Revision total hip arthroplasty using an interlocking stem with an allograft-prosthesis composite

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We report the clinical and radiographic outcomes
and complications of revision surgery using a cement-
less interlocking stem with an allograft-prosthesis
composite (APC). This study included 11 patients
with an average follow-up of 7.3 years. Of the 11 revi-
sions, 1 was aseptic, 7 were septic, and 3 were peri-
prosthetic femoral fractures. The mean Harris hip
score improved from 25.6 points before surgery to
74.8 points at final follow-up. Osseous union at the
proximal allograft-host bone junction occurred in
10 hips (90.9%) ; the greater trochanter did not unite
in 4 of 7 hips (57.1%). Moderate and severe allograft
resorption occurred in one hip each. Postoperative
complications included 1 deep infection, 2 heterotopic
ossifications, and 1 dislocation. Using an interlocking
stem with an allograft-prosthesis composite in revi-
sion surgery provided acceptable results in the pres-
ence of circumferential massive bone deficiency of the
proximal femur.

Keywords : revision total hip arthroplasty ; allograft-
prosthesis composite ; cementless ; interlocking stem.

INTRODUCTION

In revision total hip arthroplasty (THA), surgeons
may be confronted with difficulties due to prosthe-
sis loosening with massive osteolysis, stress shield-
ing, periprosthetic femoral fracture, or infection. In
particular, repeat debridement procedures in cases

of infection may eventually lead to extensive bone
loss in the proximal femur. When a femur presents
with full circumferential bone deficiency extending
into the diaphysis, a megaprosthesis or allograft-
prosthesis composite (APC) is generally used. A
megaprosthesis, however, cannot achieve biologic
reconstruction of the proximal femur. We believe a
segmental cortical allograft offers favourable
mechanical properties and allows for the recon-
struction of sizeable proximal bone defects. We re-
port the clinical and radiographic outcomes and
complications of revision THA using a cementless
interlocking stem with an APC in the presence of

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circumferential bone deficiency of the proximal femur, and for the treatment of periprosthetic femoral fracture with poor bone stock in the proximal femur.
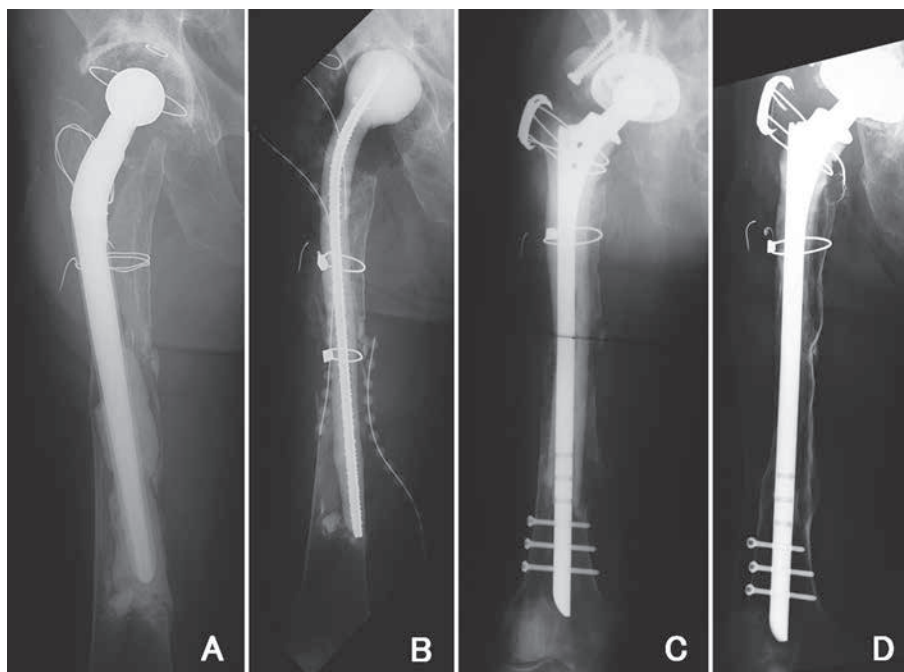
PATIENTS AND METHODS

