

Research Article

Clinical results of free vascularized fibula graft in the management of precollapse osteonecrosis of the femoral head: A retrospective clinical study

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ABSTRACT

Objective: This study aimed to evaluate clinical results, femoral head survival, and the need for total hip arthroplasty (THA) in patients with precollapse osteonecrosis of the femoral head (OFH) (Steinberg stage II and III) treated by free vascularized fibula graft (FVFG) application.**Methods:** We retrospectively reviewed 54 hips of 47 patients (39 males, eight females; mean age 36 ± 14 years) who underwent FVFG due to OFH, with at least two years of follow-up. The patient data, including Harris Hip Score (HHS), Visual Analogue Scale (VAS), and conversion to THA, were documented.**Results:** The right hip of 26 patients and the left hip of 28 patients were involved. Bilateral FVFG surgery was performed on seven patients due to bilateral OFH. The mean follow-up time was 5.5 (range 2-14) years. Survival of the femoral head was observed in 39 hips (72.2%), while the femoral head collapse was observed in 15 femoral heads (27.8%). The mean preoperative HHS increased from 46.5 (range = 12-85) to 86.5 (range = 33-100) postoperatively ($P < 0.001$). The mean preoperative VAS score improved from 8.2 (range = 2-10) to 1.3 (range = 0-10) postoperatively ($P < 0.001$). THA was performed on seven hips at a mean follow-up time of 1.8 years (range = 0.7-3.3). There was no significant difference in the collapse rate between unilateral or bilateral OFH ($P = 0.175$). A higher survival rate was observed in the Steinberg stage II femoral head patients compared to the stage III femoral head ($P = 0.021$).**Conclusion:** This study has shown that FVFG surgery can be a good option for managing patients with Steinberg stage II and III precollapse OFH to prevent femoral head collapse and joint function.**Level of Evidence:** Level IV, Therapeutic Study

Introduction

Osteonecrosis of the femoral head (OFH) is often observed in the third to fifth decade of life.¹ The natural course of untreated osteonecrosis is degenerative arthrosis, which causes progressive pain and loss of function in the hip.² The goals of treatment are to stop the progression of osteonecrosis, prevent chondral collapse, and preserve the sphericity of the femoral head. Thus, survival of the hip joint can be achieved or at least total hip arthroplasty (THA) can be delayed.^{1,3}

The first line of treatment for OFH is generally conservative treatment. However, conservative treatment sometimes fails to protect the femoral head even at the early stages of OFH.⁴ Surgeries that preserve the joint such as core decompression, non-vascularized autologous bone grafts, porous tantalum rod implantation, and osteotomies have been described; however, the results were described as unsatisfactory.^{1,2,5-7} Free vascularized fibular graft (FVFG) has shown good results in patients less than 50 years of age with symptomatic OFH without collapse of the femoral head.^{3,8} Free vascularized fibular graft is a biological reconstructive procedure that can enable the new

bone formation and provide nutrition to the cartilage in the subchondral area of the femoral head.⁹⁻¹³ A survival rate of 59%-100% of the grafted femoral head has been reported.¹⁴⁻¹⁷

In the current study, we aimed to evaluate the effect of FVFG surgery on femoral head survival and the need for THA for Steinberg stage II and III OFH patients.

Materials and Methods

Patient selection

The current study was conducted in accordance with the Helsinki Declaration of Ethics, following its ethical appraisal and approval by the local ethical committee (Decision No: 1/July 17, 2017). Patients who underwent FVFG surgery for OFH between January 2002 and December 2016 were retrospectively analyzed. Indications for FVFG surgery at our center include being age 50 years or younger, the presence of symptomatic OFH, Steinberg stage II-III OFH (no collapse of the femoral head), the presence of intact fibula in a well-perfused leg, and acceptance to not load the leg for 4-6 months. Contraindications are body mass index higher than 30 and a totally restricted hip

