Strut allografts for failed treatment of periprosthetic femoral fractures

Good outcome in 13 patients

Bertram Barden[1], Yue Ding[1], Josef G Fitzek[2] and Franz Löer[1]

Departments of Orthopaedic Surgery, [1]University of Essen, DE-45147 Essen, [2]Kreiskrankenhaus, Mechernich, DE-53894 Mechernich, Germany.

Correspondence: Bertram Barden, Department of Orthopaedic Surgery of the University of Essen, DE-45147 Essen, [2]Kreiskrankenhaus, Mechernich, DE-53894 Mechernich, Germany. Correspondence: b.barden@uni-essen.de

Submitted 02-02-11. Accepted 02-06-18

ABSTRACT Strut allografts are not recommended after a femoral shaft exposure, because they may endanger the femoral blood supply. Up till now, we have seen no clinical reports on this problem. We treated 13 consecutive patients with very large anteromedial and anterolateral femoral strut allografts to restabilize periprosthetic fractures which had become loose after a previous attempt at surgical fixation (Vancouver type B fractures with severe bone loss). In 8 cases, the stem was revised in conjunction with the use of strut allografts and in 5 cases, strut allografts alone were used. All refractures and nonunions healed without further treatment. At a mean follow-up of 3 (1.2–7) years, the mean Harris Hip Score was 78 (65–92). All strut grafts showed ingrowth with augmentation of periprosthetic bone on the radiographs. There were 3 complications, 1 nonprogressive subsidence of a revision stem (fibrous stable), 1 deep hematoma and 1 partial lesion of the sciatic nerve. In this series, strut grafts gave reliable healing with augmentation of the host bone stock despite previous femoral exposure, severe bone loss, adverse type of fracture, and persistent instability at the index operation.

In patients who sustain primary periprosthetic type B fractures around or close to the prosthesis stem (Duncan and Masri 1995; Table 1, section H), refixation with cortical onlay strut allografts with or without prosthesis stem revision is thought to improve bone stock and stability in the long term (Duncan and Masri 1995, Chandler and Tigges 1997, Lewallen and Berry 1997, Brady et al. 1999, Crockarell et al. 1999, Haddad et al. 1999). In revision hip arthroplasty with severely deficient, but not fractured periprosthetic bone, Head et al. (1998) reported reliable augmentation and incorporation of femoral strut grafts in 251 patients after 8–12 years. In failed internal fixation of periprosthetic fractures, structural bone grafting may also be beneficial. Chandler and Tigges (1997), however, did not recommend treatment of periprosthetic fractures with strut grafting after previous shaft exposure, because the femoral blood supply might be compromised by placement of the grafts. Nevertheless, until today, there have been no studies of this problem. Our aim was to evaluate the results of procedures, in which strut grafts were used to refix failed osteosynthesis of periprosthetic type B fractures. In these cases, femoral vascularization may have been compromised by preceding exposure of the femur, excessive cement extrusion, displacement at the fracture site, instability of the femur and severe bone deficiencies.

Patients and methods

In a consecutive study from 1992 until 1999, we treated 13 patients who had 13 refractures or nonunions, following failed surgical stabilization of periprosthetic fractures of the femur, with very large femoral cortical strut grafts (Table 1).

The mean age of the patients at the time of reoperation was 69 (45–87) years. In all 13 patients the refracture occurred spontaneously and had not

Table 1. Data on the patients: Preoperative findings, treatment of refractures and results

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	X
1	M	57	Nf	1	c	sc	B3	c	v	19	+	ss	5.7	72	0.5	s	0	11	20	3	-
2	M	70	Pa	1	c	s	B3	o	t	49	+	ss	1.8	77	1	s	0	12	-	3	-
3	F	56	Nf	1	c	s	B3	c	v	10	+	ss	3.6	73	0	s	0	14	24	4	ns
4	F	68	Pr	1	c	sm	B3	o	v	1	+	ss	1.2	72	0	s	0	12	14	4	-
5	F	45	Ra	2	c	fa	B3	t	v	7	+	ss	7.4	90	0	s	0	11	18	3	-
6	M	67	Ra	1	c	sc	B3	o	t	4	+	ss	1.4	83	0	s	0	12	-	4	-
7	F	77	Da	1	c	fs	B1	c	v	2	+	ss	1.2	92	0	s	0	13	-	4	-
8	F	68	Ra	4	c	rn	B1	t	t	21	-	ns	2.3	73	2	cs	0	9	19	6	-
9	F	69	Dy	2	c	s	B3	c	t	240	+	ss	1.8	73	4.0	fs	3.5	9	-	4	-
10	F	87	Ra	4	c	fs	B1	o	v	1	-	s	1.6	65	0	cs	0	9	-	4	-
11	F	75	Nf	2	c	sl	B1	o	v	7	-	s	1.4	92	0	cs	0	12	17	3	-
12	F	79	Da	1	nc	sc	B1	c	v	1	-	s	5.5	73	0	s	0	12	23	3	rh
13	F	75	Da	1	nc	sc	B1	c	v	1	-	s	5.8	83	0.5	s	0	12	18	3	-

