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Iliac Graft Vascularization for Femoral Head Osteonecrosis

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We determined the long-term clinical and radiologic outcomes of patients with osteonecrosis treated with a combination of autologous cancellous bone impaction and pedicled iliac bone block transfer perfused by the ascending branch of the lateral femoral circumflex artery. We retrospectively reviewed 197 patients (226 hips) operated on from 1985–1998 who had a mean age of 38 years (range, 19–65 years) and an average followup of 12.5 years (range, 6–19 years). Fourteen hips (13 patients) (6%) had conversion to a total hip arthroplasty because of progressive collapse, severe pain, or both. Of the remaining 212 reconstructions, 195 hips were clinically successful (92%), and 76% were radiographically successful. The postoperative Harris hip score substantially improved in the patients without hip failure. Successful results were achieved in 96% of the patients with Ficat and Arlet Stage II osteonecrosis, 90% with Stage III osteonecrosis, and 57% with Stage IV osteonecrosis. Good results were obtained in 94% of the patients younger than 45 years. Our data suggest the method is useful for treating osteonecrosis of the femoral head only in active symptomatic patients with good integrity of hip cartilage and Stages II or III osteonecrosis.

Level of Evidence: Therapeutic study, Level IV (case series). See the Guidelines for Authors for a complete description of levels of evidence.

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Osteonecrosis, a relatively common disease in younger, active patients seemingly has a wide range of etiologies and a poorly understood pathogenesis.[16,20–22,30,36,38,40,51] Despite improvements in hip arthroplasty design and techniques, it is unlikely that prosthetic replacements will endure for life.[5,8,25,41,44] Alternatively, various head-preserving procedures have been used to avert or delay the need for a total hip arthroplasty (THA). The procedures include core decompression,[4,11,33,37] various types of osteotomies,[17,26,42,47] different methods of nonvascularized bone grafting procedures,[6,31,32,37] vascularized bone grafting including the fibula,[1,23,48] and iliac crest bone block[13,18,29] transfer for revascularization of necrotic bone aimed at directly influencing the pathologic event.[10] To date, no single treatment method has been shown to reliably prevent progression.

Symptomatic osteonecrosis of the femoral head typically progresses with collapse and incongruity of the joint.[13] Therefore, it is worthwhile investigating methods that restore sphericity of the femoral head and revascularize the necrotic bone to minimize the risk of collapse. Although the vascularized fibula has been widely used, a vascularized bone graft from the iliac crest with decreased donor site morbidity might be an attractive alternative.[10,15,18,27] The efficacy of vascularized procedures also might be enhanced by nonvascularized bone grafting, which could provide structural support to the subchondral bone and articular cartilage to prevent collapse during the repair mechanism.[31,32,37] The iliac crest bone block perfused by the ascending branch of the lateral femoral circumflex artery was selected in this study because it can be obtained and implanted through the same single incision without dissecting or exposing the inguinal ligament.[10,54]

We have used this technique since 1985. It involves total excision of the necrotic bone through a window made at the femoral head-neck junction. The necrotic bone then is replaced by impacted autologous cancellous bone associated with a vascularized iliac bone block transfer to improve the mechanical properties of the femoral dome and to revascularize the femoral head.

We wanted to determine whether this procedure provides durable, improved function and whether the improved function differs by stage or size of necrotic areas or age of patients.

MATERIALS AND METHODS

We retrospectively reviewed 243 hips in 211 consecutive patients with segmental femoral head necrosis treated from 1985–1998. All patients had a vascularized iliac bone graft combined with an autologous cancellous bone impaction and were operated on by one surgeon (DWZ). Of these, 197 patients (226 hips) were evaluated clinically and radiographically at an average followup of 12.5 years (range, 6–19 years) postoperatively. Five patients died after a mean of 7 years postoperatively from causes unrelated to the index hip surgery, three patients moved abroad, and six patients were lost to followup. In these 14 patients, the last note in the records indicated an asymptomatic hip. The end of followup was determined by the time of conversion to total hip arthroplasty (14 hips in 13 patients) or the long-term followup. The average age of the 197 patients (126 men and 71 women) was 38 years (range, 19–65 years) at the time of surgery. The diagnosis of osteonecrosis was based on clinical history; anteroposterior (AP) and frog-leg lateral radiographs, and computed tomography (CT) (27 patients at the later stage of the study).

