Femoral Impaction Grafting in Revision Total Hip Replacement

- A follow-up of 540 hips

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Abstract

Between 1987 and 1999, 540 revision total hip replacements in 487 patients were performed at our institution with the femoral impaction grafting technique with a cemented femoral stem. All patients were prospectively followed for 2-15years post-operatively with no loss to follow-up.

494 hips remained successfully in situ at an average 6.7years. The ten year survival rate was 98.0% (95% CI 96.2 to 99.8) with aseptic loosening as the endpoint and 84.2% (95% CI 78.5 to 89.9) for re-operation for any reason. Indication for surgery and the use of any kind of reinforcement significantly influenced outcome ($p<0.001$).

This is the largest known series of revision THR with femoral impaction grafting and the results support continued use of this technique.

Keywords: impaction grafting, revision hip surgery, bone grafting, femoral revision, Exeter stem

Introduction:

Bone loss is often the principal technical consideration in revision arthroplasty surgery.[1;2] Bone restoration, if possible, is therefore an important goal of this surgery. Impaction of cancellous allograft bone at the time of revision of the femoral component in failed total hip joint replacement (THR) was pioneered in Exeter, UK, in 1987 [3-5] with implantation of a cemented Exeter stem (Stryker Orthopedics, Mahwah, NJ). The technique was based upon a similar technique used for the restoration of acetabular bone loss which had proved very successful.[6-10]

The procedure has evolved since it was first reported.[3;4;11] Initially the procedure was performed without the use of any specific instruments; milled allograft bone was impacted distally with femoral canal sizers and proximally it was packed radially with a trial stem two sizes larger than the final implant. In 1991 cannulated instruments were introduced in order to improve the quality of the impaction. A series of long Exeter stems (Stryker Orthopedics, Mahwah, NJ) were introduced commencing in 1992, permitting bypass of weak areas. Specific stainless steel reconstruction meshes for graft containment were available from 1995, improving the stability of the reconstruction. The second generation of impaction instruments ("X-Change III", Stryker Orthopedics, Mahwah, NJ) have been used since 1998. Details of the technique have been previously described, [12-14] including results of a subset of the patients reported in this study. [12]

As the technique was popularized, reports on the outcome of this technique from various centers have ranged from very encouraging [12;15;16], to those highlighting the technical difficulty of the procedure [17;18].

The purpose of this study was to report the clinical outcomes, survivorship, and complication rate of our experience with this technique from its inception over a 15 year period.

Material & Methods

From March 1987 to December 1999, 540 revision total hip replacement (THR) operations in 487 patients (53 bilaterally) were performed at the authors' institution with the femoral impaction grafting (FIG) technique in conjunction with a cemented polished, collarless, tapered femoral stem. The Exeter femoral component® (Stryker Orthopedics, Mahwah, NJ) was used almost exclusively (one Charnley stem was used). This series is a consecutive unselected series, including the "learning curve" of the very first cases. Eighty five percent (459/540) of hips had concomitant acetabular revision procedures, predominantly with a cemented all-polyethylene cup (68/459) and acetabular impaction grafting (367/459).

All patients were evaluated pre-operatively and post-operative scores were collected indefinitely; no patient was ever discharged. Pre-operative evaluation consisted of a clinical evaluation as well as identification of the mode of failure of the index arthroplasty. Clinical scores collected included the Charnley categorization,[19] the Merle d'Aubigne-Postel score,[19] the Harris Hip Score [20] and (since 1996) the Oxford Hip Score [21] (0-48 scale worst to best [22]).

Routine pre-operative radiographs consisted of an antero-posterior (AP) pelvis, AP femur, lateral hip and lateral femur views. Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) measurements were routinely taken. Any evidence of sepsis either pre-operatively or at revision led to management with a two-stage revision procedure. This did not discourage use of the FIG technique at the time of second stage re-implantation (this subgroup has been previously reported [23]).

