Arch Orthop Trauma Surg (2001) 121:437–442

ORIGINAL ARTICLE

Masataka Noguchi · Teruhiko Kawakami
Hiroshi Yamamoto

Use of vascularized pedicle iliac bone graft in the treatment of avascular necrosis of the femoral head

Received: 19 October 2000

Abstract A vascularized pedicle iliac bone graft was performed in patients with extensive necrosis in whom the necrotic area occupied more than two-thirds of the femoral head. The purpose of this procedure is to supply vascularity and mechanical strength to the avascular femoral head. Our series consisted of 18 hips. The patients' age at surgery ranged from 21 to 55 years. Fourteen hips were identified as stage II and 4 hips as stage III. Iliac bone graft alone was performed in 4 stage II joints. Transtrochanteric anterior rotational osteotomy of the femoral head was done additionally in 10 stage II joints and 4 stage III joints. In the group who underwent iliac bone graft alone, the mean Japanese Orthopedic Association (JOA) score improved from 58.5 to 63.8 (mean follow-up 52 months). In the group who underwent combination procedure with osteotomy, the mean JOA score improved from 71.7 to 85.0 (mean follow-up 43 months). Stage progression was noted in 3 of 4 joints in the group who underwent iliac bone graft alone. In the group who underwent the combined procedure, stage progression was noted in 2 of 10 joints at more than 1 year after operation. A vascularized pedicle iliac bone graft to treat avascular necrosis of the femoral head is considered promising for joint preservation.

Keywords Femoral head necrosis · Vascularized bone graft · Iliac bone

Introduction

Avascular necrosis of the femoral head (ANFH) is occuring increasingly frequently in adolescent and middle-aged persons and is a difficult disease to treat. In many cases, it results in deterioration of the hip joint. Regarding surgical treatment, an artificial femoral head or total hip replacement poses problems in the long term because of the age of onset. We perform a transtrochanteric anterior rotational osteotomy of the femoral head [9] as the treatment of first choice, to preserve the joint as much as possible, in patients aged 60 years or younger with a relatively high activity level in daily life. However, in cases of extensive necrosis in which the necrotic area occupies two-thirds or more of the weight-bearing zone of the femoral head, and a favorable outcome cannot be expected with transtrochanteric rotational osteotomy of the femoral head alone [10], a vascularized pedicle iliac bone graft is performed to acquire weight-bearing properties and repair the necrotic bone by improving local blood flow. In this paper, we report our surgical techniques and clinical results.

Patients and methods

The progression of ANFH has been classified into four stages (Table 1) by the Japanese Investigation Committee. These range from femoral heads with no radiographic abnormality (stage I) to those with osteoarthrosis (stage IV). The affected femoral heads were also further classified into six types by the Japanese Investigation Committee, according to the size and location of the necrotic area in relation to the weight-bearing surface of the ac-

Table 1 Staging of avascular necrosis of the femoral head

Stage	Characteristics
I	Preradiologic stage. There are neither symptoms nor radiographic changes in the femoral head. However, a definite abnormality, diagnosed by magnetic resonance imaging or bone scintigraphy, is present.
II	Early stage. Radiographs show abnormality in the femoral head with either no collapse or a collapse of less than 2 mm.
III	Advanced stage. Radiographs show irregular density with obvious collapse of the femoral head.
IV	Late stage. Severe deformity of the femoral head and secondary osteoarthrosis are evident.

M. Noguchi (✉) · T. Kawakami · H. Yamamoto
Department of Orthopaedic Surgery, Kochi Medical School, Nankoku, Kochi 783–8505, Japan
e-mail: noguchim@kochi-ms.ac.jp,
Tel.: +81-88-8802387, Fax: +81-88-8802388

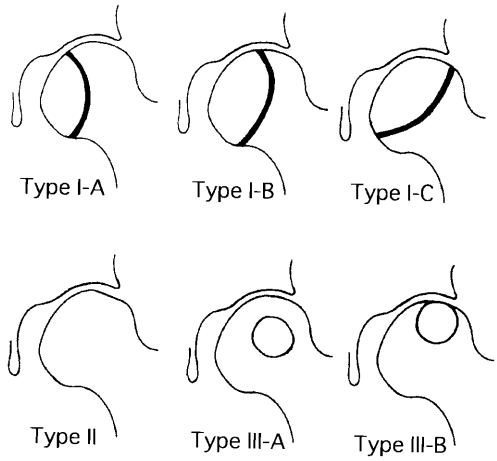


Fig. 1 Radiographic classification of avascular necrosis of the femoral head (ANFH). Type I is characterized by the presence of a demarcation line in the femoral head and is divided into three subtypes. Type II shows early flattening of the weight-bearing surface but has no demarcation line around the necrotic area. Type III has cystic lesions and is divided into two subtypes