A Case
B Gender
C Age
D Original diagnosis for replacement
- Da Degenerative arthritis
- Dy Dysplasia
- Nf Neck fracture
- Pa Psoriasis arthritis
- Pr Protrusio
- Ra Rheumatoid arthritis

E Number of previous revisions
F Previous Implant
- c cemented
- nc noncemented

G Previous fracture treatment
- fa 2 fibular struts + autogenous bone
- fs 2 femoral struts
- rn retrograde nailing
- s stem exchange
- sc stem exchange + cerclage wires
- sl stem exchange + lateral strut
- sm stem exchange + medial strut

H Type of fracture, Vancouver classification (Duncan et al 1995)
- A Trochanteric
- B Around or close to stem tip
- B1 Femoral component stable
- B2 Femoral component loose
- B3 Femoral component loose and bone deficient
- C Well below the component

I Extension of fracture
- c comminuted
- o short oblique
- t transverse

K Major displacement of fracture
- t telescoping
- v varus

L Months from the first treatment to revision
M Stem exchange
N Bridging of fracture
- ns nail + strut
- s struts
- ss stem + strut/s

O Follow-up, years
P Hip score (Harris 1969)
Q Clinical length discrepancy
R Classification of stem fixation (Engh and Massin 1989)
- cs cemented and stable
- fs fibrous stable
- s stable

S Subcidence of the stem, cm
T Months to 50% partial bridging of struts
U Months to complete bridging of struts
V Months to union of refracture
X Complications
- ns nerve lesion
- rh revision of hematoma

been preceded by a fall or trauma. 1 patient (case 9) sustained a refracture 20 years after the primary fracture as a result of very marked cement perforation at the fracture site. As a result of the refracture, all patients were bedridden at the time of rerevision. Before the original fracture, 12 patients had been able to walk at least 3–7 blocks with little, if any, mild pain. None of them had used crutches or canes. 1 (case 10) had been able to walk only with a walker.

In 9 patients, the original periprosthetic fracture had not been completely bypassed by the stem component, but extramedullary stabilization had been performed (cases 1, 4, 5, 6, 7, 10, 11, 12 and 13) (Figures 1 and 2). The remaining 4 patients had had intramedullary bridging of the fracture: 3 had had a cemented long stem without extramedullary fixation (cases 2, 3 and 9), and considerable cement extrusion was seen at the primary fracture site. In the 4th patient (case 8), a retrograde