The etiology of the osteonecrosis was steroid use in 53 patients (65 hips), alcohol abuse in 14 patients (23 hips), posttraumatic in 58 patients (59 hips), idiopathic in 51 patients (57 hips), hyperlipidemia in nine patients (one patient had bilateral involvement), postinfectious in 11 patients, pregnancy-related in one patient, and other in 21 patients (22 hips). Each hip is discussed separately, independently of whether a patient had bilateral surgeries. Of the 226 (197 patients) clinically symptomatic hips, 91 hips had Ficat and Arlet Stage II osteonecrosis, 93 hips had Stage III osteonecrosis, and 42 hips had Stage IV osteonecrosis. Patients did not have this procedure if they had Ficat Stage I osteonecrosis or a cartilage defect.

The patient was placed in the supine position with the buttock and ilium elevated 30°. An approximately 12-cm double curve incision was made 4 cm proximal to the anterosuperior iliac spine for an anterolateral approach to the hip (Fig 1). The interval between the sartorius muscle and tensor fasciae lata muscle was located and split in the direction of the skin incision. Care was taken when splitting the rectus femoris muscle and gluteus medius muscle before exposing the hip capsule because the ascending branch of the lateral femoral circumflex vessels beneath the rectus femoris muscle enters the tensor fasciae lata laterally and ascends directly to the anterosuperior iliac crest along the tensor fasciae lata muscle. The vessels were isolated and the respective vascular branches were ligated to the vessels and iliac crest transplant. Based on the location of the ascending branch of the lateral femoral circumflex vessels, a vascularized bone block was harvested from the anterosuperior iliac crest that was approximately 5-cm long and 3-cm wide, keeping the inner plate of ilium in situ with a vascular pedicle of as much as 12 cm. The pedicled bone block was saved in saline-wrapped gauze for later use and an adequate amount of autologous cancellous iliac bone harvested from the area. The capsule was incised in a T shape to expose the femoral head and neck. The hip was dislocated and the femoral head cartilage and acetabular cartilage were inspected thoroughly to ascertain if there were any full-thickness defects or areas of detached cartilage. With defects greater than 0.5 cm, we used an alternative microsurgical method to reconstruct the femoral head.[53] A bone window approximately 2 cm × 3 cm was made at the femoral head-neck junction using an osteotome. A high-speed abrasive drill was used to remove the dead bone and curette a cavity in the femoral head until bleeding could be seen. Specially designed impaction instruments of different sizes were used to impact autologous cancellous bone graft from the iliac crest to the excavated region of the femoral head. An attempt was made intraoperatively to elevate the collapsed segment of the femoral head with impaction instruments. This area then was supported with the autologous bone graft and the previously harvested vascularized bone graft (Fig 2). During insertion, care was taken not to squeeze the soft tissue cuff containing the vessels to the bone block. The transplant was completed by exerting some pressure with impaction instruments

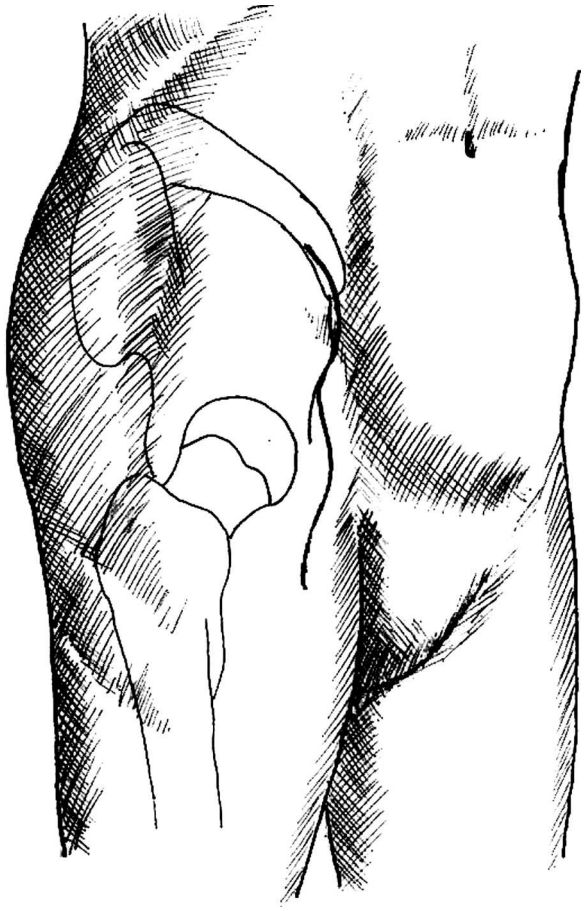

Fig 1. A drawing shows a 12-cm double curve incision made anterolaterally starting 4 cm proximal to the anterosuperior iliac spine.