Post-operative evaluation consisted of clinical review at six weeks, three months, six months, one year, and then annually until failure or death.

A comprehensive clinical review of all patients who had undergone revision THR with FIG at our centre up to 31 December 1999 was carried out, followed by detailed analysis of all gathered data.

There were 540 consecutive cases of FIG used in revision THR in 487 patients. 297 hips were in female patients (55%) and 243 in males (45%). The average age at surgery was 69.7 years (range 31-95 years). The indication for revision surgery was aseptic loosening in 438 cases (81.1%), infection in 61 cases (11.3%), acute peri-prosthetic fracture in 18 hips (3.3%) and 23 (4.3%) miscellaneous indications (Table 1). This was the first revision operation in 73% of operations, the second in 21% and third or more in 6%.

A cemented Exeter femoral component was used in all but one case (Charnley stem which failed), with Antibiotic Simplex AKZ cement (Stryker Orthopedics, Mahwah, NJ) which contained erythromycin and colistin. The majority of stems (83%) used were 44mm offset, 13% required a 37.5mm offset with other offsets making up the remainder. A standard length Exeter stem was used in 473 hips (88%) and 67 used Exeter long stems (12%), ranging from 200 to 260mm. There has been a general trend towards longer stems, mainly the 205mm stem, which have been used in one third of cases since 1995. Surgical approach was at the discretion of the surgeon. The posterior approach was used in 92.5%, direct or antero-lateral in 7% and trans-trochanteric in 0.5%. A posterior approach was combined with an extended trochanteric osteotomy in 17 hips (3.1%).

The graft used for the femoral impaction was predominantly non-irradiated fresh-frozen allograft femoral heads (Table 2). For a short period, some of the graft was pasteurized and irradiated bone was used very rarely. Occasionally, the patient's own femoral head was available from contralateral primary THR surgery. Bone extenders were occasionally used in addition, as part of clinical trials but these variations to standard morsellized femoral head allografting did not influence the outcome of the procedure.

If the cortical integrity of the femur was in doubt or frankly deficient, then various forms of augmentation were employed (Table 3). In the simplest form, cerclage wires were applied around the proximal femur to control a calcar split if one occurred during the impaction procedure or prophylactically to prevent a split. For bone loss in the medial femoral neck, these proximal defects were reinforced in early cases with the use of a fine wire mesh over a reconstruction plate screwed around the deficient neck of the femur. Pelvic reconstruction plates were also used on occasion. These techniques have been abandoned subsequent to the availability of dedicated, pre-shaped stainless steel reconstruction meshes (Stryker Orthopedics, Mahwah, NJ), secured around the proximal femur by cerclage wires or cables. In the event of grossly deficient diaphyseal bone, or in the presence of a femoral shaft fracture, additional supplementation was added, with the application of a cortical strut allograft or a 4.5mm DCP plate, often in combination with wire mesh to cover defects. Over half of the cases (56%) needed supplemental reinforcement of the femur, and 36% required two or more forms of reinforcement. A 26mm head was used in 54% of hips and a 30mm head in 43%. The other 3% were made up of 22mm and 32mm heads. Untoward events that occurred during the reconstructive procedure were documented.

Clinical scores are presented as means and standard deviations (SD) due to sample size and score recommendations.[22] Kaplan Meier survivorship [24] analysis was carried out; survival rates with 95% confidence intervals calculated and survival curves constructed. After confirmation of proportionality, Cox proportional hazards regression analysis [25] was used to determine if the indication for operation, number of previous revisions, reinforcement (none, cerclage wiring only or other), type of graft (fresh frozen allograft, treated allograft or other), gender or age at surgery significantly influenced failure (defined as revision for any reason – aseptic loosening, fracture, infection or perforation). Statistical analysis was performed using SPSS version 16.0 (SPSS Inc, Chicago, Il).

