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HIP ARTHROPLASTY

Impaction bone grafting for femoral revision hip arthroplasty with Exeter Universal stem in Japan

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Abstract
Objectives The purpose of the present study was to analyze the retrospective clinical and radiographic results of femoral revision arthroplasties with impaction bone grafting performed by experienced Japanese surgeons.
Patients and methods We investigated the radiographic and clinical records more than 2 years after the surgery in 99 hips of 93 patients. The average age was 66.3 years (36–84 years) and the average follow-up period was 5.2 years (2–13 years). The Merle d'Aubigné and Postel hip score was used for clinical assessment, and peri-operative fractures were recorded. The survival curve was estimated using Kaplan–Meier method.
Results The mean Merle d'Aubigné and Postel hip score improved from 9.0 points to 15.2 points at the final follow-up. Augmentations for segmental defect of femoral cortices were undertaken in 55 hips. Metal or strut allograft plates were applied to 9 hips and 21 hips, respectively. Intra-operative fractures or perforations occurred in 20 hips. Re-operations of the femur were undertaken in nine hips including five post-operative femoral fractures. More than 5 mm of subsidence was observed in only 2 hips. The survival rates at 8 years after the operation were 94.8 % with femoral fractures as the end point, 93.1 % with any stem removal or exchange as the end point, and 99.0 % with aseptic stem loosening as the end point, respectively.
Conclusion The present study showed encouraging mid-term results of impaction bone grafting for femoral revision arthroplasty by experienced surgeons in Japan. Aggressive augmentation of segmental defects and attenuated femoral shafts prevents massive stem subsidence and periprosthetic fracture.

Keywords Impaction bone grafting · Revision THA · Allograft · Periprosthetic fracture · Survival curve

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Introduction

Bone stock recovery and stable implant fixation are the most important objectives in revision total hip arthroplasty, and impaction bone grafting of the femur using a polished tapered collarless stem is an attractive method to achieve both of them.

Since Gie et al. [1] showed encouraging preliminary results of this procedure in 1993, some researchers have reported favorable clinical follow-up results [1–9] but others have reported issues such as early subsidence or periprosthetic femoral fracture [10–13]. However, information about femoral impaction bone grafting has mostly been reported from Western countries [1–13], and only a few experiences in Asian countries have been described [14, 15].

Since 2000, we have organized training courses in Japan to teach the theoretical background and surgical skills needed for primary and revision total hip arthroplasty using the polished tapered collarless Exeter Universal stem (Stryker International; Mahwah, NJ, USA). In these training courses, detailed lectures on issues including femoral impaction bone grafting have been delivered by faculty members from the originating center in Exeter, UK.

The purpose of the present study is to describe mid-term radiographic and clinical follow-up results at least 2 years after femoral revision with impaction bone grafting by multiple Japanese surgeons who learned the precise technique from faculty members from the originating center in Exeter.

Patients and methods

Between February 1997 and December 2007, four surgeons (TI, HO, NK, and HF) performed 103 femoral revisions with the impaction bone grafting technique using the Exeter Universal stem in 97 patients. One patient died because of an unrelated disease within 2 years of the surgery, and three patients were lost from follow-up, so we investigated the radiographic findings and clinical records more than 2 years after the surgery in 99 hips of 93 patients. The indications for surgery were aseptic loosening of the femoral stem in 79 hips, secondary reconstruction after controlled deep infection in 11, femoral osteolysis in 6, and periprosthetic fracture with aseptic loosening in 3. The average age of the patients at the revision surgery was 66.3 years (range 36–84 years), comprising 72 women and 21 men. The average follow-up period was 5 years and 2 months (range 2–13 years). The femoral bone defects were classified according to Endo-Klinik classification [16]: grade I, radiolucent lines confined to the upper half of the cement mantle and clinical signs of loosening; grade II, generalized radiolucent zones and endosteal erosion of the upper femur leading to widening of the medullary cavity; grade III, widening of the medullary cavity by expansion of the upper femur; grade IV, gross destruction of the upper third of the femur with involvement of the middle third precluding the insertion of even a long-stemmed prosthesis. Four hips were classified as grade I, 37 hips as grade II, 42 hips as grade III, and 16 hips as grade IV.

