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CLINICAL RESEARCH

Will a Vascularized Greater Trochanter Graft Preserve the Necrotic Femoral Head?

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Abstract

Background Various head-preserving procedures have been used for young patients with osteonecrosis of the femoral head (ONFH) to avert the need for THA. However, none of these techniques are accepted universally because of the technical difficulties, complications, or mixed results that often are difficult to reproduce.

Questions/Purposes We describe a technique using vascularized bone grafting for treating ONFH in Stages II–IV (Ficat and Arlet) disease, describe our indications, and report the survival of this technique and the functional scores.

Methods We retrospectively reviewed 191 patients (195 hips) who underwent vascularized greater trochanter grafting for osteonecrosis of the femoral head (Ficat and Arlet Stages II–IV) from 1995 to 2006. The mean age of the patients was 44 years (range, 19–59 years). The minimum followup was 2 years (mean, 8 years; range, 2–11 years).

Results Twenty patients (23 hips) had conversion surgery to THA. The mean Harris hip scores for the patients who did not have conversion surgery to THA improved from 53 to 88 points. Kaplan-Meier survival analysis showed no difference in the 11-year survival rate between patients with Stage II and Stage III disease (THA as an end point). However, the survival rate was lower for patients with Stage IV disease compared with patients with Stages II and III disease. The survival rate for patients in the steroid group was lower compared with the rates for patients in the idiopathic, alcoholic, trauma, and hyperlipidemia groups. At last followup, the stage of necrosis remained unchanged in 118 hips.

Conclusions We believe vascularized greater trochanter bone grafting is appropriate for young selected patients with mild to moderate collapse of the femoral head.

Level of evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent was obtained.
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Introduction

ONFH generally affects patients in the third to fifth decades of life, and half the patients requiring treatment for this problem are younger than 40 years [8, 23, 37, 41, 42]. High failure rates (2.3%–24.1% at a minimum of 4 years' followup) have been reported in this group of patients who underwent THA [4, 7–9, 21]. Therefore, we believe the initial goal of treating ONFH should be to preserve the femoral head [18, 29, 44, 52].

There are various treatment methods for the head-preserving approach, including core decompression [3, 13, 43, 47, 48], various types of osteotomies [16, 20, 30, 39, 43], and nonvascularized [38, 40, 45] and vascularized bone

grafting [1, 5, 16, 22, 24, 33, 50]. However, none of these techniques are accepted universally because there is no compelling evidence that any of these procedures arrest the disease process. Especially when collapse of subchondral bone occurs, patients have few treatment choices other than joint arthroplasty [14, 34]. Therefore, exploring methods that restore femoral head sphericity or revascularization of the necrotic lesion is justified to prevent collapse. Although transfer of a free vascularized fibula has been used widely with survival rates of 64.5% to 96% at midterm (3.9–7 years) [1, 24, 50, 51], there are inherent concerns with this technique: it is a technically demanding procedure that requires microsurgical experience; removal of a vascularized portion of the fibula may lead to motor weakness and sensory deficits in the foot, and incidence of pain in the foot has been reported to increase with time [51].

A vascularized bone graft from the greater trochanter with decreased donor-site morbidity might be an attractive alternative. The efficacy of vascularized procedures also might be enhanced by nonvascularized bone graft, which could provide structural support to the subchondral bone and articular cartilage to minimize the risk of collapse during repair [35, 36, 41]. During the past 11 years, we have developed such a technique to repair and reconstruct the femoral head.

We describe our techniques and the indications for their use. We questioned whether (1) this technique would preserve the joint as reflected in Harris hip scores and radiographic progression; (2) factors such as age, etiology, and stage would influence long-term survivorship; and (3) blood flow to the bone graft would be confirmed by digital subtraction angiography (DSA).