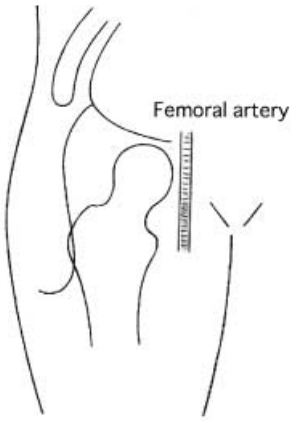
etabulum (Fig. 1). The indication for the vascularized iliac bone graft was primarily restricted to stages I, II and III ANFH.

Eleven men (12 hips) and 5 women (6 hips) underwent vascularized pedicle iliac bone grafting for extensive ANFH between June 1984 and March 2000. Their age at the time of surgery ranged from 21 to 55 years (mean 39.6 years). The etiology was alcohol-associated in 8 patients (10 hips), post-traumatic in 3 (3 hips), steroid-induced in 3 (3 hips), and idiopathic in 2 (2 hips). The preoperative stage was stage II in 14 hips and stage III in 4 hips. The preoperative type was type I-C in 15 hips, type II in 2 hips, and type III-B in one hip. Until 1994, a vascularized pedicle iliac bone graft alone had been performed in stage II patients without depression in the weight-bearing zone of the femoral head. A transtrochanteric anterior rotational osteotomy of the femoral head had been concurrently used only in stage III cases in which depression in the weight-bearing zone of the femoral head had already developed, thereby aggravating the compatibility between the femoral head and the acetabulum. Since 1995, in stage II cases in which depression in the weight-bearing zone of the femoral head was not observed but a normal area was present in the posterior inferior part of the femoral head, vascularized pedicle iliac bone grafting has been carried out after transferring the normal area as close to the weight-bearing zone as possible by approximately 90 deg of anterior rotation of the femoral head. A vascularized pedicle iliac bone graft alone was indicated in 4 hips in stage II, and a transtrochanteric anterior rotational osteotomy was concurrently used in 10 hips in stage II and 4 hips in stage III. For postoperative treatment, the hip joint was retained in a slightly flexed position (approximately 30 deg) for 3 weeks postoperatively. Partial weight-bearing was initiated 3 months postoperatively, and full weight bearing was initiated 6 months postoperatively when bone union at the site of the osteotomy was completed. Postoperative viability of the bone graft was evaluated by bone scintigraphy 1 week postoperatively, and dynamic magnetic resonance imaging (MRI) thereafter. Fourteen hips were examined for changes in the score of the diagnostic criteria for coxarthrosis proposed by the Japanese Orthopedic Association (JOA score) and the presence or absence of progression of the clinical stage 1 year or more after the surgery.

Surgical techniques

The vascularized pedicle iliac bone graft alone was basically performed by the methods described by Ganz and Buchler [2] and Leung and Chow [5, 6]. When an anterior rotational osteotomy of the femoral head was used in combination, the following procedures were performed. Patients were placed in a lateral position with the affected side up. J or reverse-J-curve skin incisions crossing at the anterior superior iliac spine were made to avoid marginal necrosis of the flap at 90 deg of the angle of the crossed incisions (Fig. 2). Initially, approximately 90 deg of anterior rotation of the femoral head was carried out according to the Sugioka method [9, 10]. To assess circulation to the bone graft and the repair status of the necrotic area in the femoral head on MRI after surgery, the site of the osteotomy was fixed with a titanium screw. On this occasion, for an iliac bone graft after rotation of the femoral head, it is necessary to insert 3 screws at the center of the femoral head toward the posterior region to prepare a bone groove about 5 cm long, 2 cm wide, and about 2 cm deep from the femoral neck toward the weight-bearing area of the anterolateral side of the femoral head. Subsequently, the iliac bone with the deep circumflex iliac artery and vein as vascular pedicles was harvested. The inguinal ligament was preserved. An osteotomy for harvesting the bone graft was initiated from the site 2.5–3 cm behind the anterior superior iliac spine, and full-thickness iliac bone about 5 cm long and about 2 cm deep was harvested. When this method was first employed, the osteotomy was initiated from a site 1.5 cm behind the anterior superior iliac spine. However, when the iliac bone was transplanted into the bone groove prepared in the femoral head, the vascular pedicle was found to be relatively short, frequently leading to strain on the deep circumflex iliac artery and vein. Therefore, an osteotomy from a slightly more posterior site was performed. The harvested iliac bone was transferred from the lower layer of the inguinal ligament, passed over the iliopsoas muscle and rectus femoris muscle, and inserted into the bone groove prepared from the femoral neck to the inside of the femoral head. The tip of the iliac bone graft was trimmed in accordance with the curve of the femoral head, with the aim of inserting the iliac bone graft at the level of the weight-bearing subchondral bone. To prevent formation of a gap between the iliac bone and subchondral bone of the femoral head, a small cancellous bone graft was added. The extent of curettage of the necrotic lesion was limited to the area in which the bone graft could be fitted because the weight-bearing capacity of even the necrotic bone was considered to be superior to that of the bone chip. In addition, the site from which the bone graft was harvested was supplemented with an iliac bone spacer (Fig. 3).