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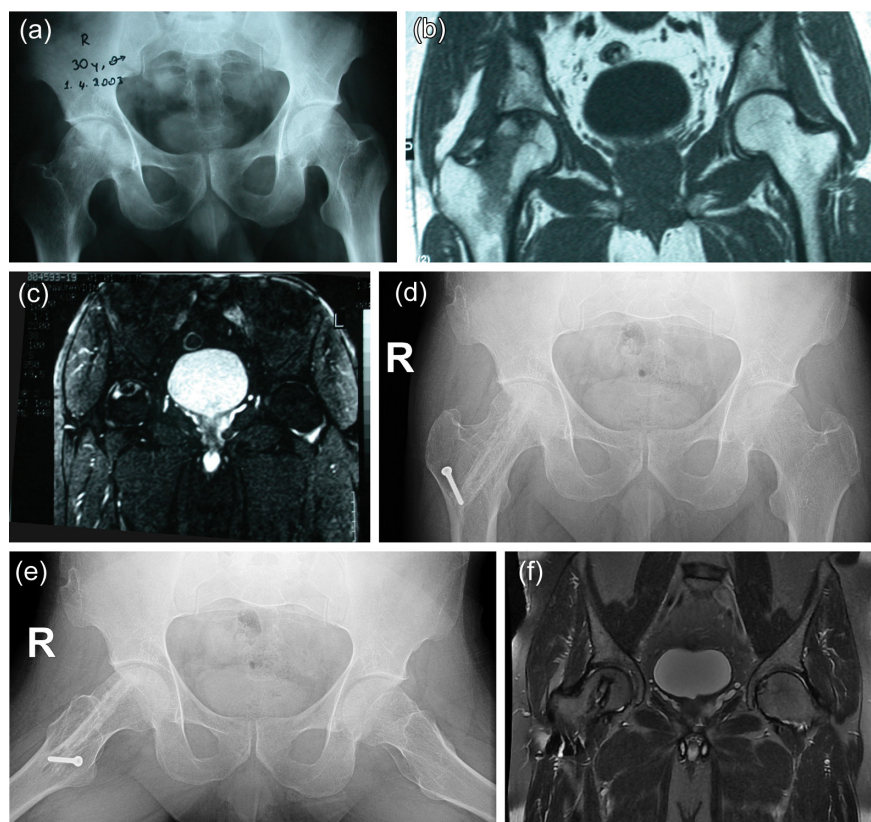


Figure 1. a-f. Preoperative anteroposterior radiographs (a) and T1 (b), T2 (c) coronal magnetic resonance image of a patient with Steinberg stage II osteonecrosis of femoral head. Anteroposterior (d) and lateral (e) radiographs and T2 (f) coronal magnetic resonance image of the patient 14 years after free vascularized fibular graft surgery.

internal rotation. Inclusion criteria for the current study were the presence of a minimum 2-year postoperative follow-up and the availability of complete preoperative radiological evaluation, including hip anterior-posterior and lateral (frog leg position) x-ray and magnetic resonance imaging (MRI).

Surgical technique

All patients were operated on by 2 teams using the surgical technique described by Urbaniak with minor modifications.¹⁴ One of the modifications was that the surgery was performed in the supine position. A sterile tourniquet was tied to the thigh and inflated. Fibula harvesting was carried out by a lateral approach with 3.5× loupe magnification. To maintain ankle stability, the distal 7 cm of the fibula was preserved and 15 cm of the fibula was harvested. Thus, a minimum of 5 cm of pedicle length was obtained. The periosteum over the fibula was protected. After the fibula was harvested, a drain was placed and subcutaneous and cutaneous layers were repaired. The facial layers

were left open in order to prevent the development of compartment syndrome.