Operative technique

Ninety-eight hips of ninety-nine hips were operated through a posterior approach and the other one hip through a direct lateral approach as described by Dall [17] because of the surgeon's preference. The four surgeons followed previously described operative techniques [18, 19] of femoral impaction bone grafting using the Exeter Universal stem.

Acetabular components were revised with impaction bone grafting technique in 60 hips, with cemented cups in 10 hips, with cementless cups in 4 hips, with bipolar hemiarthroplasty in 6 hips, with liner exchange in 2 hips, and with a cemented cup combined with a re-inforcement ring in 1 hip, respectively. In 16 hips, there was no treatment of the acetabular side.

After removal of the failed femoral component, the underlying cement and soft-tissue membrane within the femoral canal were removed. Depending on preoperative templating and/or intraoperative findings, metal wire mesh, metal plates, or strut allografts were applied to reinforce femoral cortical defects or thin femoral cortices to prevent intra- and post-operative fractures [20].

On templating, if an area of weakened bone distal to the position of the standard length stem was identified, a long stem [13] was selected if the proximal femur was large enough to accept it. In the current series, long stems were used in 13 hips. If the femoral canal was too narrow for a long stem, a standard-length stem was used combined with extra-medullary augmentation using a metal plate, or strut allograft plates. If a regional bone bank was available at the time of surgery, strut bone grafts had priority as the augmentation method. In cases with preoperative periprosthetic fractures, osteosynthesis was applied before bone impaction using a metal plate and/or strut allograft plates [21]. Calcar reconstruction with metal wire mesh [4, 22] for cases with proximal medial femoral cortical defects was planned after trial reduction to decide the appropriate size of reconstruction to prevent periprosthetic impingement.

For femoral impaction bone grafting, the technique described by Gie et al. [1] was used in all cases using the X-change revision system (Stryker International; Mahwah, NJ, USA). If the femoral canal was too narrow to use the smallest proximal packer in the X-change system, manual bone packing was performed using appropriate stem trials.

After diaphyseal impaction with small sized granules of fresh frozen morselized allograft harvested by bone mill, a trial reduction was performed using proximal packer as a phantom in order to assess stability and leg length. Metal wire mesh for calcar reconstruction was adapted at this stage if necessary. Large-sized granules of fresh frozen morselized allograft harvested using hand rongeur (diameter 5–10 mm) were used for bone packing at the most proximal end of the femur to ensure tight impaction in the neo-medullary canal.

After removal of the proximal phantom, retrograde cement dough (Simplex P Bone Cement, Stryker Limerick, Limerick, Ireland) filling using a cement gun followed by cement pressurization was performed. An appropriately sized polished tapered collarless stem was then inserted to the appropriate level to reproduce the trial setting.

Assessment

All assessment data were collected by one of the authors (T.I.) and a database was created for the following retrospective analysis.

For clinical assessment, the Merle d'Aubigné and Postel hip score [23] was assessed preoperatively and at the final follow-up. Operation time and volume of intra-operative bleeding were analyzed. Total volume of intraoperative bleeding was calculated as the sum of blood collected by suction and that absorbed by swabs. Peri-operative complications, such as dislocation, deep venous thrombosis (DVT), and intra- or post-operative fractures, were recorded. Augmentation techniques for bone defects and fracture prophylaxis were recorded.

For radiological assessment, antero-posterior hip radiographs were taken in all patients pre- and post-operatively and at the final follow-up. Radiographs were analyzed by one of the authors who belonged to the institute in which each patient had been operated. The radiographs were evaluated for subsidence according to the method of Fowler et al. [24] and for the position of radiolucent lines in the femur using the zones of Gruen et al. [25]. All the measurements were corrected for magnification using the known dimensions of the femoral head. Incorporation of the allograft was evaluated subjectively with a review of each radiograph. Using a method similar to that described by Gie et al. [1], the radiograph was judged as trabecular remodeling if stress-oriented trabeculae were recognized within the allograft and, as cortical healing if postoperative cortical thickening was recognized at the region of either pre-operative cortical defect, thinning or endosteal scalloping.

Survival curves

We analyzed details of re-operated cases and recorded the reasons for the re-operations. Survival curves were estimated by the Kaplan–Meier method [26]. The primary endpoints were any type of femoral re-operation, post-operative femoral fractures, any stem removal, and aseptic stem loosening at 5 and 8 years.