Fig. 2 Skin incision



Case reports

Patient 6. A 49-year-old man suffered necrosis after a femoral neck fracture, showing stage III and type III-B before surgery. Vascularized pedicle iliac bone grafting combined with a transtrochanteric anterior rotational osteotomy of the femoral head was performed. There was no disease progression to a more advanced stage 5 years and 6 months postoperatively, with an improvement in the JOA score from 77 points preoperatively to 100 points post-

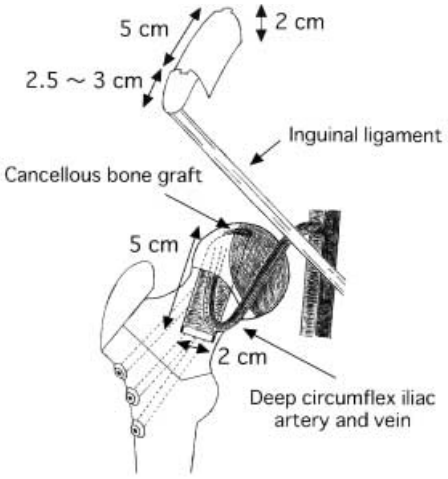


Fig. 3 Surgical techniques

operatively. Postoperative MRI revealed expansion of the high-intensity area around the transplanted iliac bone, particularly the weight-bearing zone of the femoral head, suggesting restoration of the necrotic area (Fig. 4).

Patient 7. A 38-year-old woman suffered steroid-induced necrosis, which was stage II and type I-C before surgery. Vascularized pedicle iliac bone grafting combined with a transtrochanteric anterior rotational osteotomy of the femoral head was carried out. There was no disease progression to a more advanced stage 5 years postoperatively, with an improvement in the JOA score from 65 points preoperatively to 77 points postoperatively (Fig. 5).

Patient 10. A 42-year-old man had alcohol-associated necrosis, which was stage II and type I-C before surgery. Vascularized pedicle iliac bone grafting combined with a transtrochanteric anterior rotational osteotomy of the femoral head under a varus strain (approximately 10 deg) was performed on the right femoral head. Dynamic MRI done 1 month postoperatively confirmed favorable blood flow in the bone graft. There was no disease progression to a more advanced stage 2 years and 7 months postoperatively, with an improvement in the JOA score from 72 points preoperatively to 85 points postoperatively (Fig. 6).

Results

The mean JOA score improved from 58.5 points preoperatively to 63.8 points 40–62 (mean 51.8) months postoperatively in patients undergoing a vascularized pedicle iliac bone graft alone. In patients undergoing a rotational osteotomy combined with iliac bone grafting, the score improved from 71.7 points preoperatively to 85.0 points 18–81 (mean 43.2) months postoperatively. The disease progressed to obviously more advanced stages in 3 of 4 hips undergoing an iliac bone graft alone, necessitating artifi-