The hip was approached via a 20 cm long, curved anterolateral (apex anterior) skin incision. The tensor fasciae latae was incised in a curvilinear fashion (convex posterior) to allow access to the greater trochanter. The vastus intermedius and lateralis were reflected from its origin at the trochanter major; the rectus femoris was retracted anteriorly to access the lateral circumflex vessels and these vessels were dissected. A 3 mm guidewire was placed with C-arm fluoroscopy and gradual reaming from 10 mm to 22 mm was carried out on the basis of the diameter of the fibula. The subchondral necrotic bone area was debrided to form a mushroom head cavity with a mace-shaped reamer. Bone autografts obtained by reaming of the femoral head and curetting from the trochanter major were placed in the cavity. No grafts were taken from the subtrochanteric area and trochanter minor in order to prevent the development of subtrochanteric fractures.¹² The fibula was placed with its pedicle remaining at the anterior and superior position. A 4.5 mm cannulated screw was placed (K-wires were used for 12 hips and 3.5 mm cortical screws for 2 hips in the initial surgeries performed) for fixation (Figure 1, 2). Different from Urbaniak's technique in which the K-wire was placed through 2 cortices of the fibula, we fixed only 1 cortex of the fibula to trochanter minor with a cannulated screw. The peroneal artery with its accompanying 2 vein anastomoses were attached to the ascending branch of the lateral femoral circumflex artery and its two veins under a microscope.

Postoperative care

Flexor hallucis longus stretching exercises were initiated immediately after surgery. Hip, knee, and ankle range of motion and

HIGHLIGHTS

- Surgeries such as core decompression, non-vascularized autologous bone grafts, porous tantalum rod implantation, and osteotomies generally do not provide satisfactory results in treatment of osteonecrosis of the femoral head (OFH). Free vascularized fibular graft (FVFG) has shown good results in selected patients. This method enables new bone formation and provides nutrition to the cartilage in the subchondral area.
- This study aimed to evaluate the effect of FVFG surgery on femoral head survival and the need for THA for Steinberg stage II and III OFH patients.
- In a mean follow up of 5.5 years, the survival of the femoral head was observed in 72.2% of the patients. There were significant improvement in both Harris Hip Scores and pain scores postoperatively. A higher survival rate was observed in the Steinberg stage II femoral head patients compared to the stage III. The results suggest that FVFG surgery should be considered as a possible option for managing patients with Steinberg stage II and III precollapse OFH.