Patients and Methods

We retrospectively reviewed all 220 patients (224 hips) with Ficat and Arlet [15] Stages II to IV ONFH who received a vascularized greater trochanter bone graft pedicled with the transverse branch of the lateral femoral circumflex vessel (LFCV) by the same surgeon (DWZ) between February 1, 1995, and December 30, 2006. Seventeen patients (17 hips) were lost to followup, and 12 patients (12 hips) died after a mean of 8 years postoperatively attributable to causes unrelated to the surgery. We therefore evaluated 191 patients (195 hips) clinically and radiographically at a minimum followup of 2 years (mean, 8 years; range, 2–11 years) (Table 1). The diagnosis of osteonecrosis was made on the basis of the clinical history, AP radiographs, MRI, and CT. The radiographic appearance, according to the criteria of Ficat and Arlet [15], was Stage II for 81 hips, Stage III for 93 hips, and Stage IV for 21 hips.

Table 1. Demographic data

Variable	Value
Average patient age (years)	44 (range, 19–59)
Age (number of hips)	
< 45 years	121 (62.1%)
≥ 45 years	74 (37.9%)
Gender (male:female)	104:87
Etiology (number of hips)	
Steroid-induced	73 (37.4%)
Alcoholic	74 (37.9%)
Posttraumatic	33 (16.9%)
Idiopathic	14 (7.2%)
Hyperlipidemia	1 (0.5%)
Ficat and Arlet stage (number of hips)	
II	81 (41.5%)
III	93 (47.7%)
IV	21 (10.8%)

The patients were placed in the supine position with the ilium elevated to 60°. A skin incision was made 4 cm distal to the iliac crest down to the tip of greater trochanter and then extended vertically down along the anterior margin of the trochanter. Because the transverse and ascending branches of the LFCVs beneath the rectus femoris muscle enter the tensor fasciae lata laterally, we took care when splitting the rectus femoris and gluteus muscles to expose the hip capsule. Once we identified the transverse branch of the LFCVs, we isolated the vessels to the point where they entered the greater trochanter. Based on the location of the transverse branch of the LFCVs, we harvested an approximately 3-cm long and 2-cm wide vascularized bone graft from the anterolateral greater trochanter; a maximum of the anterior 30% of the gluteus medius was detached. A volume of 1 cm^3 to 2 cm^3 of cancellous bone was harvested from the greater trochanter area. The capsule was incised in a T shape to expose the femoral head and neck. The hip then was dislocated partially with traction and the acetabular and femoral head cartilage were inspected thoroughly to ascertain if there were any full-thickness defects or areas of detached cartilage. We made an approximately 2-cm $\times$ 2-cm bone window at the femoral head-neck junction using an osteotome. A 6-mm–diameter abrasive drill was used to remove the dead bone and curette a cavity in the femoral head until bleeding was observed. We used specially designed impaction instruments of different sizes (Fig. 1) to elevate the collapsed segment of the femoral head. The excavated area then was supported by impacting the autologous bone graft with the instruments and the previously harvested vascularized bone graft. During insertion, we took care not to squeeze the soft tissue cuff containing the vessels to the bone graft. The graft transposition was

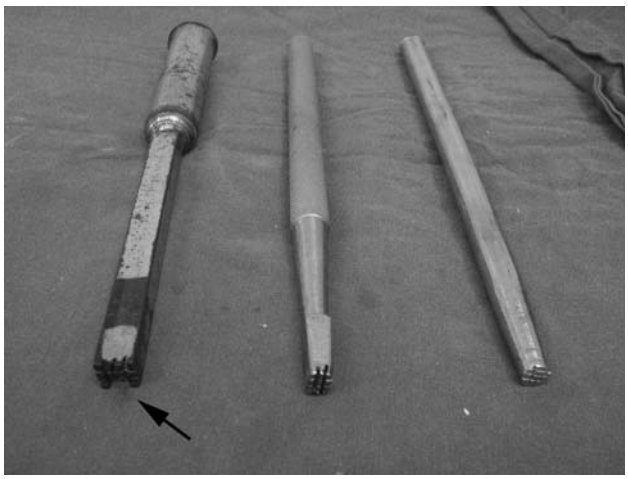

Fig. 1 Devices for bone graft impaction are shown. The indented surface (arrow) will decrease the potential compression on the vascular pedicle.