Results

Clinical assessment

Two cases (2 hips) had undergone resection arthroplasty for recurrent deep infection and these were excluded from the clinical scoring assessment. The mean Merle d'Aubigné and Postel hip score of the remaining 97 hips improved from 9.0 points (SD 3.6; range 1–17 points) before operation to 15.2 points (SD 2.3; range 3–18 points) at final follow-up.

The average operation time was 278 min (SD 93 min; range 115–546 min) and more than 5 h were needed in 61 hips (62 %) to complete the operation including time for acetabular side revision. The average volume of intra-operative bleeding was 893 ml (SD 708 ml; range 133–4,030 ml) and, in 68 hips (69 %), intra-operative bleeding was limited to <1,000 ml.

Fractures

Intra-operative fractures or perforations of the femur occurred in 20 hips, and these occurred during preparation in 13 hips, during impaction in 6 hips, and at reduction in one hip. Nineteen hips of the 20 intra-operative fractures or perforations were successfully managed with cerclage wires, metal bands, metal meshes, or metal plates. Femoral perforation in the other one hip was not recognized during the procedure and was detected by post-operative radiography. In this case, the femoral fracture had occurred 5 months after the surgery, and osteosynthesis using a metal plate with strut allografts was successfully performed.

Post-operative femoral fracture or re-displacement occurred in five hips and details of the post-operative fracture cases are shown in Table 1. All of the five post-operative fracture or re-displacement cases occurred within

Table 1 Details of post-operative fracture cases

Case no.	Age at op. (years)	Duration between op. and post-op. fracture	Endo-Klinik grade	Pre- or intra-op. fracture	Treatment
1	61	9 months	2	Pre-op. fracture (vancouver type B2)	ORIF (metal plate)
2	77	2 months	2	Intra-op. fracture (femoral perforation)	ORIF (metal plate + strut allograft)
3	56	2 months	2	Intra-op. fracture	ORIF (CCG bands)
4	51	1 year 2 months	4	Pre-op. fracture (vancouver type B3)	Revision (S-ROM)
5	63	2 years 2 months	4	(−)	ORIF (metal plate + auto fibula)

2 years and 2 months of operation, and had a history of intra-operative femoral fracture, perforation, or pre-operative periprosthetic fracture.

Four of the five post-operative fractured femurs had been treated with open reduction and internal fixation using metal bands, metal plates only, metal plate with strut allografts, and metal plate with auto-fibula grafts. One case, operated for Vancouver type B3 pre-operative periprosthetic fracture [27], had experienced failure due to aseptic loosening with re-displacement of the fracture site, and was re-revised using S-ROM [28] system. The other case, operated for Vancouver type B2 pre-operative periprosthetic fracture, had shown re-displacement of the fracture site, and open reduction and internal fixation with metal plate were performed. However, re-displacement occurred and reconstruction using a long stem with dual strut allograft bone plates was undertaken.

Dislocation, DVT, and deep infection recurrence in cases of secondary reconstruction for septic loosening were recorded in seven hips, two hips, and two hips, respectively. Augmentations for segmental defects of the femoral cortices were undertaken in 55 hips, and these were calcar mesh (Fig. 1) in 33 hips, femoral mesh in 14 hips, and calcar and femoral mesh in 8 hips. Metal or strut allograft plates were applied in 9 hips and 21 hips, respectively, for fracture fixation or fracture prophylaxis (Fig. 2).

Radiological assessment

Eighty-five of 99 hips (85.6 %) showed <2 mm stem subsidence, and only 2 hips showed more than 5 mm subsidence (Fig. 3). Radiolucent lines were detected in one or two Gruen zones in nine hips (Fig. 4), and there was no case that showed circumferential clear lines. Trabecular re-orientation was shown in 87 hips (87.9 %) and cortical healing in 85 hips (85.9 %).

Re-operations

Re-operations of the femur were undertaken in nine hips, and these were revision for aseptic loosening with fracture in one hip, osteosynthesis for periprosthetic fracture in four hips, stem removal for recurrent deep infection in two hips, and cement-in-cement re-implantation for recurrent dislocation in two hips.