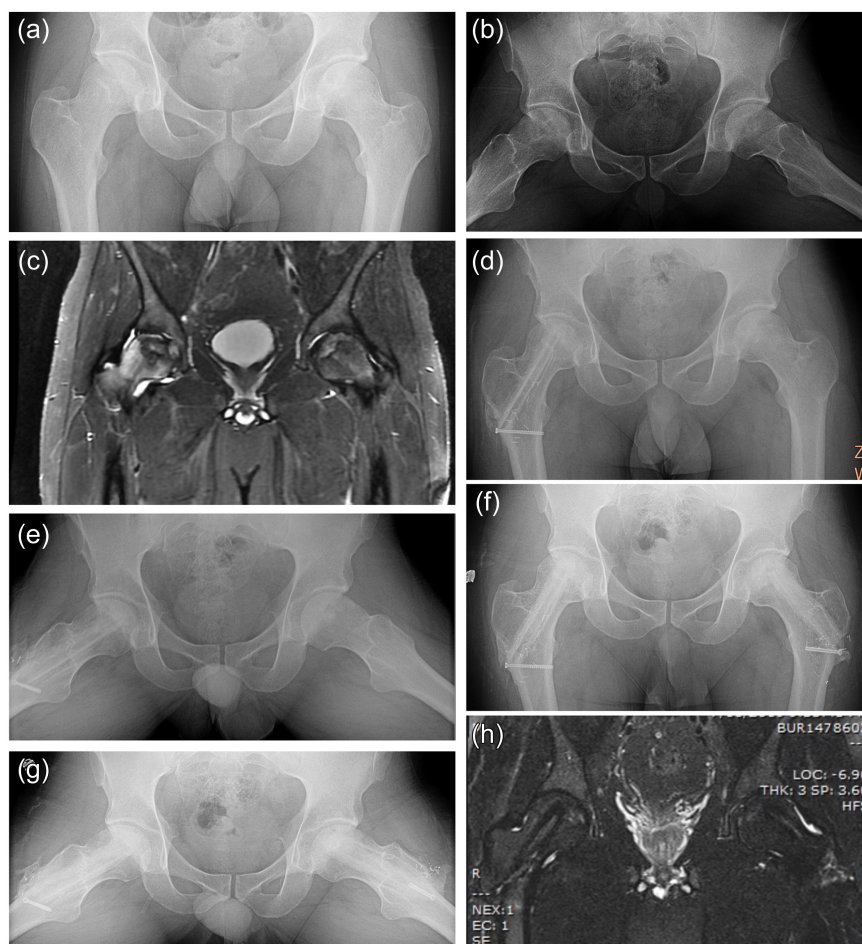


Figure 2. a-h. Anteroposterior (a) and lateral (b) radiographs and T2 (c) coronal magnetic resonance image of a bilateral osteonecrosis of femoral head, right hip Steinberg stage II and left hip Steinberg stage III. Patient had free vascularized fibular graft (FVFG) surgery initially from right hip and 6 months later from left hip. Anteroposterior (d) and lateral (e) radiographs of the patient after right hip FVFG surgery. Anteroposterior (f) and lateral (g) radiographs and T2 (h) coronal magnetic resonance image of the patient after 3 years from FVFG surgeries.

strengthening exercises were initiated at postoperative second day. Partial weight was given at the third month and full weight-bearing was allowed at 4-6 months, depending on the case. Clinical and radiological follow-up was performed at the end of 6 weeks, 3, 6, 12, 18, and 24 months. Subsequent follow-ups were carried out once a year.

Clinical and radiological evaluation

Demographic data, medical history, history of alcoholism, and corticosteroid usage of the patients were noted. Preoperative and postoperative range of motions of both hips, Visual Analogue Scale (VAS) score, and Harris Hip Score (HHS) were noted. Pre- and post-surgery radiological evaluations, x-ray (anterior-posterior and frog leg position), and MRI images were analyzed to determine Steinberg¹⁸ and Ficat-Arlet¹ classifications and percentage of OFH. Advancement to Steinberg stage IV and above was defined as collapse. Patients who underwent a conversion to THA after FVFG surgery were noted. Forty-seven patients (39 males and 8 females) met the inclusion criteria of the study and 54 hips (26 right, 28 left and 7 bilateral) from these patients were evaluated.

At the first examination and postoperative follow-up, the contralateral hip was evaluated for complaints with a plain radiograph and MRI. If OFH was detected at the contralateral hip, patients were followed-up for development of complaints and progression in radiological stage. Free vascularized fibula graft was not

carried out in cases with Steinberg stage I osteonecrosis. Surgical treatment was decided according to the stage of OFH for the contralateral hip.

Statistical analyses

Mean, standard deviation, and ratio values were used for descriptive statistics of the data. The distribution of variables was determined using the Kolmogorov-Smirnov test. Independent sample *t*-tests and chi-square tests were used to analyze quantitative independent data. Fisher's test was used when the conditions appropriate for the chi-square test were not met. A *P*-value of <.05 was considered significant for all tests. Statistical Package for the Social Sciences software (version 11.0, SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

Results

Free vascularized fibula graft was applied to 26 right hips and 28 left hips. Bilateral FVFG surgery was performed on 7 patients. The mean age of the patients was 36 years (range: 22-50 years). There was a history of corticosteroid use in 30 cases, alcoholism in 3 cases, and femoral neck fracture surgery in 1 case. Thirteen of the cases were idiopathic. According to Steinberg classification, out of 54 hips, 39 (72.2%) were of stage II and 15 (27.8%) were of stage III OFH (Table 1). According to Ficat-Arlet classification, 39 (72.2%) hips were of stage IIa, while 15 hips were of (27.8%) stage IIb. According