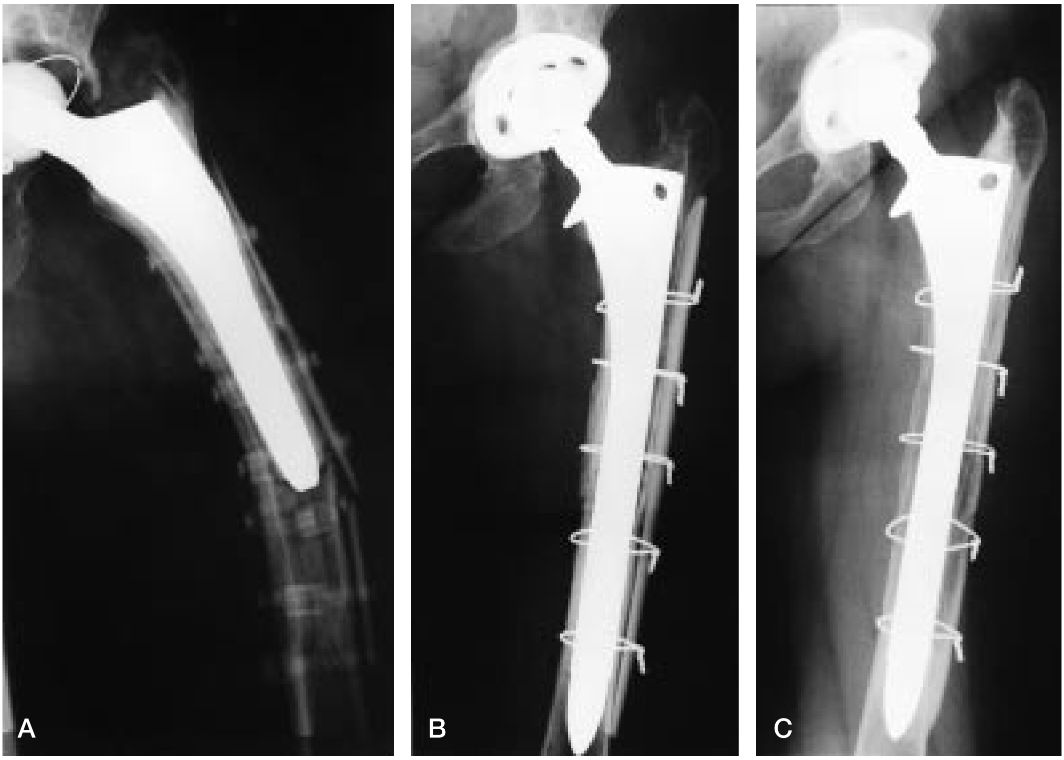

Figure 1. Periprosthetic refracture in a patient with rheumatoid arthritis (case 5).
A. Transverse refracture at prosthesis tip with fracture of small fibular allografts in a patient having severe bone loss.
B. Postoperative result: The fracture is bypassed by the prosthesis stem and a very large femoral strut graft.
C. Result 7 years after revision surgery: complete incorporation of the strut graft with cancellization.

femoral nail with interlocking screws had been fixed on the tip of the prosthesis stem after failure of the blade plate osteosynthesis, but rotational instability and telescoping of the distal femur had occurred because the interlocking screws had loosened in the severely osteoporotic bone (Figure 2). Only 1 patient had a history of deep infection (case 12) that had been eradicated before the primary arthroplasty.

In all 13 patients, we used very large fresh frozen femoral onlay strut allografts supplied by Bio Implant Services Foundation, Eurotransplant, (Leiden, The Netherlands) or Clinique Universitaires Saint-Luc A.S.B.L., Banque de Tissues de l´Appareil Locomoteur (Brussels, Belgium). The femora were retrieved from multiorgan donors under sterile conditions and stored fresh frozen at –85 °C. Donor serology and microbiological screening of the grafts were performed. Before surgery radiographs of the grafts were taken to suit the shape and size of the grafts and the patients' femora. Intraoperative cultures, taken routinely, were all negative. Using the technique described in detail by Chandler and Tigges (1997) and Brady et al. (1999), anteromedial and anterolateral strut grafts were used with 1.5 mm cerclage wires. 1 patient (case 1) received an additional posterolateral graft because of extensive bone defects. Another patient (case 5) had only one anterolateral strut graft. Cancellous bone grafting at the fracture site and around the strut grafts was performed in 9 patients: 4 autogenous grafts (cases 1, 5, 12, and 13) and 5 allogeneic ones (cases 2, 8, 9, 10 and 11). For treatment of the refracture, 7 stems (cases 1–7) were revised to a long, fully porous-coated, press-fit revision implant (Solution System, Johnson & Johnson DePuy, Warsaw, IN, USA) and the refracture was bypassed by the stem and the strut grafts for at least 2 cortical diameters (Figure 1) (Chandler and Tigges 1997, Lewallen and Berry 1997, Paprosky et al. 1999). In case 8, the fracture was bridged by a retrograde locking nail and two