Results

Intra-operative complications fell into four categories: a fracture of the greater trochanter (3.5%), iatrogenic perforation of the femoral shaft (8.5%), a calcar crack (5.9%) or a femoral shaft fracture (1.9%). Only 1 case subsequently demonstrated trochanteric escape and this did not affect the outcome.

494 FIG hips remained successfully *in situ* at an average 6.7 years post-operatively, with a minimum of 2 years follow-up and with the longest survivor out to 15 years. With 52 hips remaining at risk at ten years, the Kaplan Meier survival (Figure 1) is 98.0% (95% CI 96.2 to 99.8%) for revision for aseptic loosening. With re-operation for fracture, where the stem was not changed, or revision for loosening as the endpoint, the survivorship becomes 89.7% (95% CI 84.4 to 95.0%) at ten years. Survivorship with revision or re-operation of the stem for any reason is 84.2 % (95% CI 78.5 to 89.9%). Cox regression analysis indicated that the use of either cerclage wiring alone (odds ratio of 4.1 compared with no reinforcement) or any other type of reinforcement (odds ratio of 3.7 compared with no reinforcement), significantly affected outcome ($p=0.002$). Also, indication for surgery ($p<0.001$) was significant (odds ratio of 3.5 for other

indications compared to aseptic loosening). Age at operation, gender, number of previous revisions and graft type were not significant in the model (Table 4).

127 hips had died by the time of the review. 368 hips remain in 343 living patients. Pre-operative scores, 2 year post-operative scores and outcome at most recent review are presented (Table 5).

There was a fifteen percent post-operative complication rate (Table 6). There were 29 peri-prosthetic fractures. Four were stress fractures at the stem tip diagnosed on follow up x-ray within 12 months of surgery. All patients were elderly, had rheumatoid arthritis or significant osteoporosis and had been reconstructed with short stems. These were all sub-acute and successfully managed conservatively with protected weight-bearing. Fourteen were caused by a fall or significant trauma. Seven of these occurred in the early post-operative period and seven occurred 12 months or more after surgery. Eleven were managed with open reduction and internal fixation retaining the initial femoral reconstruction and two were managed with revision with a further FIG procedure. One was managed non-operatively. There were 10 further peri-prosthetic fractures which are considered to have occurred as a consequence of technical error or inadequate reconstruction at the time of FIG, rather than trauma. These hips either had inadequate graft containment or should have had a long stem prosthesis or cortical strut reinforcement. The majority of this sub-group failed within 24 months of surgery. Seven were managed with open reduction and internal fixation, retaining the initial femoral reconstruction, and two were managed with revision with a further femoral impaction grafting. One was managed non-operatively.

Twenty four hips experienced post-operative instability. Nineteen of these were non-recurrent: 16 of which were managed with closed reduction and three requiring open reduction. There were three hips that required re-operation for recurrent instability. Two had revision of the acetabular component only and one had a cement-in-cement revision to correct a leg length discrepancy. The femoral reconstruction was not altered or compromised by these procedures.

Of the 61 hips that underwent two-stage revision THR for recurrent deep infection and reconstructed with FIG at the second stage, eight became re-infected, giving a success rate of 87% (N.B. one of these cases was a repeat failure and is recorded twice). There were 13 cases of proven deep infection in the 479 hips (2.7%) in which the revision surgery was being undertaken for non-infective reasons (that is, were not known to be infected at the time of revision). There were no recorded vascular complications. There was one case of meralgia paraesthetica. There were six sciatic nerve palsies, three of which completely recovered, two which partially recovered and one which remained permanent.

Of the 540 hips, 46 (8.5%) had been declared failures at the time of review (Table 7). As discussed above, there were 13 cases of proven deep infection in cases not known to be infected at the time of revision.