Table 1. Results of steinberg stages II and III hips managed with free vascularized fibular graft, incidence of collapse, and switch to total hip arthroplasty at follow-up

Steinberg Stage	Number of Hips (%)	Collapse of the Hips	Conversion to THA
Stage IIA	11 (20.4)	1	1
Stage IIB	25 (46.3)	3	2
Stage IIC	3 (5.6)	2	1
Stage IIIA	4 (7.4)	2	-
Stage IIIB	10 (18.5)	6	2
Stage IIIC	1 (1.8)	1	1

THA, total hip arthroplasty.

to the percentage of OFH, 15% and below percentage of the femoral head was affected in 15 hips (27.8%), 15%-30% was affected in 35 hips (64.8%), and 30% and above was affected in 4 hips (7.4%). There were no signs of osteonecrosis in the contralateral hip of 8 patients. Osteonecrosis of femoral head was detected in both hips in 39 patients; of these, 10 had collapsed due to OFH at the contralateral hip at the time of first admission.

The mean follow-up period of 54 hips after FVFG was 5.5 years (2-14 years). The femoral head was preserved in 39 (72.2%) out of the 54 hips. Collapse was observed in the remaining 15 femoral heads (27.8%) over a mean period of 2.1 years (range: 0.5-7.5 years). Collapse was observed in 6 (15.4%) of the 39 Steinberg stage II and 9 (60%) of the 15 Steinberg stage III femoral heads. There was no significant difference in the rate of collapse between unilateral and bilateral OFH ($P = .175$) (Table 2). A higher rate of survival was observed with Steinberg stage II compared to stage III ($P = .021$) (Table 3).

Total hip arthroplasty was performed on 7 hips of 6 patients, one of whom had bilateral hip replacement at a mean of 1.8 years after FVFG surgery (range: 0.7-3.3 years). Of the 7 patients who underwent THA, 4 had Steinberg stage II and 3 had stage III OFH (Table 1).

The mean preoperative HHS was improved from 46.5 (range: 12-85) to 86.5 (range: 33-100) postoperatively ($P < .001$). The mean preoperative VAS score was improved from 8.2 (range: 2-10) to 1.3 (range: 0-10) postoperatively ($P < .001$) (Table 4).

Table 2. Statistical evaluation of unilateral/bilateral free vascularized fibular graft and rate of collapse

Uni/Bilateral	Without Collapse	Collapse of the Hips	<i>P</i>
Unilateral	31	9	0.0175
Bilateral	8	6	
Total	39	15	

Fischer's exact test.

Table 3. Statistical evaluation of the relationship between Steinberg stage and rate of collapse

Stage	Without Collapse	Collapse of the Hips	<i>P</i>
Stage II	33	6	0.021
Stage III	6	9	
Total	39	15	

Fischer's exact test.

Table 4. Comparison of the pre- and postoperative harris hip score and visual analog scale scores

	Surviving FVFG (n=39)	Collapse of Hips (n=8)	THA (n=7)	<i>P</i>
Preoperative Harris Hip Score	50.7 (24-81)	33.7 (18-61)	30.8 (15-48)	< 0.001
Postoperative Harris Hip Score	88.1 (70-100)	63.5 (33-78)	91.5 (70-99)	
Preoperative VAS	7.5 (4-10)	6.7 (2-10)	9.1 (8-10)	< 0.001
Postoperative VAS	0.87 (0-3)	4.8 (2-9)	0.57 (0-2)	

FVFG, free vascularized fibular graft; THA, total hip arthroplasty; VAS, Visual Analog Scale.