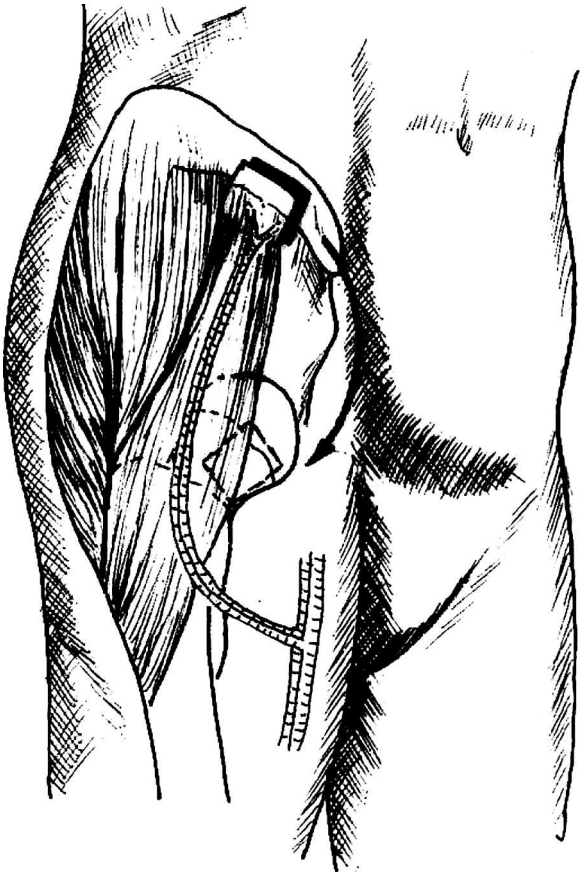

Fig 2. A drawing shows a vascularized bone block based on the ascending branch of the lateral femoral circumflex vessels, which is harvested from the anterosuperior iliac crest. It is approximately 5 cm long and 3 cm wide with a vascular pedicle long enough for transfer. An attempt is made to elevate the collapsed segment of the femoral head intraoperatively with impaction instruments through a 2 cm × 3 cm bone window made at the femoral head-neck junction. This area then is supported with the autologous bone graft and the previously harvested vascularized bone graft.

to achieve solid impaction, and the wound was closed by layers. Bleeding from the cancellous surface of the iliac graft at the conclusion of the surgery was used as an indication of vessel patency. This procedure took less than 120 minutes to complete (mean, 90 minutes; range, 55–120 minutes).

Bed rest with traction was used for 45 days postoperatively to prevent additional collapse and decrease the compression between acetabulum and femoral head. After the graft incorporated with the host area, progressive weightbearing was permitted. Full weightbearing was achieved by 6 months. Followup radiographic and clinical examinations were done at 3 months, 6 months, and yearly thereafter.

The clinical results were evaluated by one examiner (WMW), independent of the operating surgeon, using the Harris hip scoring system.[14] A clinical success was defined as a score $\geq$ 80 points. A clinical failure was defined as a Harris hip score less than 70 points or conversion to THA. A physical examination with calculation of the Harris hip score was done before the iliac bone grafting, before conversion to THA, and at the most recent followup.

The preoperative radiographs were assessed by two of the authors (DWZ, WMW) to determine the stage based on the system of Ficat and Arlet.[12] The diagnosis and surgery involved was done before availability of MRI, therefore, recent classifications like ARCO-system or Steinberg Classification could not be used. The necrotic area of the femoral head was determined by conventional AP and frog-leg lateral radiographs obtained preoperatively and postoperatively. The sizes of the lesion measurements were assessed using the combined necrotic angle technique of Kerboul et al.[24] This angle is derived by adding the sums of the angle of the lesions on AP and lateral radiographs. This radiographic parameter has been compared between patients with or without hip failure to assess whether it could be a prognostic factor for the result of treatment.[32,33,45] Preoperative radiographs also were used to assess the extent of femoral head collapse. The hips were categorized according to the degree of femoral head collapse as determined on the AP and lateral radiographs: 125 hips had $\leq$ 2 mm collapse or mild collapse, 68 hips had 2–4 mm collapse or moderate collapse, and 33 hips had $\geq$ 4 mm collapse or severe collapse. The joint space was measured on the AP radiograph over the center of the femoral head and was compared with that seen on preoperative and early postoperative (within 6 weeks postoperatively) radiographs. Radiographic success was defined as the stability of the staging according to the classification system of Ficat and Arlet.[12]