Nine of the 29 post-operative peri-prosthetic fractures ultimately led to failure of the FIG reconstruction (Table 6). Two required acute revision with another FIG procedure and nine developed subsidence or loosening of the femoral component after open reduction and internal fixation, of which seven were later re-revised. There were six failures due to non-union of a pre-existing peri-prosthetic fracture, where this had been the indication for surgery. All failed due to significant subsidence. Three were re-revised. One was a failure as a direct consequence of an unrecognized intra-operative complication, where the femoral component was implanted out through a cortical perforation and was revised acutely. The six remaining failures were all due to late subsidence. In retrospect, four of these had an obvious error in the reconstruction, such as inadequate impaction or graft containment. One stem was found to be loose at the time of revision for instability and the last case had no obvious error but was noted to have been a very difficult reconstruction. All have been re-revised at an average of 46 months (range 24 -79 months).

Discussion

Bone loss remains the single biggest technical concern in revision THR. Absence of a rigid skeleton, and a satisfactory bone surface to anchor implants to, precludes successful prosthetic arthroplasty. Whilst implant designs have proliferated over the last 20 years, no replacement for host bone has appeared. Other reconstructive options may achieve stable implant fixation to the host skeleton. However proximal bone stock is not reliably reconstituted with these options and many rely on distal fixation of the implant. Impaction bone grafting remains the only reconstructive technique that allows reconstitution of bone to the state seen at primary THR (Figure 2).

Adequate implant stability has been demonstrated to occur with femoral impaction grafting, both experimentally [26] and clinically.[27;28] A small degree of subsidence is to be expected, as seen with primary cemented THR using the Exeter stem with cement.[29]

Biological tests have demonstrated recovery of vital living bone after impaction grafting,[30-35] but is dependent on initial implant stability. However, caution must be taken in assuming that this equates to full restoration of vitalized femoral integrity.[5]

Complications with this technique have been previously highlighted.[17;18;36] The FIG technique has also been recommended by some authors for use in the most difficult situations such as Paprosky type 3 or Endoklinik type 3 and 4 femurs,[37;38] when the only other option is for distal fixation with a large diameter implant. These however, are also the most technically difficult situations. We suggest that it is primarily the nature of difficult revision hip surgery foremost, rather than the FIG technique, which is associated with a high complication rate. This is evidenced by our results of intra-operative complications in particular being largely due to the nature of the case rather than the technique (*vide supra*). Indeed a recent publication [39] has reported excellent results with this technique and survivorship of 94.0% (95% CI 92 to 96%) for revision for all causes at 15 years.

The introduction of long stems and long stem impaction instruments have allowed safer reconstruction of some of the more challenging cases, although the technique still remains challenging in cases of Endoklinik III and IV bone stock loss [40]. Options with stronger purpose-designed meshes have assisted in minimizing peri-operative problems. More recent series have demonstrated the efficacy of the technique when appropriate level of surgical experience, together with pre-operative planning, are utilized [12;41]. These favorable outcomes are seen in our series. As experience with the technique has grown, together with improvements to the instruments and technique, the clinical results have improved proportionally, although complications are still more common in the more severe cases of bone stock loss.[40]

We present the largest known single centre series of revision THR using the technique of femoral impaction grafting with morsellized cancellous bone graft in conjunction with the cemented Exeter stem. This has demonstrated excellent clinical results and survivorship in the intermediate term, with follow-up from 2 to 15 years and at an average of 6.7 years.

We conclude that if suitable methods of reconstruction are executed, femoral impaction grafting with the cemented Exeter stem provides a reliable revision solution with effective pain relief and lasting restoration of function. It remains the only revision option that reliably restores bone loss.