completed by exerting some pressure with impaction instruments to achieve solid impaction and by slightly moving the hip to confirm the bone block would not be displaced. Finally, the wound was closed in layers. We required bleeding from the cancellous surface of the greater trochanter graft at the conclusion of the surgery as an indication of vessel patency. This procedure took 55 to 100 minutes to complete (mean, 65 minutes).

All patients followed a strict rehabilitation and training program. Quadriceps muscles and passive ROM exercises were started the day after surgery. All patients had bed rest with light skin traction for 6 weeks to prevent additional collapse and decrease compression between the acetabulum and femoral head. During the second 6 weeks, touch weightbearing with two crutches was allowed; in the third 6 weeks, patients were instructed to practice weightbearing with a maximum of 30% body weight; full weightbearing was permitted by 6 months postoperatively.

The patients were seen at 3 months after discharge, 6 months, and yearly thereafter. All hips were assessed using a modification of the Harris hip score (HHS) [17]. We recorded the number of conversions to THA during followup resulting from progression of osteonecrosis or severe pain. Patients were assessed annually clinically by one of us (DWZ).

At each visit, we obtained AP and frog-leg lateral-view radiographs, and the size and location of the necrotic lesion and evidence of the progression of collapse and/or development of osteoarthritis were evaluated. The preoperative radiographic evaluation was performed independently by two of us (DWZ, BJW) to determine the staging using the system of Ficat and Arlet [15]. Two other authors (LY, XDC) also determined the sizes of lesions using the technique of Kerboul et al. [26]. Adding the sums of the angle of the lesions on AP and lateral radiographs provides the necrotic angle. For cases in which the lesion was not demarcated clearly on radiographs, we used CT and MRI to evaluate the lesion size with measurement of the index of necrotic extent [28]. We categorized final postoperative radiographs in two classes: (1) the stage remained unchanged; the femoral contour remained; trabecular formation was found in the transferred bone block; and (2) the stage progressed with progression observed based on stage. Because of the possible introduction of error in radiographic evaluation, including trabecular formation, crescent sign, joint space, head collapse, and necrotic angle made by different observers, we assessed interobserver error by comparing the radiographic results made by the two different surgeons. The level of agreement was tested using kappa statistics. The agreement between DWZ and BJW was an exact match in 95% of cases. The agreement of Kerboul angle between LY and XDC matched in 92% of cases.

Preoperative and postoperative DSA of the hips was done until 2006 to evaluate hemodynamic changes in the necrotic femoral head and blood supply in the bone flap; thus, we had preoperative and postoperative DSAs for 46 patients.

We compared the preoperative HHS with the last postoperative scores using a paired t test. We determined differences in postoperative HHS among hips of different etiologies using one-way ANOVA and Fisher's exact test. All analyses were done using SPSS® (Version 13.0; SPSS Inc, Chicago, IL). Survival rates among radiographic, etiology, and age groups were calculated using the Kaplan-Meier method [25]. For these analyses we used two end points: (1) conversion to THA and (2) conversion to THA or an HHS score less than 80 points.

Results

The HHS for the 172 patients not undergoing conversion surgery to THA improved from a mean of 53 points (range, 32–78 points) to 88 points (range, 70–94 points). The HHS for the 23 patients who had conversion surgery to THA improved from a mean of 49 points (range, 45–56 points) to 95 points (range, 83–98 points). The mean HHS improved from 54 to 94 points for hips with Stage II disease, from 51 to 88 points for hips with Stage III disease, and from 45 to 70 points for hips with Stage IV disease. Radiographic progression occurred in 17 of the 81 hips with Stage II disease (21%), but none had undergone conversion surgery to THA at last followup. Forty of 93 hips with Stage III disease (43%) had signs of osteoarthrosis, and three of these 40 had undergone conversion surgery to THA (Fig. 2). Progressive collapse of the