Because of the possible error in radiographic alignment measurements before the study, an assessment of interobserver and intraobserver error in radiographic evaluation was made. The intraobserver reliability of the two surgeons (DWZ, WMW) was excellent, with 98% agreement. The agreement was an exact match in 95% of cases. To avoid the problem of intraobserver and interobserver variability in assessing the various radiographic parameters, two of the authors (DWZ, WMW) independently evaluated the radiographs. If there was a disagreement, a third person (XC) interpreted the radiographs until a unanimous decision could be made regarding the best guess at stage, size, joint space, or degree of collapse.

The preoperative and postoperative parameters were compared by the Mann-Whitney U nonparametric test. Fisher's exact test was used for comparison of groups.

RESULTS

One hundred ninety-five of the 212 surviving hips (92%) had a successful result at a mean followup of 12.5 years (range, 6–19 years). Harris hip scores improved from a mean of 51 points (range, 31–83 points) preoperatively, to a mean of 92 points (range, 62–100 points) at final followup for surviving hips. The preoperative Harris hip score for the entire group was 46 points (range, 21–83 points). The average postoperative score for all hips was 84 points (range, 19–100 points) at the most recent fol-

lowup or just before conversion to THA (Table 1) (Fig 3). Including the 14 hips treated with THA, the overall outcome in our study was successful in 86% of the 226 hips. Fourteen hips in 13 patients (6%) required conversion to a THA at a mean followup of 3 years (range, 1–6 years). Two of these hips (two patients) had Ficat Stage II disease at the time of the surgery, whereas five hips (five patients) had Ficat Stage III disease and seven hips (six patients) had Ficat Stage IV disease. Preoperatively, patients who had subsequent conversion surgery to THA had a lower ($p = 0.005$) mean Harris hip score compared with the patients without hip failure (32 points versus 55 points, respectively). The graft had marginal or no bleeding before its insertion into the femoral neck in four patients, and in one patient the vascular pedicle was torn. These five patients needed subsequent THAs. Comparing all the patients preoperatively with the patients without subsequent hip failure at followup, there was a reduction ($p = 0.0001$) in pain sensation. The parameters of range of motion (ROM) were not improved (Table 2).

Hips with Stage II and Stage III disease were associated with a better outcome. Eighty-seven of 91 hips (96%) with Stage II disease had successful results, 84 of 93 hips (90%) with Stage III disease had successful results, whereas only 24 of 42 hips (57%) with Stage IV disease had successful results. For the majority of patients who needed conversion surgery to THA, the etiology was steroid or alcohol use (seven patients [50%] and five patients [36%] respectively). Patients who experienced subsequent failure were older ($p = 0.005$) at the time of surgery (average, 47 years; range, 36–65 years) than patients without hip failure (average, 33 years; range, 19–60 years). Of the patients younger than 45 years, 94% had successful results, whereas only 62% of the patients older than 45 years had successful results.

Patients with only moderate or mild collapse of the femoral head had better results. In hips with mild collapse, 120 of 125 hips (96%) had successful results; in hips with moderate collapse, 58 of 68 hips (85%) had successful results; however, in hips with severe collapse, only 17 of 33 hips (52%) had successful results. Computed tomography was used for 32 patients during the followup stage,