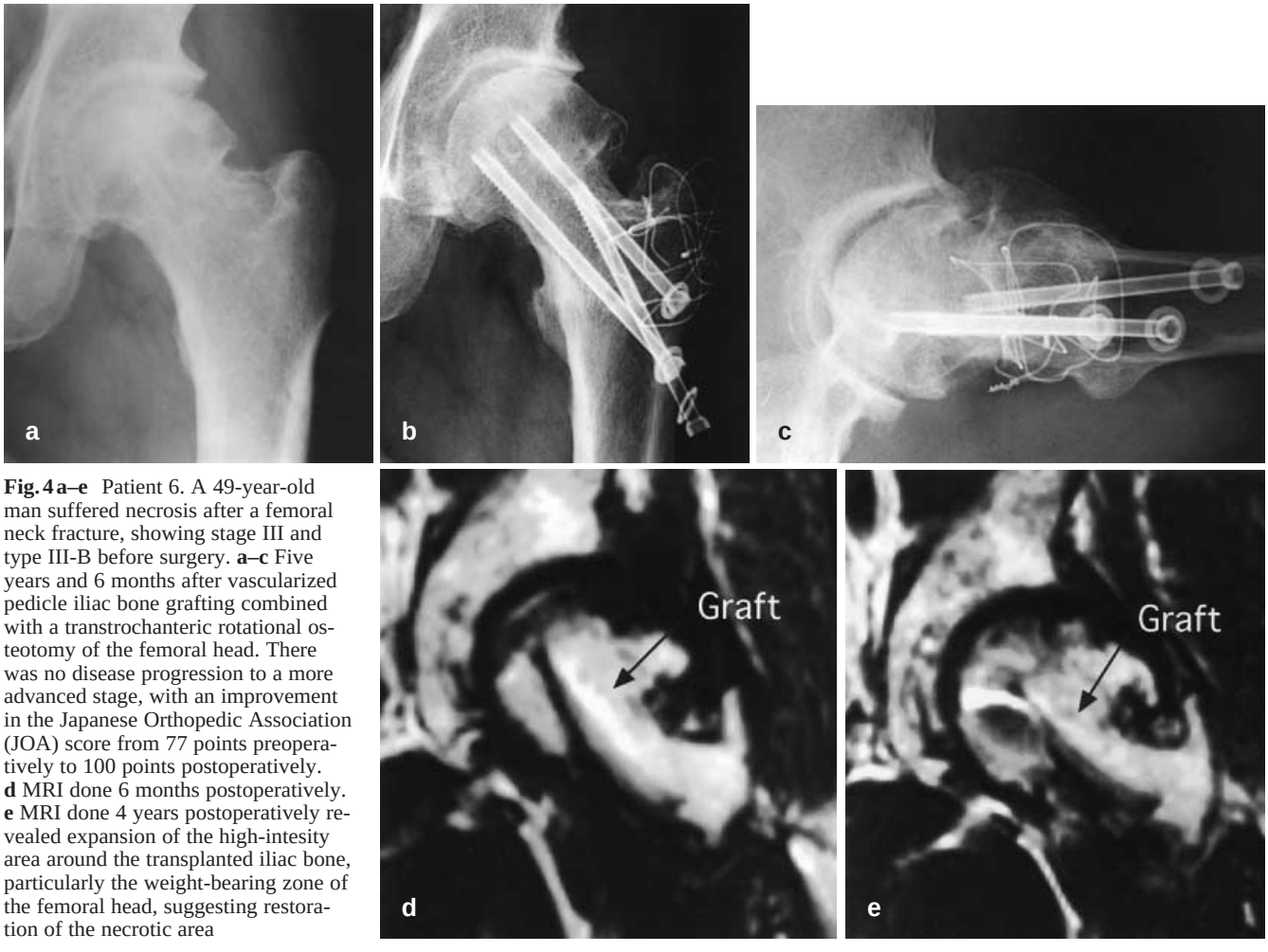


Fig. 4 a–e Patient 6. A 49-year-old man suffered necrosis after a femoral neck fracture, showing stage III and type III-B before surgery. **a–c** Five years and 6 months after vascularized pedicle iliac bone grafting combined with a transtrochanteric rotational osteotomy of the femoral head. There was no disease progression to a more advanced stage, with an improvement in the Japanese Orthopedic Association (JOA) score from 77 points preoperatively to 100 points postoperatively. **d** MRI done 6 months postoperatively. **e** MRI done 4 years postoperatively revealed expansion of the high-intesity area around the transplanted iliac bone, particularly the weight-bearing zone of the femoral head, suggesting restoration of the necrotic area