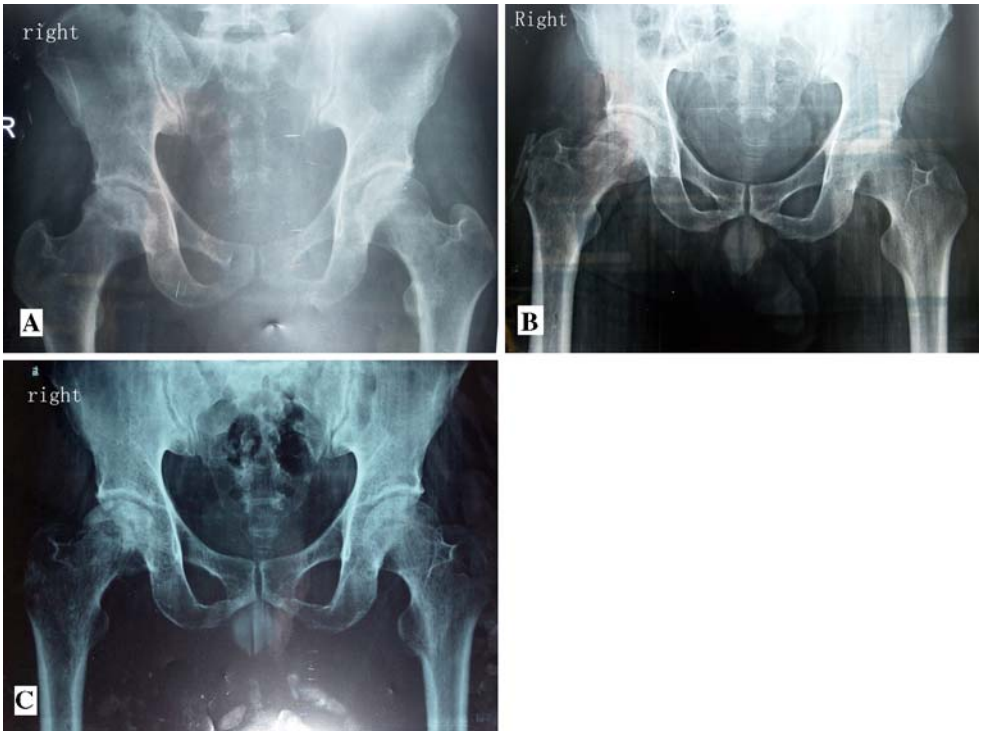

Fig. 2A–C (**A**) An AP radiograph of a patient with Stage III osteonecrosis of the femoral head with collapse (right hip, Stage III) is shown. (**B**) A radiograph obtained immediately postoperative shows the sphericity of the femoral head restored. (**C**) Eight years postoperatively, the joint space remains preserved, the trochanter bone block is well incorporated, and the sphericity of the femoral head is well maintained with no progressive collapse.

femoral head, acetabular changes, or loss of the apparent joint space occurred in 20 of the 21 hips with Stage IV disease (95%), and 20 had undergone conversion surgery to THA. At latest followup, 64 hips were classified as having Stage II disease, 69 were classified as having Stage III disease, and 39 were classified as having Stage IV disease. The preoperative angle of necrosis as defined by Kerboul et al. [26] was similar in the patients without hip failure (231°; range, 155°–270°) and with failure (253°; 185°–285°).