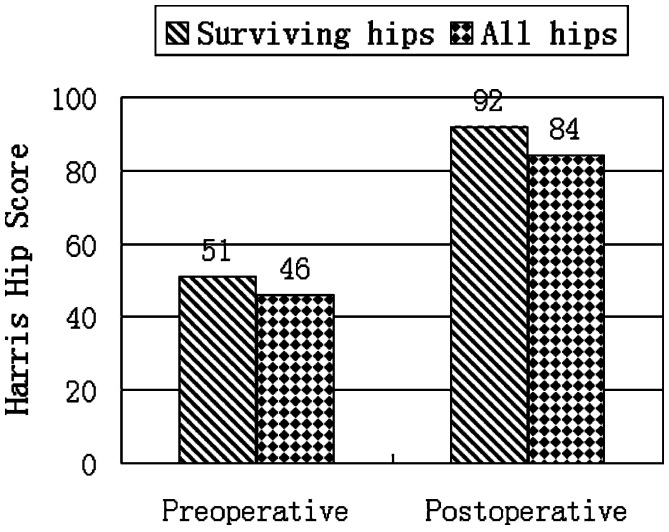

Fig 3. A graph shows the effect of vascularized iliac bone grafting on the Harris hip score.

and radiographs and CT scans show the iliac graft was fully incorporated in all surviving hips (Figs 4, 5).

At the postoperative examination of surviving hips, the stage of the necrosis remained unchanged in 161 hips (76%), 28 hips had deterioration of one stage, three hips had deterioration of two stages, and 20 hips had progressive osteoarthritis or progression of collapse. No patient had improvement in the stage of osteonecrosis. At the latest followup, 78 hips were classified as having Stage II osteonecrosis, 76 hips were classified as having Stage III osteonecrosis, and 58 hips were classified as having Stage IV osteonecrosis. Of the hips with Stage II disease, eight hips progressed to Stage III disease and three hips progressed to Stage IV disease. Twenty hips with Stage III disease progressed to Stage IV disease, and 20 hips with Stage IV disease had progressive osteoarthritis or progression of collapse (Table 3). Radiographically, for the 212 surviving hips, 53 additional hips had evidence of slight joint space narrowing (1–2 mm), which may be interpreted as a result of the deterioration of the stage of the necrosis postoperatively. The preoperative angle of necrosis as de-

TABLE 1. Clinical Results

Ficat and Arlet Stage	Number (hips)	HHS Preoperative (points)	HHS Postoperative (points)	Conversion to THA (hips)	Clinical Success Rate (percent)
II	91	51.6	85.3	2	96
III	93	44.7	83.5	5	90
IV	42	41.8	77.9	7	57

HHS = Harris hip score; THA = Total hip arthroplasty

TABLE 2. Clinical Assessment

Parameters	Entire Series Preoperatively (226 hips; 197 patients)	p Value	Survivors Postoperatively (212 hips; 184 patients)
Pain	27.6	0.0001	39.8
Flexion (degrees)	96	0.56	102
Extension (degrees)	1	0.87	2
Adduction (degrees)	21	0.09	27
External rotation (degrees)	23.5	0.26	26
Internal rotation (degrees)	9.3	0.17	11

fined by Kerboul et al[24] was similar in the group of patients without hip failure (mean, 226°; range, 162°–268°) and patients with hip failure (mean, 258°; range, 178°–286°).

There were no intraoperative complications. Postoperative complications occurred in 16 patients (8%). Four patients had deep venous thromboses, three patients had meralgia paresthetica, which resolved, and nine patients had secondary wound healing.

DISCUSSION

The natural history of symptomatic osteonecrosis of the femoral head may be progressive, and without operative intervention it results in collapse and deterioration of the joint. Orthopaedic surgeons have tried to find a surgically effective solution for preserving the femoral head, but to date no solution has been completely satisfying.[23] Of the various treatment options, nonvascularized cancellous bone grafting is appealing because it replaces the necrotic segment of the femoral head and has low donor site morbidity.[32,37] However, despite successful short-term results after bone graft, the long-term results are not convincing.[11] Using microsurgical techniques has allowed new therapeutic approaches for revascularizing necrotic bone to influence the pathologic process.[1,10,18] Free vascularized fibular transplant and vascularized iliac crest transplants have been reported to achieve this aim.[10,23,29,48] Some surgeons have considerable experience with free autogenous vascularized fibular transplantation, whereas others rely on the use of vascularized autogenous iliac crest transplants.[15,18,27] However, the necessity for microvascular anastomosis is a disadvantage to the free vascularized fibular transplant compared with the vascularized iliac crest transplant.[50] Vascularized iliac bone graft perfused by the ascending branch of the lateral femoral circumflex artery as an alternative method for osteonecrosis has been used widely in China for approximately two decades with