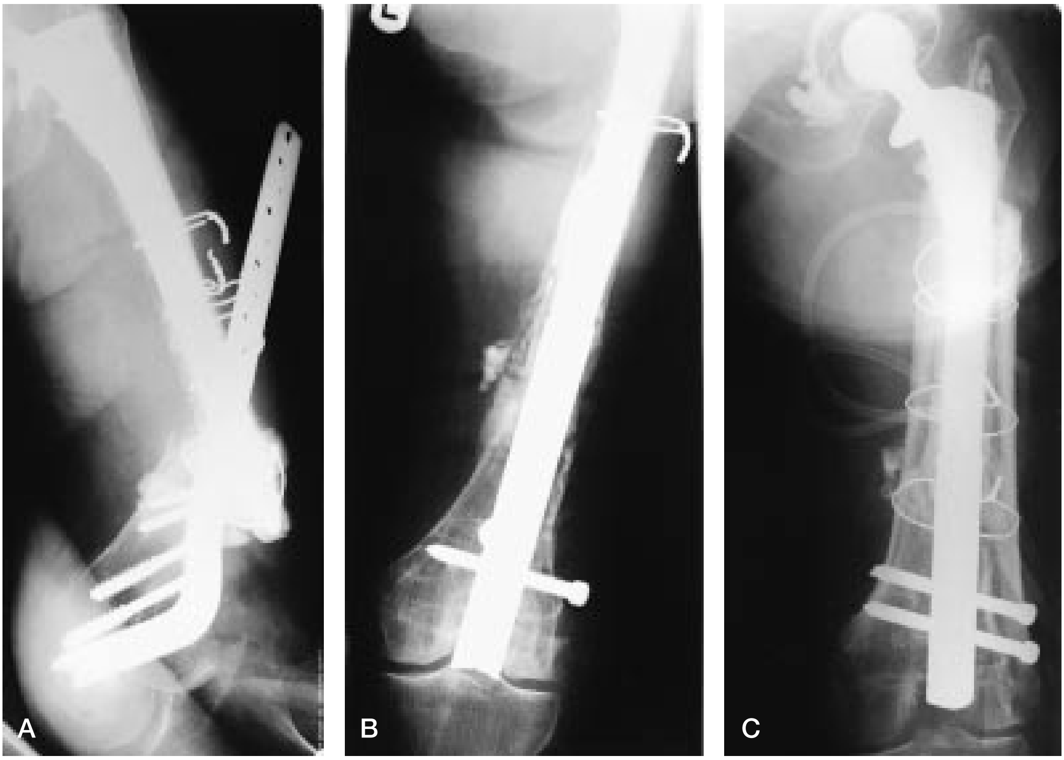

Figure 2. Recurrent periprosthetic fracture with a stable femoral revision component in the presence of severe osteoporosis (case 8).
A. Fixation lost after 3 preceding attempts at surgical stabilization.
B. Retrograde nailing then led to telescoping and rotational instability of the distal femur, because the locking screws had loosened.
C. Refixation with anteromedial and anterolateral distal femoral strut grafts helped anchor the locking screws.

strut grafts (Figure 2). In 5 fractures at the tip of the prosthesis stem, fixation was provided exclusively by the strut grafts (Figure 3). In 4 patients (10–13), the stable femoral stem was left in place. In one case with a loosened, long, cemented revision stem (case 9), the longest press-fit revision component was inserted with only distal femoral allograft struts bridging the fracture.

In all patients, the length of the strut grafts was chosen to bridge the refracture for at least two cortical diameters distally and proximally. To preserve the remaining blood supply to the host bone, the struts were placed medially and laterally to the linea aspera and the circumferential periosteum was left on the host bone, if it was technically possible (Chandler and Tigges 1997, Brady et al.1999).

Postoperatively, 10 patients were kept in bed for 1 day. The remaining 3 patients could stand up by their bed between 2 and 3 weeks after surgery (cases 5, 12, and 13). All patients used crutches for protected weight bearing (15–30 kg) during 3–6 months after surgery. No braces were applied.

Clinical and radiographic follow-ups were done 3 months after surgery and then annually. The Harris (1969) Hip Score was used for the clinical evaluation. Leg length discrepancy was measured on the clinical examination. Union at the refracture site was assessed on the anteroposterior and lateral-medial radiographs. Fracture healing was assumed to have occurred, if all 4 cortices were bridged by callus with homogeneous remodeling and there was complete obliteration of the fracture line. Implant subsidence was measured on radiographs made with the patient in standard position. We used a constant distance of the film and focus. Fixed reference points, like wires, screws and the lesser or greater trochanter, were used. Femoral component stability was determined with the radiographic criteria of Engh and Massin (1989).

Figure 3. Healed type B-1 refracture at the tip of a stable Exeter revision stem 1.6 years after surgery (case 10). Fixation is provided exclusively by the ingrown strut grafts that give femoral augmentation.