Survivorship analysis showed the probability of conversion to THA within 5 years after this procedure was 0% for hips with Stage II disease, 3% for hips with Stage III disease, and 95% for hips with Stage IV disease. There was no difference ($p = 0.12$) in the 11-year survival rates between hips with Stages II and III disease. However, survival was lower ($p < 0.001$) in hips with Stage IV disease compared with hips with Stages II and III disease. The mean survival time of the hips in patients younger than 45 years was greater ($p < 0.001$) than in patients 45 years or older. Survival analysis (with conversion to THA or HHS less than 80 points as the end point) for each of the stages of different etiologies showed higher ($p < 0.001$) survival in the alcohol abuse than in the steroid group ($p < 0.001$) and higher survival ($p = 0.004$) in the trauma than in the steroid group. The 124-month survival rates for these groups were 100% (hyperlipidemia), 83% (trauma), 76% (alcoholic), 60% (idiopathic), and 28% (steroid), (Fig. 3; Table 2).

Postoperative DSAs in the 46 patients (46 hips) showed perfusion of the transferred graft and femoral head in 42 patients (91%). Of the four hips that had no flow, three had no radiographic progression and postoperative HHS greater than 80 points. One hip had radiographic progression and a postoperative HHS less than 80 points, but none had a THA (Fig. 4).

There were no intraoperative complications. Eight patients (eight hips) had a unilateral deep thrombosis of the femoral vein after surgery, six had secondary wound healing, and 21 had chronic donor pain of the greater trochanter area.

Discussion

The rationale for vascularized bone grafting is that it allows decompression, provides structural support, and restores vascular supply. There have been multiple reports regarding the use of vascularized fibular and iliac grafts [6, 16, 27, 32, 45]. Vascularized bone graft perfused by branches