Survival analysis

Kaplan–Meier survival analysis revealed that the survival rates with any type of re-operation of the femoral side as the endpoint were 91.1 % at 5 years and 88.9 % at 8 years (Fig. 5a). The survival rate with post-operative femoral fractures as the endpoint was 94.8 % at 5 and 8 years (Fig. 5b). The survival rates with any stem removal or exchange as the endpoint were 95.3 % at 5 years and 93.1 % at 8 years (Fig. 5c). The survival rates with aseptic stem loosening as the endpoint were 99.0 % at 5 and at 8 years (Fig. 5d).

Discussion

Impaction bone grafting is well recognized as an option for revision arthroplasty for loosened femoral components.

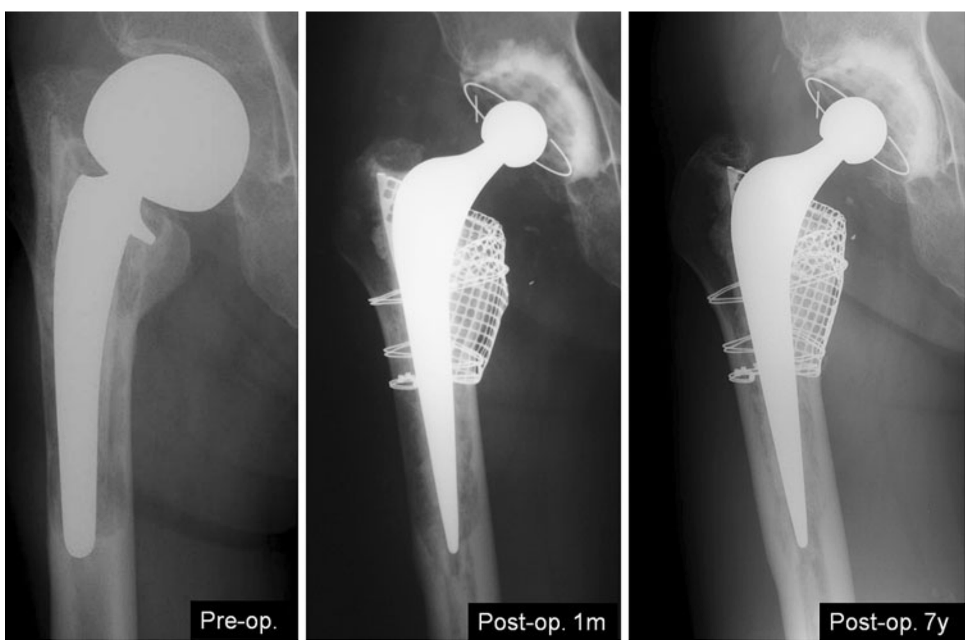

Fig. 1 A 69 year-old male with aseptic loosening of the right cemented stem of bipolar hemiarthroplasty. Segmental defect at the medial wall of the right proximal femur (calcar) was contained with metal wire mesh. At 7 years after the operation, remodeling of the femoral cortex was apparent with minimal subsidence