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Tables and Figures

Table 1: Indications for Revision

Indication	Subgroup	Number (%)
Aseptic Loosening (AL)	AL alone	410
	AL + sub-acute fracture	22
	AL + prosthetic fatigue failure	6
		438 (81.1%)
Deep Infection		**61 (11.3%)**
Acute Peri-prosthetic Fracture		**18 (3.3)**
Miscellaneous	Conversion from Girdlestone	3
	Conversion from Hemiarthroplasty	4
	Peri-prosthetic Fracture Non-union	8
	Technical Error with FG requiring repeat FG procedure	5
	Recurrent Instability	3
		23 (4.3%)
Total		**540**

Table 2: Types of Bone Graft Used

Graft Type	**Number**	**%**
Fresh Frozen Allograft	379	70.2
Irradiated Allograft	41	7.6
Pasteurized Allograft	84	15.6
Allograft + Bone Extender	19	3.5
Pure Autograft	8	1.5
Mixed Allograft/Autograft	9	1.7

Table 3: Frequency and Type of Femoral Reinforcements (some operations used more than one method of reinforcement)

Method	**Number**	**%**
Cerclage Wiring	274	50.7
Proximal Reinforcement	163	31.9
Cortical Struts	25	4.6
Diaphyseal Plate	30	5.6
Diaphyseal Mesh	50	9.3

Table 4: Odds ratios for failure for any reason and 95% confidence intervals for Cox regression

Variable	**p-value**	**Odds ratio (95% confidence interval)**
Age at op (odds ratio is increase in hazard ratio for each increasing year of age at op)	0.87	1.0 (0.98 to 1.03)
Gender (male cf female)	0.71	0.90 (0.49 to 1.63)
Graft (overall)	0.35	
treated cf fresh frozen	0.41	0.71 (0.31 to 1.63)
other cf fresh frozen	0.29	1.67 (0.65 to 4.35)
Indication (cf ASL)	<0.001*	3.55 (1.94 to 6.48)
Number of previous revisions (odds ratio is increase in hazard ratio for each additional revision)	0.83	1.04 (0.70 to 1.55)
Reinforcement (overall)	0.002*	
cerclage wiring alone cf none	0.003*	4.07 (1.64 to 10.1)
other cf none	0.001*	3.71 (1.67 to 8.27)

*indicates significant at 5% level

Table 5: Charnley categories and mean (SD) clinical scores at each time point

Score		Pre-op	2 year	Most recent
Charnley cat	A	154 (30%)	78 (20%)	71 (15%)
	B	228 (45%)	171 (43%)	152 (33%)
	C	124 (25%)	148 (37%)	237 (52%)
Charnley pain (0-6 worst to best)		2.7 (1.1)	5.5 (0.9)	5.3 (1.0)
Charnley function (0-6 worst to best)		2.1 (1.2)	4.1 (1.7)	3.5 (1.7)
Charnley range of motion (0-6 worst to best)		4.0 (1.2)	5.4 (0.8)	5.3 (0.9)
Mean Oxford score (0-48 worst to best)		19.0 (8.9)	38.1 (9.3)	34.5 (10.6)
Harris hip score - pain (0-44 worst to best)		21.7 (16.9)	38.2 (9.3)	36.0 (10.9)
Harris hip score - function (0-47 worst to best)		25.7 (14.1)	31.9 (9.3)	27.5 (11.1)

Table 6: Post-Operative Complications

Post-Op Complications	Number (%)	Details
Peri-prosthetic fracture	29 (5.4%)	4 stress fractures (treated conservatively) 14 trauma (7 < 1 year) 11 ORIF retaining FIG (2 FIG revised later) 2 revision with further FIG 1 treated non operatively 11 technical error 7 ORIF retaining FIG (3 FIG revised later) 2 revision with further FIG 2 treated non operatively
Instability	22 (4.1%)	19 non-recurrent 16 closed reduction 3 open reduction 3 recurrent 2 acetabular revision only 1 cement in cement revision for LLD
Neuro–vascular	7 (1.3%)	0 vascular 1 meralgia paraesthetica 6 sciatic nerve palsy 3 complete recovery 2 partial recovery 1 permanent
Deep infection new recurrent	21 (3.9%) 13 (2.4%) 8 (1.5%)	 13/479 previously not infected 8/ 61 previously revised for infection