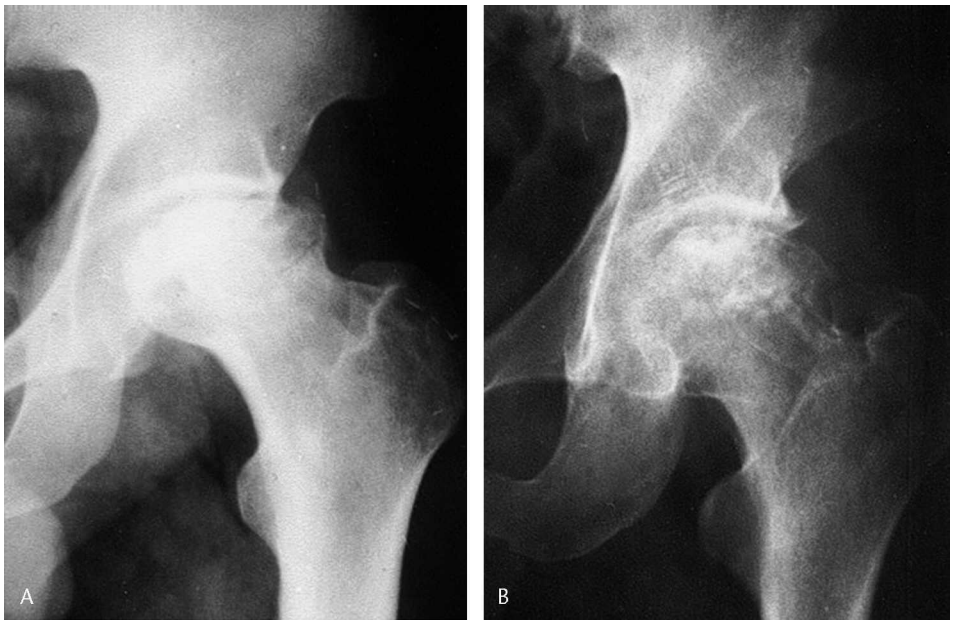

Fig 4A–B. (A) A radiograph of a patient with good results who had Stage IV necrosis of the femoral head is shown. (B) A radiograph obtained 16 years postoperatively shows that the iliac bone block is well incorporated with the femoral head and the femoral head is completely rebuilt.