The study was approved by our institutional review board. Between January 1997 and January 2008, we performed 61 revision THAs for femoral bone deficiency by using bone allografts obtained from our bone bank (Kitasato University Hospital Bone Bank) (14,27). In 50 revisions, we used a Wagner type stem (conical stem) with a cancellous chip bone allograft for cavitary bone deficiency. Our indications for the use of an APC in revision surgery using a cementless interlocking stem included a femur with full circumferential bone deficiency extending into the diaphysis, classified as Gustilo type IV (8), and for the treatment of periprosthetic femoral fracture classified as Vancouver type B3 (5). Consequently, this study included 11 hips in 11 patients (3 men, 8 women) with an average age of 60.5 years (range : 28-78 years) at the time of revision surgery. All patients were followed for a minimum of 4.8 years, with an average follow-up duration of 7.3 years (range : 4.8-11.3 years).

The primary diagnosis for the index operation was osteoarthritis in 5 hips, idiopathic avascular necrosis in 2, femoral neck fracture in 2, and rheumatoid arthritis in 2. Of the 11 revision THAs, 1 was aseptic, 7 were septic, and 3 were periprosthetic femoral fractures. We classified femoral defects according to findings on preoperative plain radiographs and intraoperative findings. We encountered 8 cases of full circumferential segmental bone deficiency (Gustilo type IV) and 3 cases of periprosthetic femoral fracture with poor bone stock in the proximal femur (Vancouver type B3).

All 7 of the infected hips were treated using a 2-stage protocol (24). The first stage involved removal of the infected implant, bone cement, and devitalized tissues, followed by insertion of an antibiotic-impregnated cement spacer (Fig. 1). Examination of the fluid or soft tissue drawn from the hip joint during the operation identified *Staphylococcus epidermidis* in 3 cases, methicillin-resistant *S. aureus* in 2 cases, *Escherichia coli* in one case, and there was 1 case with a non-identified pathogen (Table I). Postoperatively, parenteral antibiotic therapy

Fig. 1. — Radiograph of a 65-year-old man (Case 1) : **A)** Loosening due to infection with methicillin-resistant *Staphylococcus aureus* was observed. **B)** The infected hips were treated using a 2-stage protocol. **C)** We performed revision surgery using a cementless interlocking stem with a allograft-prosthesis composite. **D)** Radiograph 8.8 years postoperative, showing favorable incorporation of the allograft but nonunion of the greater trochanter.

Table I. — Patient characteristics, treatment outcomes, and complications

Case	Age, y/sex	Preoperative diagnosis	Previous operations, N°	Length of segmental allograft, cm	Follow-up period, y	Allograft resorption	Complications
1	65/M	Infected THA (MRSA)	5	27.0	8.9 died	Moderate	Dislocation Nonunion of GT
2	69/F	Periprosthetic fracture	3	15.2	10.6	Mild	None
3	51/F	Infected THA (*St. epi.*)	6	14.7	11.2	Mild	Disappearance of GT
4	28/M	Infected THA (*St. epi.*)	8	13.9	9.3	Severe	Heterotopic ossification (Brooker class IV) Disappearance of GT
5	60/M	Periprosthetic fracture	2	12.5	5.8 died	Mild	Nonunion of GT
6	57/F	Aseptic loosening	4	12.5	6.7	Mild	Nonunion of GT
7	78/M	Periprosthetic fracture	3	22.1	6.8	None	Nonunion of GT
8	47/M	Infected THA (*E. coli*)	6	9.1	5.2	—	Infection 2-stage revision
9	66/F	Infected THA (*St. epi.*)	3	14.2	5.0	None	None
10	77/M	Infected THA (MRSA)	11	7.3	4.9	None	Disappearance of GT
11	67/M	Infected THA (Unknown)	6	12.0	4.8	None	Heterotopic ossification (Brooker class II)