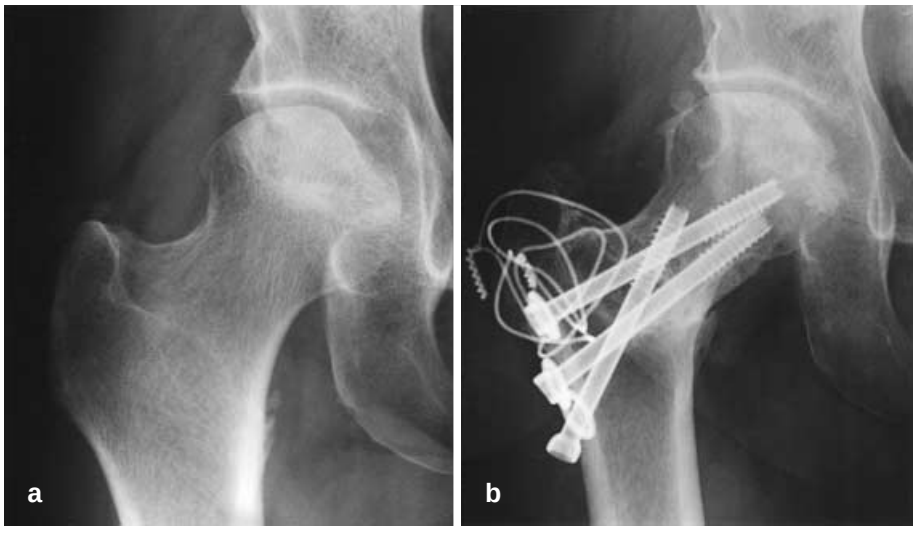


Fig. 5 a, b Patient 7. A 38-year-old woman with steroid-induced necrosis, which was stage II and type I-C before surgery. **a** Before surgery. **b** Five years after vascularized pedicle iliac bone grafting combined with a transtrochanteric rotational osteotomy of the femoral head. There was no disease progression to a more advanced stage, with an improvement in the JOA score from 65 points preoperatively to 77 points postoperatively