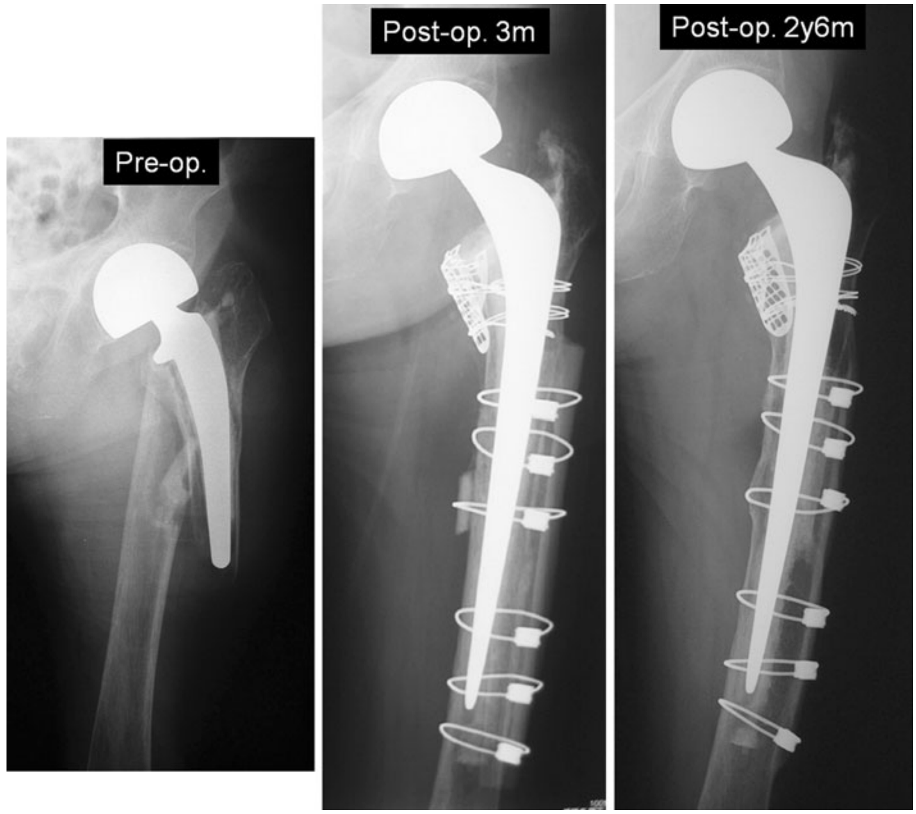

Fig. 2 A 77 year-old female with Vancouver type B3 femoral periprosthetic fracture. After internal fixation with dual strut allograft bone plates, long stem was inserted with impaction bone grafting technique. At 2 years and 6 months after the operation, incorporation of the allograft and stable long stem with minimal subsidence was shown

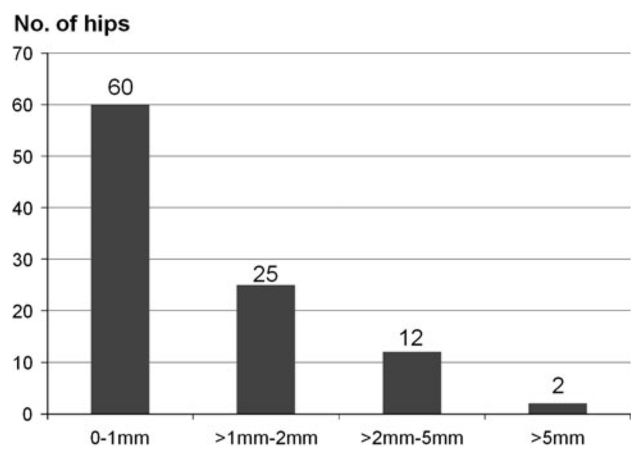

Fig. 3 Amount of stem subsidence

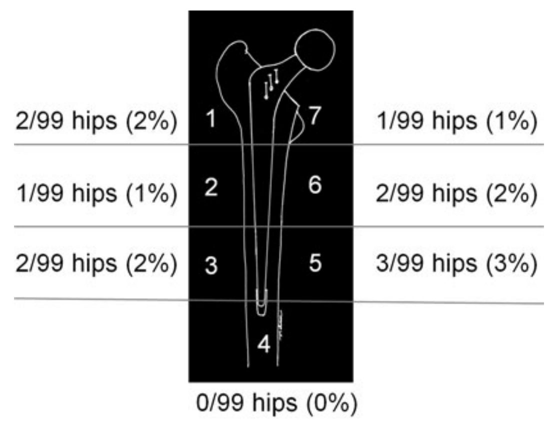

Fig. 4 Distribution of radiolucent lines of the cement-bone interface at the final follow-up according to the Gruen 7 zones

The advantages of this methodology are its capability of achieving biological reconstruction [29–32] of femoral bone stock loss and the expectation of good clinical results from the well-established polished tapered collarless stem [1–4, 6–9, 33, 34].

However, the procedure of impaction bone grafting of the femur is recognized as technically demanding, and one of the reasons for this is the frequent occurrence of intra-operative periprosthetic femoral fractures [10–12].

As the femoral cortex in revision cases is often attenuated [14, 20], intra-operative fractures and femoral perforations are common issues. Meding et al. [10] reported two femoral shaft perforations (6 %) and four intra-operative femoral fractures (12 %) during impaction in their 34 femoral impaction bone grafting series. Farfalli et al. [12] reported that 25 incidental perforations (9 %) and 34 fractures (12 %) had occurred in their 285 femoral revisions, and mentioned that most of those perforations and fractures were associated with cement removal.