Abbreviations : *E. coli : Escherichia coli* ; F : female ; GT : greater trochanter ; M : male ; MRSA : methicillin-resistant *Staphylococcus aureus* ; *St. epi. : Staphylococcus epidermidis* ; THA : total hip arthroplasty.

was administered for approximately 2 weeks until laboratory tests, including white blood cell count and C-reactive protein level, revealed normal results. The second stage of the procedure commenced once the infection was under control, as confirmed by laboratory tests (excluding 2 cases with rheumatoid arthritis). The average time between the 2 stages was 6.7 weeks (range : 2-9 weeks). Antibiotic-impregnated cement was used for prosthesis fixation to the allograft in the revision surgery (vancomycin in 6 hips, gentamicin in 2, a combination of vancomycin and amikacin in 1, and clindamycin in 1).

Surgical technique

The allografts were stored in the bone bank at -80°C. Preoperatively, radiographs were templated to select the appropriate allograft. The osteotomy level was also templated to avoid producing an unacceptable leg length discrepancy. Stem length and diameter as well as the position of the interlocking screws were also templated. All allografts were screened for transmissible viruses, including HIV, HTLV and hepatitis. The allografts were heated by thermostatic bath for inactivation of some viruses and bacteria at 60°C for 10 h one day before the surgery.

All patients underwent surgery in the lateral position. A posterolateral approach was used in 10 hips (90.9%) and a anterolateral approach in 1 hip (9.1%), all using the incision from the previous procedure, when possible. Surgeries were performed by two surgeons (MI in 7, NT in 4). A transtrochanteric approach was used routinely for removal of the acetabular component, residual cement, femoral head prosthesis, and/or cement spacer. The greater trochanter of three hips already had disappeared due to repeated revision surgery. We performed a transverse trochanteric osteotomy in 7 hips and an extended trochanteric osteotomy in 1 hip. We replaced 10 acetabular and 11 femoral components during surgery.

After removal of cement spacers or cementless stems, and preparation of the acetabular bed, we inserted 4 standard hemispheric cups, 1 cemented polyethylene cup, 3 Ganz reinforcement rings (Zimmer, Warsaw, USA), and 2 Burch-Schneider antiprotrusion cages (Zimmer), as dictated by the bone stock. One standard hemispheric cup was not removed because there was no loosening. Bone deficiency of the acetabulum was reconstructed with morselized bone allografts or whole femoral head allografts secured with screws. We used metal-on-polyethylene in all 10 acetabular components.

All femoral implants were made of titanium alloy. We used Huckstep revision stems (B. Braun Medical, Sheffield, U.K.) in 7 hips. This stem comes in 4 different lengths (160, 210, 260, or 320 mm) and a 12.5-mm diameter only. We used this stem in infectious cases because of its solid type, as we believe a solid-type stem is better than a cannulated-type stem in infectious cases. The straight Huckstep stem has distal interlocking with 3 or 6 screw holes, enabling distal fixation of the stem with 4.5-mm interlocking screws. Most of the stems have a porous coating on their proximal part. We also used Cannulock stems (Waldemar-Link, Hamburg, Germany) in 3 hips. This stem has 3 different lengths (180, 240, or 300 mm), 3 different diameters (11, 13, or 15 mm), and a curved design following a radius of 2,000 mm and 10° anteversion. Distally, 3 or 5 screw holes allow locking with 4.5-mm self-tapping screws. Most of the proximal stem surface is coated with Ti plasma spray. We used the 11-mm-diameter stem in 2 hips with a narrow femoral bone canal, and the 13-mm-diameter stem in 1 hip. The Huckstep and Cannulock stems are based on the concept of primary distal fixation by interlocking, even in cases with extensive bone loss, followed by secondary fixation by osseointegration. This distal mechanism of fixation permits precise restoration of the lower limb length, and provides initial axial and rotational stability. The average stem length was 250 mm (range : 180-320 mm), while the average stem diameter was 12.3 mm (range : 11-13 mm).