Category 1 refers to an optimal interface appearance with signs of early fixation by bone ingrowth. Category 2 has a suboptimal interface appearance, but stability. There is delayed stabilization by fibrous tissue encapsulation with a bone adaptive response to initial migration. Category 3 has an unstable interface appearance with protracted migration of the implant. The fibrous tissue and bone responses have been insufficient to stabilize the implant. The ingrowth of the strut grafts was assessed, using the classification system of Emerson et al. (1992) (Table 2). The radiographic evaluation was done by a single blinded orthopedic surgeon and 2 of the authors (J.F. and B.B.).

Table 2. Radiographic Ingrowth of strut grafts according to Emerson et al. (1992)

Radiographic observations	Average months to onset
Round-off	7
Scalloping	8
Partial bridging	8
Complete bridging	13
Cancellization	27

An assignment of union is made, if the strut grafts demonstrate greater than 50% bridging to the host bone.

Results

At the time of the most recent clinical follow-up, 3 patients had died of unrelated medical causes 6–7 years after the index operation (cases 1, 12, and 13). Until their deaths, all 3 patients had been available for regular follow-ups. Bony union of the fracture occurred in all patients within 3–6 months after the index operation. Before fixation of the periprosthetic refracture, all 13 patients had severe local pain and considerable dislocation at the fracture site. They were bedridden or wheelchair-bound. After surgery, at a mean follow-up of 3 (1.2–7) years, the mean postoperative Harris Hip Score was 78 (65–92). As for pain and function, the patients had returned to their level before the original periprosthetic fracture. The only patient with a poor result (case 10) had to use a walker, which she had had before sustaining the first fracture. 7 patients could walk 3–7 blocks; the remaining 5 had no limitation on walking distance. They had had no infections. The fair and poor results were mainly caused by limited function scores because of systemic disease, degenerative disease of the lumbar spine, and contralateral hip or knee arthritis.

Leg length was fully restored in most patients (Table 1). No strut graft impingement at the acetabulum or knee joint was observed. The ipsilateral knee had a mean range of motion of 115° (80°–125°). 1 patient had a reduction in extension of 15° (case 8).

Complete radiographic union at the refracture site was seen at the most recent follow-up in all 13 cases. Adequate radiographic graft union and incorporation were present in all 13 patients. In

4 (cases 1, 5, 12, and 13), we found bony union across the full length of the grafts with extensive remodeling after 6–7 years of follow-up (Figure 1). In 4 patients (cases 3, 4, 8, and 11), the strut grafts showed extensive bone bridging to the host femur at a mean follow-up of 2 (1.2–3.6) years, but they could still be seen clearly, because hardly any cancellization had occurred (Figure 3). Bony bridging of more than 50% of the contact area between the grafts and the host bone was seen at a mean follow-up of 1.5 (1.2–1.8) years in 5 patients (cases 2, 6, 7, 9, and 10). Our overall impression of the anteroposterior and lateral radiographs was that all strut grafts caised circumferential augmentation of the deficient bone stock of the host femur. No resorption developed within the grafts. Lengthening of the struts was obvious in 9 patients, as periosteal bone and cancellous graft formed at the ends of the struts. We saw no signs of femoral osteonecrosis that could have been caused by the placement of strut grafts.

One cementless revision stem had migrated 3.5 cm without clinical symptoms in the first postoperative year (case 9). The bone-implant interface suggested delayed stabilization by fibrous tissue encapsulation with a bone adaptive response to initial migration. As no progression of subsidence, no cortical hypertrophy, and no change in the interface were seen after the first year, this implant was classified as having stable fibrous fixation according to Engh and Massin's classification. The remaining 12 prosthesis stems were stable. Other complications included 1 postoperative evacuation of a deep hematoma and 1 transient partial sciatic nerve palsy with persistent neuralgia.