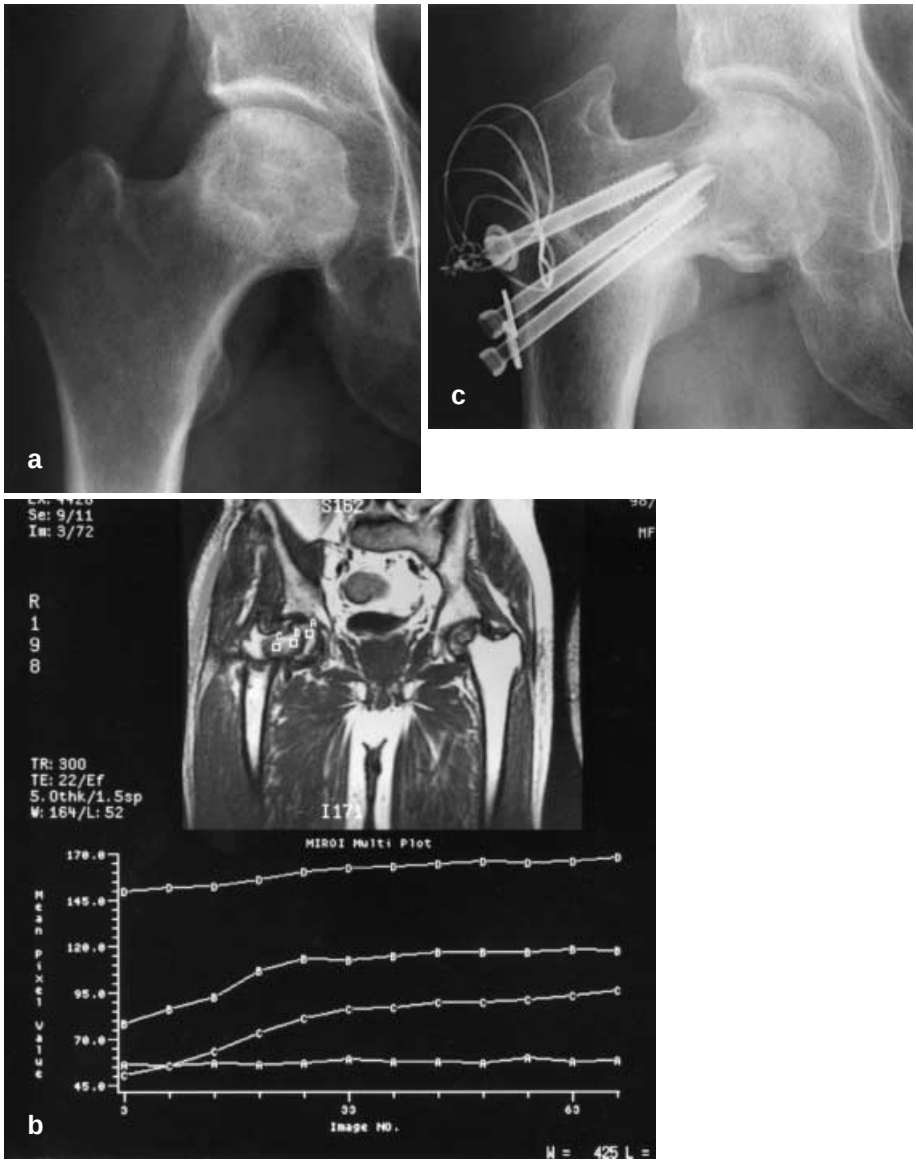


Fig. 6 a–c Patient 10. A 42-year-old man with alcohol-associated necrosis, which was stage II and type I-C before surgery. **a** Before surgery. **b** Dynamic MRI done 1 month postoperatively confirmed favorable blood flow in the bone graft. **c** There was no progression to a more advanced stage 2 years and 7 months postoperatively, with an improvement in the JOA score from 72 points preoperatively to 85 points postoperatively

Table 2 Summary of patient data (*TRO* transtrochanteric anterior rotational osteotomy, *VPIG* vascularized pedicle iliac bone graft)

Patient no.	Age/sex (years)	Etiology	Preoperative JOA score	Preoperative stage	Preoperative type	Operative procedure	Follow-up (months)	Postoperative JOA score	Stage progression	Remarks
1	44/M	Alcohol associated	87	III	I-C	TRO + VPIG	81	87	–	
2	55/M	Alcohol associated	69	II	I-C	VPIG	62	64	+	
3	48/M	Post-traumatic	55	II	II	VPIG	60	53	+	
4	26/M	Post-traumatic	45	II	II	VPIG	45	45	+	Artificial femoral head replacement
5	47/M	Alcohol associated	65	II	I-C	VPIG	40	93	–	
6	49/M	Post-traumatic	77	III	III-B	TRO + VPIG	66	100	–	
7	38/F	Steroid induced	65	II	I-C	TRO + VPIG	60	77	–	
8	37/M	Idiopathic	72	II	I-C	TRO + VPIG	59	100	–	
9	21/F	Steroid induced	60	II	I-C	TRO + VPIG	34	100	–	
10	42/M	Alcohol associated	Rt : 72	II	I-C	TRO + VPIG	31	85	–	
			Lt : 65	II	I-C	TRO + VPIG	28	85	–	
11	31/F	Alcohol associated	Lt : 60	II	I-C	TRO + VPIG	18	38	+	Artificial femoral head replacement
			Rt : 86	II	I-C	TRO + VPIG	28	92	–	
12	45/M	Idiopathic	73	II	I-C	TRO + VPIG	27	86	+	

cial femoral head replacement 45 months postoperatively in one case (patient 4). Among 10 hips undergoing a concomitant rotational osteotomy, 2 showed obvious disease progression. Artificial femoral head replacement became necessary 18 months postoperatively in one (patient 11), but circulation to the bone graft had been poor, and the angle of varus fixation of the femoral head had also been insufficient during initial surgery (Table 2).