We cemented the interlocking stem into the allograft with antibiotic-loaded bone cement (Surgical Simplex P, Stryker, Limerick, Ireland) introduced manually. The allograft was reamed until a good fit was achieved for the implant, allowing for a 2-mm cement mantle around the stem. The average length of the allograft used was 14.6 cm (range : 7.3-27 cm). The APC was then inserted into the host bone. A cortical strut onlay allograft and chip allograft were used to stabilize the allograft-host bone junction. The remnants of a very thin proximal part of the host femur with the soft tissue attachments were covered with a proximal segmental cortical allograft, secured with a cable cerclage at the allograft-host junction. We already reported on 2 cases included in this study (Table I, Cases 2 and 9), in which we inserted a cortical strut allograft into the femoral bone canal on the medial side and another on the lateral side of the distal femur. Subsequently, the 2 strut allografts were secured with interlocking screws to achieve distal stability of an interlocking stem, and to improve the bone stock of the distal femur in revision THA. Good clinical progress has been recorded using this technique (26). When the remaining host greater trochanter was substantial, osseous reattachment was attempted by using either the A-I wiring system (5 hips ; AI Medic, Tokyo, Japan) (25), the Dall-Miles cable-grip system (1 hip ; Howmedica, Rutherford, NJ), or the Accord Cable Plate system (2 hips ; Smith &Nephew, Memphis, USA). This provides better soft tissue support and may limit the considerable risk of dislocation ; however, late trochanteric fracture is common. We believe reattachment of the abductors, either to the tensor fasciae latae or to the allograft, is worthwhile, even when the trochanter is deficient.

The postoperative protocol was as follows : Wheelchair transfer was permitted 3 days after operation, partial weight bearing was allowed after 3 weeks , and complete weight bearing with support from 1 T-cane was permitted from 6 to 8 weeks after the surgery.

Clinical and radiographic evaluation

Clinical evaluations were graded using the Harris hip scoring system preoperatively and at the final follow-up (12). We performed a radiographic assessment for evidence of union at the proximal allograft-host bone junction, nonunion of the greater trochanter, or allograft resorption at final follow-up. Union was defined as callus formation, periosteal sclerosis, and lack of radiolucent line between allograft and host bone. We measured allograft resorption using the classification system of the University of British Columbia (9), in which the allograft is divided into 5 zones, similar to those used in the system of Gruen *et al* for THA (7). Zones 1 and 4 were excluded because of the absence of an allograft trochanter (zone 1) and because of the allograft-host junction (zone 4). The severity of bone resorption was graded as mild (resorption of less than one-third of the cortex in 1 zone), moderate (resorption of less than one-third of the cortex in 2 zones, or between one-third and two-thirds of the cortex in 1 zone), or severe (resorption of less than one-third of the cortex in more than 2 zones, between one-third and two-thirds of the cortex in 2 zones or more, or

resorption of more than two-thirds of the cortex or complete resorption in any zone).

We also examined the incidence of complications, including deep wound infection, revision surgery, dislocation, and heterotopic ossification in the Brooker classification.

RESULTS

Two patients (18.2%) died after the latest follow up, but the results of their final follow-up were included in this study. No patient died as a direct complication of this procedure. We excluded 1 case of infection that occurred immediately after surgery ; we could not evaluate this case, which was treated using a 2-stage protocol again. We did not use a segmental cortical allograft in re-revision surgery in this patient. Currently, he can walk without a cane and has a favourable functional outcome.

This left 8 patients still alive at the time of this review ; thus, we evaluated a total of 10 patients. The mean Harris hip score was 25.6 points preoperatively (range : 0-47 points), versus 74.8 points (range : 54-95 points) at final follow-up. Union occurred at the allograft-host bone junction in all 10 cases. The mean time to healing at the allograft-host bone junction was 11.8 months (range : 6-23 months). The greater trochanter did not unite in 4 of 7 hips (57.1%) and disappeared in 3 hips owing to resorption and resection after repeated revision surgery. After excluding one case of infection, 4 cases (40%) showed mild allograft resorption ; 1 (10%), moderate ; 1 (10%), severe ; and 4 (40%), none.