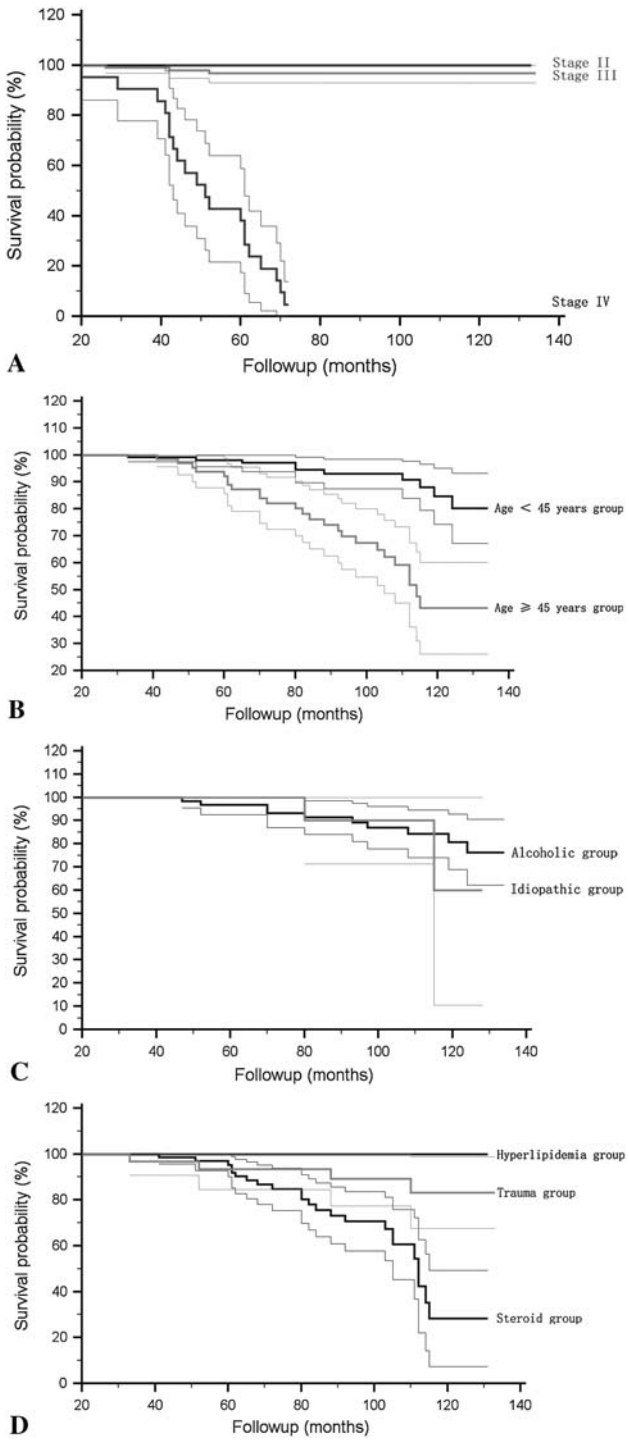

Fig. 3A–D (**A**) Kaplan-Meier survivorship curves at 11 years, with conversion to THA as the end point, show the probability of conversion to a THA on the basis of Ficat and Arlet stage at the time of the operation. (**B**) Kaplan-Meier survivorship curves at 11 years, with conversion to THA or Harris hip score less than 80 points as the end point, show the survival rate of hips with Ficat and Arlet Stages II to IV osteonecrosis in patients younger than 45 years and 45 years or older versus observation time. Kaplan-Meier survivorship curves at 11 years, with conversion to THA or Harris hip score less than 80 points as the end point, show the survival rates of hips from patients in the (**C**) alcoholic and idiopathic groups and (**D**) hyperlipidemia, trauma, and steroid groups versus observation time. The thin lines indicate 95% confidence intervals.

of the LFCVs as an alternative method for osteonecrosis has been used in China for approximately two decades with satisfactory joint-preserving rates [31]. We therefore asked whether (1) this technique would preserve the joint as reflected in HHS and radiographic progression; (2) factors such as age, etiology, and stage would influence long-term survivorship; and (3) blood flow to bone grafting would be confirmed by DSA.

We note several limitations of our study. First, we did not include a control group or comparative cohort. Therefore, we cannot ensure the surgical technique reduces the development of osteoarthritis compared with the natural history or whether this vascularized procedure produces results better than those of merely packing cancellous bone using the same surgical technique. Second, because the diagnosis and surgery were performed before MRI was available, we did not use quantitative volumetric measurements to determine lesion size by MRI or digital image analysis, which has been proven more accurate than angular measurement. Third, to minimize the risk of collapse of the head before the graft incorporated, our patients had a long period of bed rest with light skin traction. We recognize this approach might not be practical in many situations and we cannot ensure the bed rest actually reduced the risk of collapse as we had no limited or non-weightbearing walking control group. However, none of the hips had progressive collapse and/or displacement of the graft 6 weeks postoperatively.

Despite continuous improvement in the design and techniques of hip arthroplasty, it is not likely prosthetic replacements will endure the entire life expectancy in young patients partly owing to the patient's activity level and partly to the cumulative effects of load or wear. Alternatively, joint-preserving surgery theoretically restores sphericity, supports the femoral head, and prevents additional collapse before progression to degenerative changes. Various techniques of nonvascularized bone grafting and vascularized fibular and iliac grafts had been used for femoral head preservation. In the 1960s and 1970s, nonvascularized bone grafting techniques were used commonly. Joint-preserving rates have ranged from 17% to 90% after surgery at short- to midterm followup (2–8 years) with lower joint-preserving rates at longer followups [2, 11, 46, 48]. The trapdoor technique reportedly has better joint-preserving rates (81%–83%) [37, 38, 41]. In the late 1970s and early 1980s, vascularized bone grafting was introduced, most notably by Urbaniak and Harvey [50]. In their technique, a vascularized autogenous fibula graft is harvested and sustained through a