Discussion

As hip-preserving surgery for ANFH, a transtrochanteric rotational osteotomy of the femoral head reported by Sugioka [9, 10] can yield very favorable outcomes when the ratio of the normal area to the entire joint surface of the femoral head is one-third or more. However, in patients with extensive necrosis showing a ratio of the normal area of one-third or less, a transtrochanteric rotational osteotomy of the femoral head alone cannot provide satisfactory results. In contrast, vascularized pedicle iliac bone grafting for ANFH is considered an excellent method because the necrotic area is replaced by tissue with blood circulation. Accordingly, we suggested vascularized pedicle iliac bone grafting in patients with extensive necrosis showing a ratio of the normal area of the femoral head of one-third or less after considering the outcomes of a transtrochanteric rotational osteotomy of the femoral head. Bones such as the pedicle iliac bone [2, 3, 4, 5, 6, 7] and free fibula [1, 8, 11] are used for vascularized bone grafting to treat ANFH. We believe that iliac bone with pedicles of the deep circumflex iliac artery and vein is easy to use and has a sufficient strength as a weight-bearing bone. Soon after we started employing pedicle iliac bone grafting as hip-preserving surgery for ANFH, vascularized pedicle iliac bone grafting alone was carried out in patients without depression in the weight-bearing zone of the femoral head. Since 1995, however, we expanded indications for a transtrochanteric rotational osteotomy of the femoral head from only stage III patients, who have developed depression in the weight-bearing zone of the femoral head and show poor compatibility with the acetabulum, to patients in whom the normal area was in the posterior inferior part of the femoral head even though depression in the weight-bearing zone of the femoral head was not noted. This was because we considered it advantageous in such patients to transfer the normal area as close to the weight-bearing zone as possible by approximately 90 deg of anterior rotational osteotomy of the femoral head prior to vascularized pedicle iliac bone grafting in the necrotic area in its new position ahead of the femoral head to prevent depression in the femoral head and to facilitate repair of the necrotic area. The results of this study also showed that disease progression to more advanced stages was less frequently observed in patients undergoing a concurrent rotational osteotomy. The advantages of this method are that it can be indicated in patients with extensive necrosis, which is not a good indication for a rotational osteotomy alone, and its techniques

are simple because vascular anastomosis is not necessary. The disadvantage is that when a transtrochanteric rotational osteotomy of the femoral head is combined with this technique, the surgical duration is prolonged by approximately 2 h compared with that of a rotational osteotomy alone. We believe that the indications for this method are patients showing stage III or less, and type I-C, II, or III-B. The causes of a poor outcome of this method include inappropriate size of the bone graft, inadequate position of insertion, poor circulation to the bone graft, and insufficient varus fixation when a transtrochanteric rotational osteotomy of the femoral head is used in combination. If we pay close attention to these points, this method is useful as femoral head-preserving surgery for extensive ANFH.

References

1. Brunelli G, Brunelli G (1991) Free microvascular fibular transfer for idiopathic femoral head necrosis: long-term follow-up. J Reconst Microsurg 7: 285–295
2. Ganz R, Buchler U (1983) Overview of attempts to revitalize the dead head in aseptic necrosis of the femoral head-osteotomy and revascularization. In: Hungerford DS (ed) Hip. CV Mosby, New York, pp 296–305
3. Ishizaka M, Sofue M, Dohmae Y, Endo N, Takahashi H (1997) Vascularized iliac bone graft for avascular necrosis of the femoral head. Clin Orthop 337: 140–148
4. Iwata H, Torii S, Hasegawa Y, Itoh H, Mizuno M, Genda E, Kataoka Y (1993) Indications and results of vascularized pedicle iliac bone graft in avascular necrosis of the femoral head. Clin Orthop 295: 281–288
5. Leung PC, Chow YYN (1984) Reconstruction of proximal femoral defects with a vascular-pedicled graft. J Bone Joint Surg Br 66: 32–37
6. Leung PC (1987) Use of vascularized pedicle iliac crest graft in treatment of ischemic necrosis of femoral head. In: Urbaniac JR (ed) Microsurgery for major limb reconstruction. CV Mosby, St Louis, pp 200–204
7. Noguchi M, Kawakami T, Iai H, Matsusaki H, Yamamoto H (1996) Use of vascularized iliac bone graft in treatment of avascular necrosis of femoral head. Cent Jpn J Orthop Trauma 39: 907–908
8. Sotereanous DG, Plakseychuk AY, Rubash HE (1997) Tree vascularized fibula grafting for the treatment of osteonecrosis of the femoral head. Clin Orthop 344: 243–256
9. Sugioka Y (1978) Transtrochanteric anterior rotational osteotomy of the femoral head in the treatment of osteonecrosis affecting the hip. Clin Orthop 130: 191–201
10. Sugioka Y, Hotokebuchi T, Tsutsui H (1992) Transtrochanteric anterior rotational osteotomy for idiopathic and steroid-induced necrosis of the femoral head. Clin Orthop 277: 111–120
11. Urbaniak JR, Coogan PG, Gunneson EB, Nunley JA (1995) Treatment of osteonecrosis of the femoral head with free vascularized fibular grafting. J Bone Joint Surg Am 77: 681–694