Table 7: Mode of Failure

Failures	**Sub Type**	**Number**	**%**
Infection	New infection	13	
	Recurrent	8	
		21	**3.9**
Fracture	Acute	3	
	Loose or subsided post-fracture	9	
	Non-union of pre-op peri-prosthetic fracture	6	
		18	**3.3**
Technical	Stem out through cortical perforation	**1**	**0.2**
Aseptic Loosening/ Subsidence		**6**	**1.1**
TOTAL		**46**	**8.5**

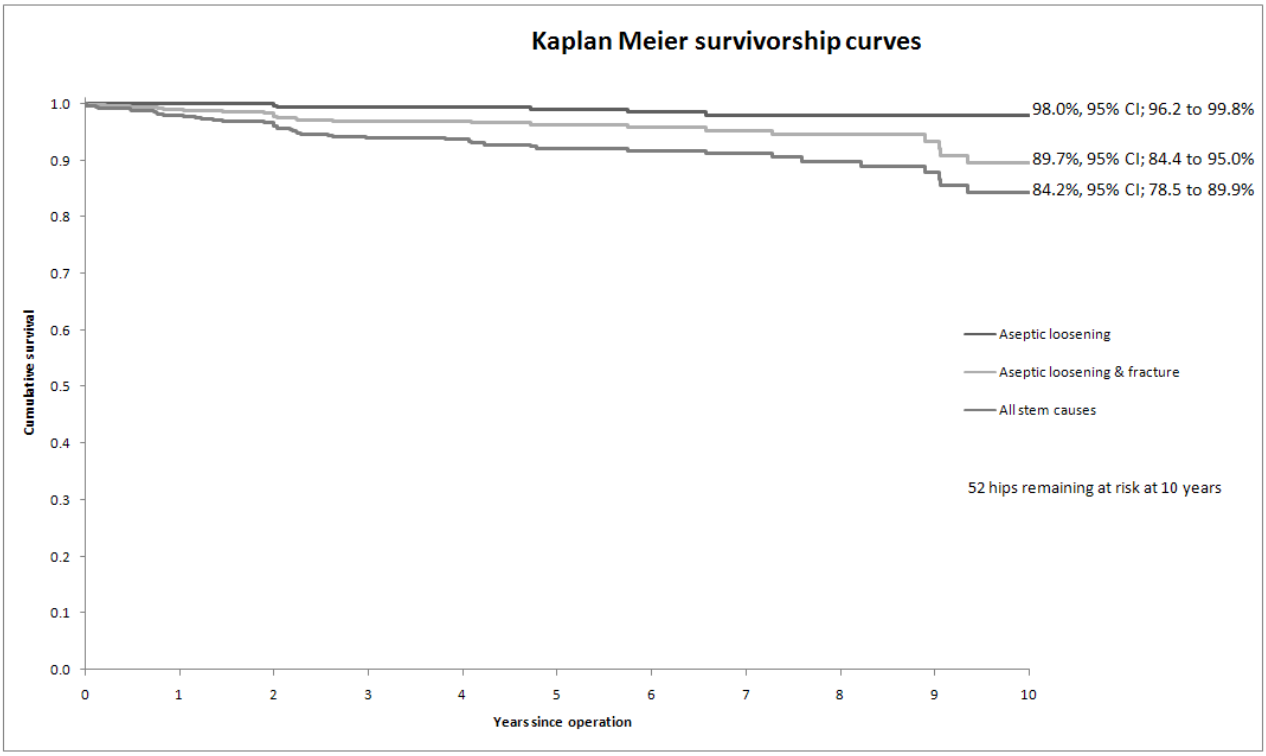

Figure 1. Kaplan Meier Survival curves for each endpoint.