Table 3. Periprosthetic fractures and incidence of refractures

Study	Year published	No. of fractures	No. of refractures	Incidence of refractures
Lewallen and Berry	1997	97	15	0.2
McLauchlan et al.	1997	45	3	0.1
Jukkala-Partio et al.	1998	75	16	0.2
Siegmeth et al.	1998	54	3	0.1
Tower and Beals	1999	93	9	0.1
Tadross et al.	2000	9	6	0.7

Discussion

In patients with very deficient periprosthetic bone stock, mechanical complications commonly occur because of cortical perforations, infection, stress shielding, granuloma, previous surgery and osteoporosis. In the present study, 6 failures were seen within 6 months after the preceding attempt at stabilization (cases 4, 6, 7, 10, 12 and 13) and refractures resulted mainly from overestimation of the patient's periprosthetic bone stock. Some reports on the surgical treatment of primary periprosthetic fractures have shown a high incidence of malunions, refractures and nonunions (Table 3). The results of refixation were unsatisfactory or the outcome was not included in the follow-up evaluation. Only one study has dealt specifically with the treatment of failed fixation of periprosthetic fractures (Crockarell et al. 1999). 15 patients were available for evaluation of bone healing; in 7, primary union occurred after surgical treatment. In 8, nonunion persisted, but in 3, bone healing occurred after 1, 2 or 4 more operations. None of them received strut grafts because of concern about devascularization, if very large strut grafts are used after previous femoral exposure (Chandler and Tigges 1997). In contrast, we found complete union in all 13 patients treated with femoral cortical strut grafts after failed fixation of periprosthetic fractures. These results correlate well with the successful clinical data reported for strut graft fixation in primary periprosthetic fractures (Chandler et al. 1993, Haddad et al. 1999, Barden et al. 2001). Unlike augmentative strut grafts in revisions without a periprosthetic fracture (Head et al. 1998), the strut grafts we used also had to stabilize the refractured, severely deficient, femur. In 8 patients, the refractures were stabilized by the strut grafts combined with a press-fit revision stem that bridged the refracture. In 5 cases, fixation was achieved solely by the strut grafts. This technical procedure without intramedullary bridging is disputed. Chandler et al. (1993) reported 2 nonunions in 19 cases of primary periprosthetic fractures that required revision. 1 of the nonunions leading to the index operation in the present series also was a failure of technically correct anteromedial and anterolateral femoral strut graft fixation without intramedullary bridging. Brady et al. (1999) and Lewallen and Berry (1997) favor additional bridging by the femoral component. If implant revision is difficult in the presence of a well-fixed stem, strut graft fixation alone is considered. Haddad et al. (1999) have reported a successful periprosthetic fracture treatment with femoral strut grafts combined with the Dall-Miles cable and plate system in 4 cases, where the stable prosthesis stem did not bypass the fracture.

Since the strut grafts had a considerable weight bearing function in the present series, only femoral grafts were used, as the stability of tibial grafts had been inadequate in comparative mechanical testing (Chandler et al. 1993). All strut grafts we used were fresh frozen. Freeze-dried bone grafts were not used, because they are mechanically weaker (Chandler et al. 1993).

Potential treatment alternatives in refractures and nonunions of periprosthetic type B fractures include standard plates, special plates like the Ogden plate or the Dall-Miles system, distal locking revision stems, sleeves or nails that are fixed at the prosthesis tip by retrograde insertion, two-stage procedure with intramedullary nailing, tumor prosthesis or proximal femoral allografts (Kolstad 1994, Duncan and Masri 1995, Chandler and Tigges 1997, Lewallen and Berry 1997, Crockarell et al. 1999, Haddad et al. 1999). Unlike these procedures, strut grafts routinely become incorporated with restoration of deficient bone stock, which is made stronger than it was originally (Chandler and Tigges 1997, Brady et al. 1999,). As the modulus of elasticity of the bone plates is similar to that of the host bone, stress shielding is avoided. Moreover, healing of the fracture is directly stimulated by the grafts (Chandler et al. 1993).

Strut grafts become weaker 4–6 months after implantation (Chandler et al. 1993, Brady et al. 1999). This might lead to failure in case of delayed union that is more likely to occur after previous femoral exposure and together with severe bone loss, adverse type of fracture and persisting instability. Therefore, the combination of strut grafts with plate fixation or with other treatment options mentioned above seems suitable, if tight intramedullary fracture bridging can not be obtained by the femoral component in patients with unsatisfactory compliance or in cases where the grafts can not extend a minimum of 10 cm distal to the refracture (Chandler and Tigges 1997, Haddad et al. 1999). As recommended by Chandler and Tigges (1997) and Lewallen and Berry (1997), autogenous cancellous bone grafts from the iliac crest were added to the fracture site in the present series. If there was not enough bone available from the patient as a result of severe osteoporosis, allogeneic cancellous grafts were used. In 4 patients no cancellous bone could be used because the strut grafts circumferentially covered most of the femur at the refracture site.