In the current study, we experienced intra-operative perforations and fractures in 20 % (20 hips) of the cases and 65 % of them (13 of the 20 intra-operative perforations

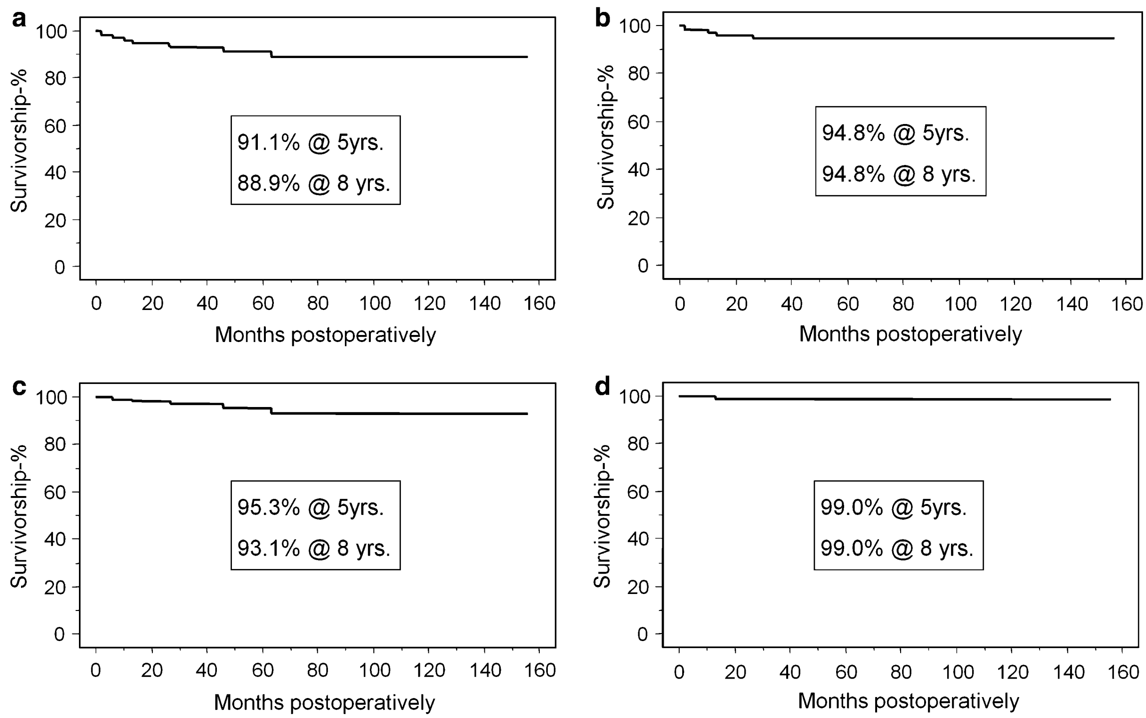

Fig. 5 Kaplan-Meier survival curves of the stem with various endpoints. **a** Survival curve with an endpoint of any re-operation for the femoral side. **b** Survival curve with an endpoint of post-operative periprosthetic fracture or re-displacement. **c** Survival curve with an endpoint of any stem removal or exchange. **d** Survival curve with an endpoint of re-operation for aseptic loosening of the stem

and fractures) occurred during preparation, removal of loose implants, and intra-medullary curettage.

The frequency of intra-operative perforations and fractures in the current study were almost equivalent to that in the previous studies. Moreover, most of those complications had occurred during preparation. Hence, aggressive augmentation before implant removal should be considered.

In addition, post-operative fracture is one of the most serious post-operative failure modes of femoral impaction bone grafting [20]. As well as intra-operative perforations or fractures, pre-operative periprosthetic femoral fractures and femoral segmental defects at the level of the stem tip are also risk factors for post-operative femoral fractures.

Cabanela et al. [11] reported six postoperative femoral fractures (11 %) in 54 femoral impaction bone grafting cases. Schreurs et al. [7] reported that the rate of post-operative femoral fracture was 9 % in their 33 cases. Halliday et al. [4] experienced nine post-operative fractures (4 %) in 226 hips and mentioned that the use of longer stems should be considered in cases with severe loss of bone stock. Sierra et al. [13] reported later from the same institute that even with the use of a long stem for impaction bone grafting, two (4.7 %) post-operative fractures had occurred in their 42 hips because of severe bone loss by the host femur. These studies suggest that more than the usual pre-operative planning and preventive measures for post-operative fracture are necessary in this demanding procedure.