Complications

Sensory loss was observed in 3 patients in the fibular nerve sensory area, which improved in 6-9 months without any intervention. Deep vein thrombosis occurred in 1 patient who was treated with medical therapy. Flexion contracture of the toe was seen in 2 patients that resolved in 2 months with passive stretching. Subtrochanteric fracture occurred in 1 patient on the 10th postoperative day during patient transport. This patient underwent open reduction and internal fixation. During the surgery of this patient, a thrombosis was found in the peroneal artery and vein between the fragments in the fracture line. Plate osteosynthesis was performed without removing the fibula graft and union was achieved.

Discussion

The most important finding of this study was the 72.2% survival rate after 5.5 years of follow-up in patients undergoing FVFG surgery. Progressive collapse occurred in 15 femoral heads (27.8%) over a mean period of 2.1 years. Total hip arthroplasty was performed in 7 hips (1 bilateral case) after an average of 1.8 years post-FVFG surgery. We observed that FVFG significantly prevented or delayed collapse in Steinberg stages II and III femoral heads. Femoral head survival after FVFG was found to be significantly higher in Steinberg stage II femoral heads compared to Steinberg stage III femoral heads. In this study, the Steinberg classification was used because it includes MRI findings and the size of the osteonecrotic lesion, as well as chondral and subchondral involvement. It also provides information about the location of the lesion.⁶

Comparing conservative treatment with core decompression, Stulberg et al⁵ showed that core decompression was more successful in Ficat I, II, and III OFH patients. In the same study, femoral head survival in the conservative treatment group was determined as 20% in Ficat I, 0% in Ficat II, and 10% in Ficat III. On the other hand, Fairbank et al¹⁹ reported that collapse after core decompression in OFH patients was seen after 3.3 years in Ficat III patients and 4.8 years in Ficat stage II hips, whereas Ficat stage I showed collapse after an average of 9.8 years. Additionally, Steinberg et al⁶ performed total hip replacement after an average of 29 months on 113 (36%) out of 312 hips that underwent core decompression and cancellous grafts with a follow-up period of at least 2 years. Therefore, we performed core decompression only for Steinberg stage I (Ficat stage 1) patients.

Another treatment method is non-vascularized grafting of femoral head before or just after collapse where the femoral head joint cartilage is relatively intact.^{1,20} Yildiz et al²⁰ obtained good/excellent results in 14 of 21 hips that were treated with the lightbulb technique. Total hip arthroplasty was performed on 5 of the 7 hips with moderate/poor results. These authors recommended the application of the light bulb technique in the early stages of OFH. Kim et al²¹ achieved good results in 70% of a vascularized fibula graft group and 35% of a non-vascularized fibula graft group in a cohort of 23 cases who were followed-up for a mean duration of 4 years. In the same study, 3 hips (13%) in the vascularized group and 5 hips (22%)

in the non-vascularized group were converted to THA. Additionally, Plakseychuk et al²² reported the 7-year survival rate of stage I and II OFH cases as 30% with non-vascularized fibula graft and 86% with vascularized fibula graft. In the current study, we observed a femoral head survival rate of 72.2% after FVFG.

Stem cell therapies have been conducted for the past 20 years for the treatment of OFH. Hernigou et al²³ reported that in a cohort of 189 OFH cases, THA was needed in 9 out of 145 hips that were operated with autologous bone marrow grafting before collapse, whereas THA was necessary in 25 of the 44 hips that were operated after collapse.²³ There are other studies suggesting that FVFG may be suitable for early-stage patients with no collapse when compared to core decompression.²⁴ However, currently there are no studies comparing stem cell therapy with FVFG surgery. In addition, we think that the femoral head in OFH should be supported with a structural and biologically active graft.