There are limitations in the use of strut grafts in patients with very small requirements or other severe diseases. Here the surgical trauma can be reduced by the use of a proximal femoral replacement stem. Moreover, strut grafts should not be used before an infection has been completely cured.

In all our patients, the femur had already been exposed in the area of the refracture during the preceding fracture treatment. The theoretical objections to this procedure were not confirmed. Exposure of the host femur for positioning of the strut grafts did not essentially affect the femoral blood supply. Instead, it led to bone healing in the present study.

No competing interests declared.

Barden B, Fitzek J G, Huttegger C, Löer F. Supportive strut grafts for diaphyseal bone defects in revision hip arthroplasty. Clin Orthop 2001; 387 (6): 148-55.

Brady O H, Garbuz D S, Masri B A, Duncan C P. The treatment of periprosthetic fractures of the femur using cortical onlay allograft struts. Orthop Clin North Am 1999; 30 (2) : 249-57.

Chandler H P, King D, Limbird R B et al. The use of cortical allograft struts for fixation of fractures associated with well-fixed total joint prostheses. Semin Arthroplasty 1993; 4 (2): 99-107.

Chandler H P, Tigges R G. The role of allografts in the treatment of periprosthetic femoral fractures. J Bone Joint Surg (Am) 1997; 79 (9): 1422-32.

Crockarell J R Jr., Berry D J, Lewallen D G. Nonunion after periprosthetic femoral fracture associated with total hip arthroplasty. J Bone Joint Surg (Am) 1999; 81 (8): 1073-9.

Duncan C P, Masri B A. Fractures of the femur after hip replacement. Instr Course Lect 1995; 44: 293-304.

Emerson R H Jr., Malinin T I, Cuellar A D et al. Cortical strut allografts in the reconstruction of the femur in revision total hip arthroplasty. A basic science and clinical study. Clin Orthop 1992; 285 (12): 35-44.

Engh C A, Massin P. Cementless total hip arthroplasty using the anatomic medullary locking stem. Results using a survivorship analysis. Clin Orthop 1989; 249 (12): 141-58.

Haddad F S, Masri B A, Garbuz D S, Duncan C P. Femoral bone loss in total hip arthroplasty. Classification and preoperative planning. J Bone Joint Surg (Am) 1999; 81 (10): 1483-8.

Harris W H. Traumatic arthritis of the hip after dislocation and acetabular fractures: Treatment by mold arthroplasty. J Bone Joint Surg (Am) 1969; 51 (4): 737-55.

Head W C, Malinin T I, Mallory TH, Emerson R H Jr. Onlay cortical allografting for the femur. Orthop Clin North Am 1998; 29 (2): 307-12.

Jukkala-Partio K, Partio E K, Solovieva S et al.. Treatment of periprosthetic fractures in association with total hip arthroplasty. A retrospective comparison between revision stem and plate fixation. Ann Chir Gynaecol 1998; 87 (3): 229-35.

Kolstad K. Revision THR after periprosthetic femoral fractures. An analysis of 23 cases. Acta Orthop Scand 1994; 65 (5): 505-8.

Lewallen D G, Berry D J. Periprosthetic fracture of the femur after total hip arthroplasty. J Bone Joint Surg (Am) 1997; 79 (12): 1881-90.

McLauchlan G J, Robinson C M, Singer B R, Christie J. Results of an operative policy in the treatment of periprosthetic femoral fracture. J Orthop Trauma 1997; 11 (3): 170-9.

Paprosky W G, Greidanus N V, Antoniou J. Minimum 10-year-results of extensively porous-coated stems in revision hip arthroplasty. Clin Orthop 1999; 369 (12): 230-42.

Siegmeth A, Menth-Chiari W, Wozasek G E, Vecsei V. Periprosthetic femur shaft fracture. Indications and outcome in 51 patients. Unfallchirurg 1998; 101 (12): 901-6.

Tadross T S, Nanu A M, Buchanan M J, Checketts R G. Dall-Miles plating for periprosthetic B1 fractures of the femur. J Arthroplasty 2000; 15 (1): 47-51.

Tower S S, Beals R K. Fractures of the femur after hip replacement: the Oregon experience. Orthop Clin North Am 1999; 30 (2): 235-47.