Postoperative complications occurred in 4 patients. One of 11 hips (9.1%) developed deep wound infection one month after revision surgery ; it was treated with debridement after resection of the segmental cortical allograft. One of 10 hip (10%) which dislocated was managed with closed reduction under general anaesthesia, and 2 hips (20%) developed heterotopic ossification (1 each class II and IV).

DISCUSSION

Revision surgery in the setting of severe proximal femoral bone deficiency is one of the major challenges in hip replacement surgery (3). The accepted reconstruction methods following repeated revision surgery include impaction allografting with long-cemented stems (12,16,18), distal press-fit fixation (21), and the use of a megaprosthesis (22,30) or a segmental cortical allograft as an APC (1,23). Impaction allografting is a well-described technique that has some success in patients with proximal femoral bone deficiency (10,16,28). However, radiographic and histologic examinations have suggested neovascularization of impacted allograft bone in the proximal femur (16). When there is substantial segmental bone deficiency, prosthesis subsidence and intraoperative fracture of the femur during impaction of the allograft bone are concerns (6,17,20). As such, we believe impaction grafting is better reserved for patients with contained or limited circumferential bone deficiency, whereas an APC or megaprosthesis is a more appropriate option for a femur presenting with full circumferential bone deficiency extending into the diaphysis, and in some cases of femoral discontinuity. A megaprosthesis, however, cannot achieve biologic reconstruction of the proximal femur. Moreover, the use of a megaprosthesis increases the complexity of the surgery, and with it, the rate of infection. In addition, the lack of abductor attachment to the prosthesis may compromise functional outcome (19). Loosening, implant breakage, or periprosthetic fracture also may occur, requiring salvage with an APC (4). Therefore, a segmental cortical allograft might offer favourable mechanical properties and allow for the reconstruction of sizeable proximal bone deficits. In addition, it facilitates reattachment of the hip abductors and soft tissues in an effort to preserve hip function (29). Some reports have described using a proximal segmental cortical allograft as an APC in revision THA, showing satisfactory long-term results after several years (2,23,29).

The prosthesis should be fixed to the allograft with cement. This was done in all of the present 11 cases. Bone ingrowth cannot occur within the allograft, and the allograft bone provides a good surface for cement interlock. Prophylactic antibiotics should be added to the bone cement. In this study, the proximal part of the femoral component was cemented into the allograft, and the distal stem was

positioned in the host distal femur without cement to permit compression at the osteotomy site. Although the technique of cementing the stem into the proximal femoral allograft has been well documented (1,23), there is no consensus regarding distal fixation. The options for distal fixation have included distal cementing, distal interference fit, and interlocking fixation. With a cementless stem, after achieving union at the bone-allograft junction, the allograft has a greater potential to share the weight bearing. We preferred using an interlocking stem when the junction was around or beyond the isthmus of the host femur, as we were concerned about the security of fixation in the distal femur. Their principal effect is to improve stem fixation until union at the allograft-host bone junction has occurred to such an extent that additional stability is no longer necessary. If there is inadequate union at the allograft-host bone junction, the screws will be exposed to excessive strain, and eventually, will break.
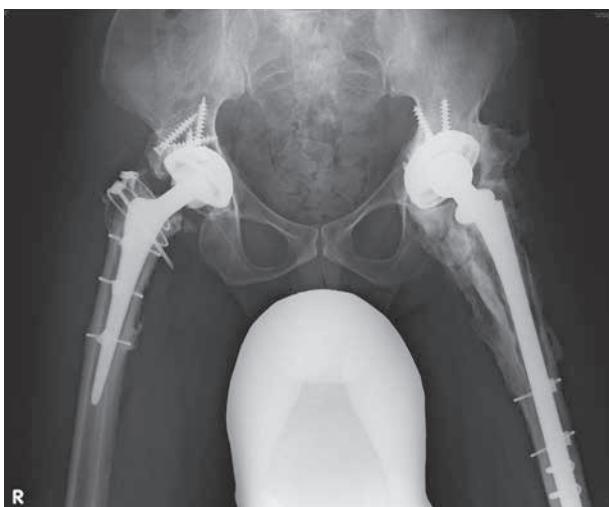
The literature documents several complications and their rates in reconstruction with a segmental cortical allograft as an APC. Nonunion at the allograft-host bone junction and the greater trochanter osteotomy site, postoperative infection, allograft resorption at the final follow-up, and aseptic loosening of the femoral component are the most frequently recorded. Nonunion is one of the more common complications when using an APC. The cause of nonunion presumably was motion at the allograft-host bone junction (2). In our 10 patients (excluding 1 case of infection), healing occurred at the allograft-host bone junction. We believe it is very important to achieve rigid stabilization of the junction at the time of the initial surgery. We routinely utilize allograft struts and morselized autograft or allograft bone around the junction, if there is concern regarding stability at the time of surgery. Moreover, the remnants of a very thin proximal part of the host femur as a vascularized sleeve were covered with the allograft-host bone junction and proximal segmental cortical allograft, and the allograft-host junction was secured using a cerclage cable.