Table 2. Summary of outcomes

Variable	Radiographic progression (number of hips)	Conversion to THA (number of hips)	HHS > 80 (number of hips)	DSA performed/blood flow confirmed (number of hips)
Ficat and Arlet stage				
II	17 (21.0%)	0 (0%)	78 (96.3%)	26/25 (96.2%)
III	40 (43.0%)	3 (3.2%)	78 (83.9%)	19/17 (89.5%)
IV	20 (87.0%)	20 (95.2%)	0 (0%)	1/0 (0%)
p value*	< 0.001	< 0.001	0.006	0.052
Age				
< 45 years	31 (25.6%)	8 (6.6%)	108 (89.3%)	30/28 (93.3%)
≥ 45 years	46 (62.2%)	15 (20.3%)	48 (64.9%)	16/14 (87.5%)
p value*	< 0.001	0.057	< 0.001	0.434
Etiology				
Steroid-induced	35 (48.0%)	13 (17.8%)	50 (68.5%)	19/18 (94.7%)
Alcoholic	29 (39.2%)	9 (12.2%)	64 (86.5%)	21/20 (95.2%)
Posttraumatic	8 (24.2%)	1 (3.0%)	29 (87.9%)	4/2 (50%)
Idiopathic	5 (35.7%)	0 (0%)	12 (85.7%)	2/2 (100%)
Hyperlipidemia	0 (0%)	0 (0%)	1 (100%)	0
p value*	0.139	0.089	0.044	0.069

* Fisher's exact test was used to test significance among the groups; HHS = Harris hip score; DSA = digital subtraction angiography.

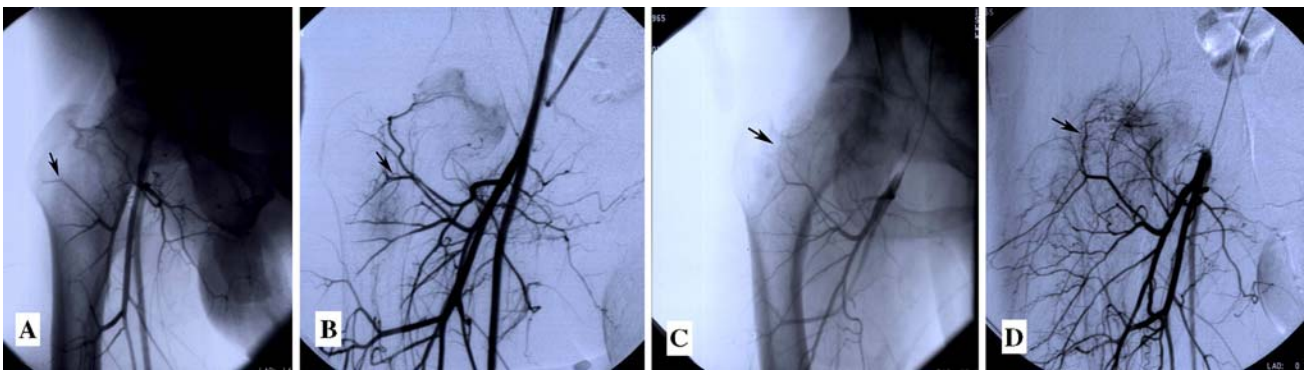

Fig. 4A–D (**A**) Preoperative digital subtraction angiography (DSA) of a hip with Stage II disease shows the transverse branch of the lateral femoral circumflex vessel (LFCV; arrow) running along the surface of the greater trochanter with its small branches entering the greater trochanter to carry the blood supply from the center to the distal end. (**B**) DSA shows the insufficient blood supply of the femoral head. The transverse branch of the LFCV is clear and in good condition (arrow). (**C**) Postoperative DSA shows the greater trochanter bone block pedicled with the transverse branch of the LFCV (arrow) transferred to the neck-head junction of the necrotic femoral head. (**D**) DSA shows the femoral head was revascularized by the transverse branch of the LFCV and the vessels were not squeezed (arrow).

vascularized pedicle anastomosed at the hip. After a mean of 7 years, 31 of 103 hips (30%) underwent conversion surgery to THA. However, this procedure requires experience in microvascular techniques, and complications from harvesting the fibular graft should be considered [33, 52]. In the study of Eisenschenk et al. [12], clinical results according to the HHS were good or excellent in 86.6% of the patients, and the radiographic appearance remained stable in 56.1% of the patients according to the ARCO classification system after an average of 5 years (Table 3).

