast-enhanced MRI is another method used to evaluate the degree of bone marrow perfusion of the fibular graft following injection of gadolinium contrast medium.^[33] To the best of our knowledge, there are no studies in the existing literature using these tests for long-term follow-up.

In the present study, patients were followed with standing anteroposterior roentgenograms and evaluated for joint space narrowing and shape of the femoral head. We believe that these 2 criteria are sufficient to evaluate the radiologic outcomes of the FVFG technique. Furthermore, we believe that proper surgical technique is another important factor for success. Specifically, preventing the pedicle of the graft from being stranded inside the femoral tunnel and adjustment of pedicle length so as not to be kinked or stretched are the technical key points of the procedure.^[34] Vascularized fibular grafting provides the most consistently successful results of any joint-preserving method, including core decompression, conventional bone grafting, and osteotomy.^[35] We believe

that FVFG yields extremely good results, particularly in pre-collapse stages of the disease in young patients. In this study, 15 of 17 (88%) Ficat stage II hips achieved excellent or good results according to HHS. The outcomes of less-invasive techniques such as core decompression are unpredictable, and published results are not superior to FVFG.^[36] Vascularization of fibular strut graft does not result in a marked increase in operation time if the surgical team is familiar with the procedure. The residual fibular defect of the donor site does not impair the functions of daily living. As mentioned above, theoretically there are many factors present which may interfere with the expected results of FVFG, but we found that there was no clear evidence of contraindications for FVFG of avascular necrosis of the femoral head, except in cases of advanced stages of the disease and patients of advanced age.

Conflicts of Interest: No conflicts declared.

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