Haddad et al (9) reported that the high rate of trochanteric nonunion might be related to the fact that this junction is under distraction, rather than com-

pression. Moreover, the blood supply to the junction of the trochanter and the graft comes from only the greater trochanter. The resulting instability is difficult to manage and is best avoided by the use of a trochanteric slide, rather than a transverse osteotomy. We achieved a good result in only one case, following an extended trochanteric osteotomy ; we think it is better to perform an extended trochanteric osteotomy when possible.

The overall infection rate of this series was 9.1%, which might seem high but was not unexpected, given the complexity of the surgery. Staged revision to another APC for infected hip arthroplasty (7 of 11 hips ; 63.6%) is a recognized technique that we employed successfully in the treatment of our patients. The use of massive structural allografts for reconstruction in a previously infected environment is controversial. Nusem and Morgan (19) reported a 5.6% reinfection rate at an average follow-up of 9 years. However, Hsieh et al (13), who used a 2-stage revision in a mixed cohort of patients receiving morselized or structural allografts, with an average follow up of 4.2 years, reported no reinfections. They concluded that using massive allografts in revision surgery after septic conditions restores bone stock and provides satisfactory results without the risk of recurrent infection.

Other authors have described varying degrees of graft resorption, which is similar to our findings. Only a small part of the allograft, where it comes in contact with the host femur, is replaced by host bone. Hamadouche et al (11) reported that, in the case of 1 patient who was followed for 10 years, they noticed that areas of the massive allograft that were in contact with the host bone were partly revascularized, but the portions that were not in contact were mostly resorbed. Blackley et al (2) reported 12 cases of mild-to-moderate resorption and only 1 case of severe resorption in 48 APCs, after an average follow-up of 11 years. In our 10 patients (excluding 1 case of infection), resorption of the graft was evident in 60%, and was graded as severe in 10%. Only 1 hip had almost complete resorption of the graft, which led to heterotopic ossification (Fig. 2). The stress shielding that occurs when interlocking long stems are used in osteoporotic bones should be regarded as a disadvantage of this method.

Fig. 2. — Radiograph, showing almost complete resorption of the allograft and heterotopic ossification (Case 4).

Therefore, we think that the host femur should be retained to enhance allograft incorporation and prevent resorption, the proximal segmental cortical allograft should be covered by the remnants of a thin proximal part of the host femur.

To conclude, after performing revision THA using a cementless interlocking stem with an APC, we obtained good stability and healing at the allograft-host bone junction in all our patients. If infection is prevented, this procedure can provide acceptable results in the presence of circumferential bone deficiency of the proximal femur caused by repeated revision surgery, and for the treatment of periprosthetic femoral fracture with poor bone stock in the proximal femur.

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