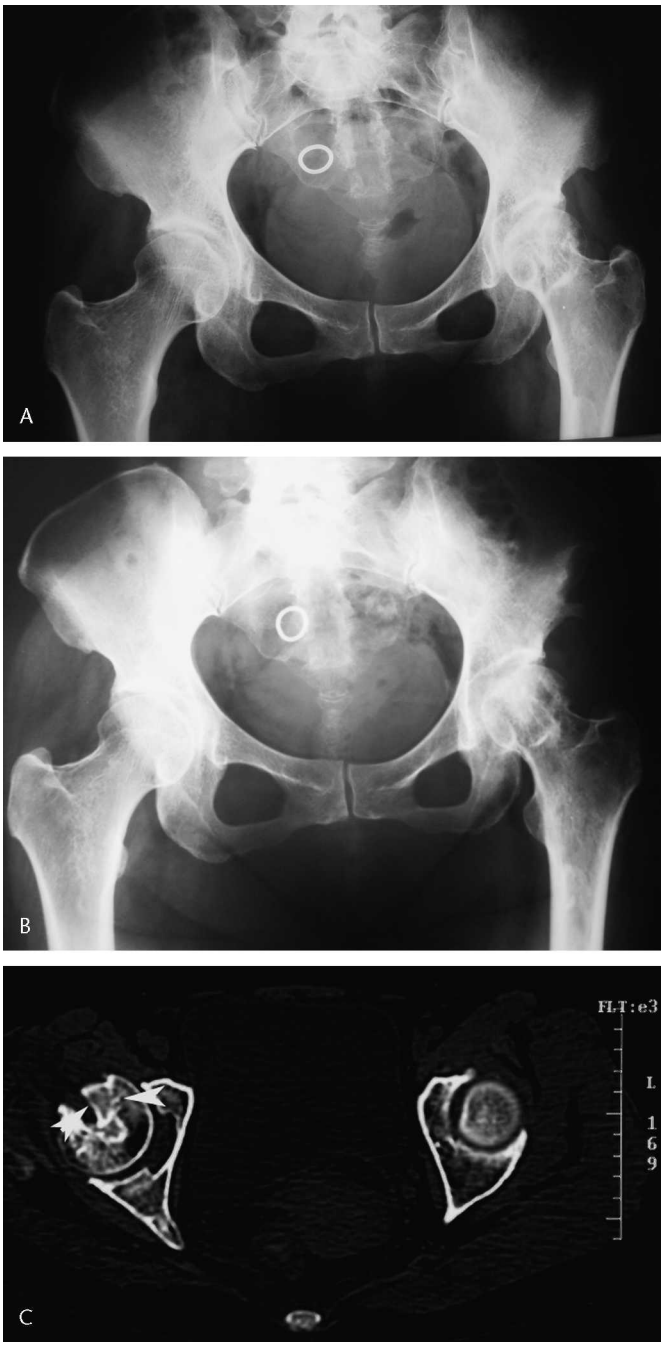

Fig 5A–C. (A) A radiograph of a patient with Stage III necrosis of the femoral head is shown. (B) Fifteen years postoperatively the joint space remains preserved and the sphericity of the femoral head is well maintained. (C) A CT scan shows that the iliac graft is fully incorporated in the host area.

TABLE 3. Radiologic Progression of Osteonecrosis in Patients without Conversion to Total Hip Arthroplasty

Ficat and Arlet Stage		
Preoperative	*Followup*	**Number of Hips**
II	II	78
II	III	8
II	IV	3
III	III	68
III	IV	20
IV	Stable	15
IV	Progression	20

satisfactory results.[7,54] An anatomy study[52] and clinical research[28,53] documented that the vascular branches that run into the anterosuperior iliac crest along the tensor fasciae lata muscles consistently are present. The only variations of the vasculature were the branches of the artery to the anterosuperior iliac crest, which would not affect perfusion of the graft. Because this vascularized iliac bone graft can be harvested and implanted through the same single approach used to expose the femoral head anterolaterally, the process is less time consuming and less technically demanding.[54] Combining the vascular bone transfer with autologous cancellous bone impaction provides insight as to whether the addition of a vascularized bone block improves the long-term clinical and radiographic outcomes compared with nonvascularized bone grafting or vascularized bone block transfer alone.

Several limitations must be kept in mind. We had no control group or comparative cohort. Therefore, we cannot ensure the surgical technique reduces the development of osteoarthritis compared with the natural history. However, the results were good compared with those in the literature. There is a certain level of interobserver variability in interpreting radiographs, but we did this with blinded observers with good reliability. Postoperative digital subtraction arteriography to confirm patency of the pedicle was not available, and we did not monitor postoperative blood flow through the pedicle. We did check intraoperative blood flow for patency, but have no evidence that blood flow through the vascularized graft had a major impact on the revascularization and salvage of the femoral head. However, we suspect good function of the blood supply in the postoperative period is crucial for a successful outcome, and that it is important to prevent occlusion of the pedicle in the bone graft at the time of insertion.

Despite these limitations, the subjective clinical outcome of patients without conversion surgery to THA is encouraging at a mean 12.5 years postoperatively. However, most patients reported a decrease in high-demand activities and sports. There is a discrepancy between clinical and radiographic outcomes in the current patients. This may be because the patients reduced their daily activities to accommodate their hip disease. The hips were preserved

radiographically in 161 hips in our series. In selected patients, autologous cancellous bone impaction and iliac graft revascularization potentially may avoid or postpone subsequent conversion to THA and its inherent long-term complications. This is significant for a disease that particularly affects young patients. Patient selection for this type of surgery must be restrictive, particularly considering preoperative parameters such as stage, age, and collapse.