In the current series, post-operative fractures occurred in 5 cases (5.1 %), and this is comparable to the results of the series by Halliday et al. [4] and Sierra et al. [13]. However, four of the five post-operative fracture cases had had pre- or intra-operative femoral fractures or perforations (Table 1). Two of these five cases were originally periprosthetic fracture cases, one case had an intra-operative fracture, and the other case had a femoral perforation during the operation. Although long stems were used in 13 hips (13.1 %) in the current series, regular length stems were used in those four post-operative fracture cases because of the limitations of shape and size of the femoral canals. More aggressive usage of long stems or femoral augmentation should have been given greater consideration in cases with thin femoral cortices at the tip of the regular length stem or with periprosthetic fractures [20].

Post-operative massive subsidence is another failure mode of impaction bone grafting of the femur. Kaneuji et al. [35] reported on their biomechanical experiment in which the largest compression force under load at the bone-cement interface around a collarless polished tapered stem was observed at the proximal medial site of the femur. This observation suggests that reconstruction of the proximal medial part of the femur, so-called “calcar”, is a key for the prevention of massive subsidence after impaction bone grafting using collarless polished tapered stems.

Ornstein et al. [5] reported in their radio stereometric and radiographic study that 11 of 15 hips showed more than 2 mm distal migration when using small size (approximately 3 mm in size) bone chips. Nelissen et al. [36] reported in their radio stereometric analysis study using 2–4 mm bone chips for bone graft that 8 of 18 hips showed progressive migration, and mentioned that the extent of bone defects and presence of cement mantle defects influenced the amount of stem migration. Meding et al. [10] reported that 13 of 34 hips showed an average 10.1 mm of subsidence at an average of 30 months after surgery; the method of reinforcement of the proximal femur was not described in their operative method. Hassaballa et al. [37] used irradiated allograft of around 5 mm in size and showed 15 of 69 hips subsided 5 mm or more within 2 years and concluded that irradiated bone is not suitable for this technique. The poor results due to post-operative subsidence in these studies may reflect a failure to achieve enough stem stability at the proximal part of the femur because of a lack of stable calcar reconstruction with metal mesh and tightly impacted larger bone chips.

To reduce the amount of subsidence, Halliday et al. [4] recommended the use of larger bone chips in capacious canals and tighter compaction of these chips within the femur. Since the calcar defect in aseptic loosening of the femoral stem is a common condition, the technique for calcar reconstruction can be considered a key influence on the whole of the post-operative results of femoral impaction bone grafting.

Leone et al. [20] reinforced the calcar region with metal mesh in 28 cases (68 %) of their 41 reconstructions and reported that the maximum amount of measured subsidence in their series was 2.5 mm. They emphasized vigorous impaction of bone graft and claimed that containment in the metaphysis of the stem with impacted bone graft was responsible for the minimal subsidence. We performed calcar reconstruction with metal wire mesh [4, 22] and tight packing of large morselized bone in 41 hips (41.4 %) of the whole series, and only two (2 %) of 99 hips subsided more than 5 mm within the follow-up period. This positive attitude towards calcar reconstruction with metal mesh might have resulted in the low rate of substantial subsidence in the current study (Fig. 3).

There are some limitations in the present study, such as its retrospective nature without control cases and it being a multi-surgeon series. However, as all surgeries were performed by well-experienced surgeons who were using the Exeter Universal stem for almost all of their hip arthroplasties, the present series is suitable as an assessment of the technical issues of femoral impaction bone grafting.

In conclusion, femoral revision with impaction bone grafting is a technically demanding procedure. Augmentation for proximal medial segmental defects and attenuation of the femoral shaft prevent massive stem subsidence and periprosthetic fracture. Using these aggressive femoral augmentation techniques, good mid-term survival rates after femoral impaction bone grafting were achieved, and this has encouraged us to continue to use this technique as the main option for femoral revision surgery.

Conflict of interest The authors declare that they have no conflict of interest.

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