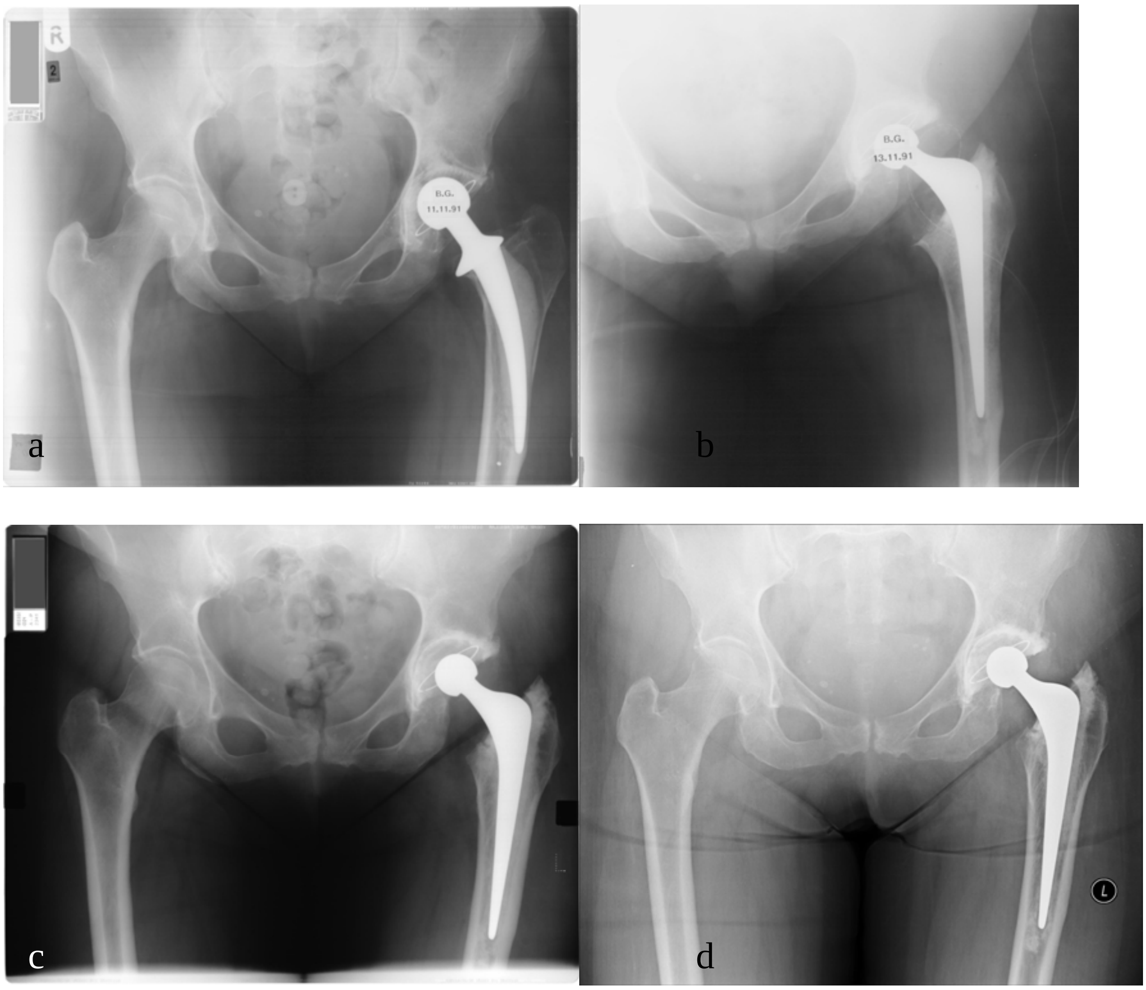

Figure 2. X-rays of a 38 year old lady with a previously failed revised THR at a) pre-revision femoral impaction grafting, b) post-op femoral impaction grafting, c) 10 years post-op and d) 18 years and 10 months post-op. X-rays released with the kind permission of the Exeter Hip Foundation.

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