Despite the limitations of our study, the subjective clinical outcomes of patients without conversion surgery to THA (23 hips) was encouraging at a mean of 8 years postoperatively. Of all 195 hips, 78 of 81 hips with precollapse osteonecrosis and 78 of 114 hips with postcollapse osteonecrosis had HHSs greater than 80 points at last followup. Although 38 hips had radiographic deterioration, their postoperative HHS was greater than 80 points; the potential for additional clinical deterioration of the hips of these patients should be recognized. The femoral head

Table 3. Comparison of results

Study	Year	Procedure type	Number of hips	Followup (years)*	HHS > 80 (%)	Survival (%)
Rosenwasser et al. [41]	1994	W	15	12 (10–15)	NS	87
Mont et al. [36]	2003	W	21	4 (3–4.7)	86	85.7
Urbaniak et al. [49]	1995	VF	103	7 (4.5–12.2)	81	70
Urbaniak and Harvey [50]	1998	VF	646	(1–17)	NS	83
Hasegawa et al. [18]	1997	VI	31	8 (5–11)	61.3	96.8
Eisenschenk et al. [12]	2001	VI	82	5 (0.5–10)	86.6	91.1
Current study	2009	NVG	195	8 (2–11)	80	88.2

* Values are expressed as means with ranges in parentheses; HHS = Harris hip score; W = window in the femoral neck, nonvascularized bone graft; VF = vascularized fibular graft; VI = vascularized iliac graft; NVG = nonvascularized bone graft combined with vascularized greater trochanter bone graft; NS = not stated.

preservation rate was 88%, which was comparable to that reported by Rosenwasser et al. [41]. They used cancellous bone packing through a window opened in the femoral-neck junction in 13 patients with a mean followup of 12 years (range, 10–15 years), and two (13%) hips underwent conversion surgery to THA. Drescher et al. [10] reported treatment of ONFH with intertrochanteric flexion osteotomy. The 5-year head-preserving rate was 90%. They suggested the procedure was effective for hips with a necrotic angle less than 200°. We suspect, if a portion of necrotic bone remains and is not revascularized, this part will collapse and the procedure may fail, thus underscoring the importance of thoroughly débriding the necrotic lesion and carefully protecting the vascular pedicle. This may explain why in our study, the Kerboul necrotic angle did not influence the results of the treatment.

Urbaniak and Harvey [50] reported no difference in survival rate according to etiology. Berend et al. [1] and Yoo et al. [52] also suggested etiology was not a factor in the success of vascularized bone grafting in their groups. However, we found a lower survival rate for the steroid group compared with the idiopathic, alcoholic, and trauma groups. Steroid-associated diseases such as systemic lupus erythematosus and inflammatory bowel disease often require ongoing management with corticosteroids. An explanation for this difference in outcome may be that some of the patients in our steroid-induced group were chronic users (ie, continued to use steroids after vascularized bone grafting). Furthermore, it is difficult to separate the effects on bone of corticosteroids from those of the underlying diseases. We speculate these are the reasons the steroid-induced group had a relative low survival rate. Long-term followup also revealed a better outcome in patients younger than 45 years, which was in accordance with a previous study in which vascularized bone grafting was used [50].

Selective DSA investigations of the arteries of the femoral head, reported by Heuck et al. [19], detected vascular alterations in 97% of cases in the traumatic ONFH group (31 hips) and 33% of cases in the nontraumatic (34 hips) and control groups (35 hips). In our study, the postoperative DSA of 46 patients (46 hips) showed perfusion of the transferred grafts and femoral head in 42 patients (42 hips [91%]). Two of the four no-flow hips were in the posttraumatic group.

Our data suggest the indications for patients undergoing this vascularized bone-grafting technique are Ficat and Arlet Stages II to III disease, not receiving continuous corticosteroid treatment, or age younger than 45 years. This technique is relatively simple, requires no special surgical technique, and eliminates donor-site morbidity.

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