If applied before subchondral collapse, FVFG has been reported to have advantages over THA, such as increased range of motion of the healed femoral head and the viability of the femoral head over the patient's lifetime.³ In a report of 103 hips treated with FVFG, Urbaniak et al¹⁴ reported a 91% survival in Marcus stage II and 77% in stage III femoral heads after a 5-year follow-up. Yoo et al¹⁵ achieved excellent results with a survival rate of 89% with at least 10 years of follow-up of 124 hips with Ficat stages II and III osteonecrosis.¹⁵ Asymmetric bone healing, non-union between the necrotic bone, and the graft under the cartilage in the load-bearing area have been reported as some of the reasons for failure, enabling the requirement for early THA.¹¹ Even if full graft union after FVFG surgery is maintained, it has been reported that arthrosis still may develop and requirement for THA may arise after 8-10 years.^{3,9,11} Soucacos et al⁹ reported that of 184 hips studied, 25 had stage progression within the first 5 years and 44 within 6-10 years. Eward et al³ reported that after FVFG in 65 precollapsed hips, 49 hips (75%) survived for 10 years and 39 (60%) survived for 14.9 years (range: 10.5-26.1 years), with the mean duration of hip protection of 8.3 years (range: 7 months to 17 years) before conversion to THA. In the current study, the best results were obtained in Steinberg stage II cases without subchondral collapse. Collapse occurred in 15 femoral heads after an average of 2.1 years. Total hip arthroplasty was performed in 7 hips that were symptomatic due to collapse at the end of 1.8 years of follow-up.

The probability of developing symptomatic avascular necrosis in the contralateral hip without signs of osteonecrosis is reported to be 7.8%. At admission, if abnormal MRI findings in the unaffected contralateral hip are consistent with stage I osteonecrosis, the probability of disease progression is 28%. If the unaffected contralateral hip has radiographic findings consistent with stages II and III osteonecrosis, there is an 82% possibility of radiographic or clinical progression.¹² The presence of bilateral involvement negatively affects the results.^{8,15,25} A FVFG graft can be used when symptoms appear or when radiographic findings progress.¹² For 18 bilateral OFH patients, Zeng et al²⁶ applied core decompression or non-vascularized fibular graft to one of the hips that was at an early stage OFH and THA to the other hip that was at an advanced stage OFH. These authors stated that removal of the necrotic bone and giving the body weight to the side that underwent THA yielded good results. In the same study, collapse was observed in both femoral heads in 2 cases and in 1 femoral head in 2 cases. Total hip arthroplasty was performed on 3 hips, one of which was bilateral. In the current study, we observed different

levels of OFH in the contralateral hip of 39 patients (%82). Bilateral FVFG surgery was performed on 7 patients. Additionally, bilateral or unilateral application of FVFG surgery was not found to have an effect on collapse.

After FVFG, loss of sensation in the feet and toe flexion contracture has been reported as the most frequent donor site complications.²⁷ In 3 of the cases in the current study, the complaint of sensory loss due to fibular nerve traction was resolved during follow-up. The frequency of subtrochanteric femur fracture, which is attributed to excessive debridement of the trochanteric region to obtain the cancellous graft, was less than 1%.^{12,28} We observed femur fracture in one of our patients and treated it with open reduction internal fixation with plate fixation.

The main limitation of the current study is its retrospective design. Secondly, in our study, mean follow-up duration was less than 10 years, which is relatively short. A prospective study with a longer follow-up period would be more beneficial. Additionally, the post-operative follow-up times were heterogeneous and included both short and mid-term results. Finally, the current study included both Steinberg stage II and stage III patients, which may have affected the results. Application of FVFG surgery in Steinberg stage I cases may increase the rate of survival of the femoral head.

In conclusion, FVFG surgery was found to be a good option for Steinberg Stage II and III OFH patients for preventing femoral head collapse and preserving hip functions.

Ethics Committee Approval: Ethics committee approval was obtained from the Local Ethical Committee of Metin Sabancı Baltalımanı Bone Diseases Training and Research Hospital (Decision No: 1/July 17, 2017).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Author Contributions: Concept - K.Ö., A.Ş.; Design - K.Ö., A.Ş.; Supervision - O.O.; Materials - O.O.; Data Collection and/or Processing - M.B., Y.A., S.A.; Analysis and/or Interpretation - S.A.; Writing - K.Ö.

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