Results of this new procedure should be compared with results of the traditional bone grafting techniques for this disease. In the 1960s and 1970s, nonvascularized bone grafting techniques were used commonly. Core decompression combined with nonvascularized bone grafting has had less than optimal results. Results have ranged from 17%–90% at short to midterm followup (range, 2–8 years), with lower success rates at longer followups.[2,3,9,35,39,43,46] Nonvascularized bone grafting techniques through a window in the femoral head cartilage or femoral neck have had better success rates (81%–83%).[31,34,37] In these reports, local bone graft or iliac crest bone was used as the graft donor. In the late 1970s and early 1980s, vascularized bone grafting was introduced to improve the success rate of nonvascularized bone grafting for treatment of osteonecrosis. Ishizaka et al[18] reported on a cohort of patients treated with vascularized iliac bone block alone. At 6 years followup they found a decrease in the average score for mobility, and osteoarthritic changes were found in ⅓ of the patients. Ishizaka et al[18] had better results in patients with medial type necrosis than in patients with the necrosis in the lateral weightbearing zone, underlining the importance of the mechanical properties. In the study of Eisenschenk et al,[10] clinical results according to the Harris hip score 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 Association for Research of Circulation Osseous (ARCO) classification system after an average of 5 years. Urbaniak et al[48] assessed the long-term followup of patients treated by a vascularized fibula alone. After a mean of 7 years, 31 of 103 hips (31%) required conversion to THA. However, if only patients with early necrosis are considered, the rate for conversion to THA is only 17%. Malizos et al[29] reported that 35 of 40 (87.5%) patients who had a free vascularized fibular transplant had radiographically improved or unchanged necrosis after 32 months. Although comparison among studies is difficult, the results of our study suggest that the clinical success rate in patients treated with this technique is improved compared with results of patients who had nonvascularized bone grafting or revascularization alone (Table 4).

If revascularization is considered, the use of an iliac crest block perfused by the ascending branch of the lateral femoral circumflex artery is the logical alternative to a vascularized fibula[1,50] or another iliac bone graft perfused by the circumflexed ilium profunda artery,[10,18] because donor site morbidity can be reduced. The ideal condition would be Ficat Stages II or III disease with a mild-to-moderate collapse of the femoral head that does not involve cartilage destruction in a patient younger than 45 years. In patients older than 45 years who have an advanced stage of necrosis and severe femoral head collapse, autologous trabecular bone grafting in combination with revascularization is not justified.

The insertion of a corticocancellous iliac crest transplant perfused by the ascending branch of the lateral femoral circumflex vessels in the femoral head places a high quality autogenous bone transplant in a weak host bed, and the impaction with autologous trabecular bone in the femoral head once occupied by the necrotic bone elevates the cartilage and restores the sphericity of the femoral head. The current procedure has several advantages: restoration of sphericity and prevention of femoral head collapse with autologous bone impaction; removal of the necrotic or poorly vascularized bone replaced with healthy cancellous bone and autogenous bony material with reliable blood supply; lack of microvascular anastomosis; and

TABLE 4. Results of Bone Grafting Techniques

Authors	Year	Procedure	Number of Hips	Followup [mean, range (years)]	Clinical Success Rate (percent)
Itoman and Yamamoto[19]	1989	WN	38	9 (2–15)	61
Rosenwasser et al[37]	1994	WN	15	12 (10–15)	81
Mont et al[32]	2003	WN	21	4 (3–4.7)	86
Urbaniak and Harvey[49]	1998	VF	646	7 (1–17)	83
Judet and Gilbert[23]	2001	VF	60	18 (15–22)	52
Hasegawa et al[15]	1997	VI	31	8 (5–11)	63
Eisenschenk et al[10]	2001	VI	82	5 (0.5–10)	86.6
Current	2004	NCR	226	12.5 (6–19)	86

WN = Window in femoral neck, nonvascularized bone graft; VF = Vascularized fibular graft; VI = Vascularized iliac graft; NCR = Nonvascularized bone graft combined with revascularization iliac bone graft

temporary delay or prevention of an additional therapy, such as THA.

Although there was a trend toward increasing collapse of the femoral head, the amount of flattening or preoperative linear collapse of the femoral head was not a predictor of survival or functional outcome. We think that elevation of the collapsed segment intraoperatively and support with impaction cancellous graft and a pedicled iliac block mitigates the influence of this variable on outcome. However, we suspect that if a portion of necrotic bone remains and is not revascularized, this small area will collapse and the procedure may fail, underscoring the importance of thoroughly débriding the necrotic lesion and carefully protecting the vascular pedicle. This may explain why the extent of necrosis as defined by Kerboul et al[24] did not influence the results of this treatment.

Our results suggest that vascularized iliac bone block transfer combined with autologous cancellous bone impaction as described is not appropriate for patients with advanced stages of osteonecrosis of the femoral head. However, when this procedure is used in patients younger than 45 years who have Stages II or III osteonecrosis with mild-to-moderate collapse of the femoral head but integrity of the weightbearing surface, the patients had satisfying results regardless of the extent of the sequestrum.

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