Mid- to long-term outcomes of cementless modular, fluted, tapered stem for massive femoral bone loss in revision total hip arthroplasty

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Abstract

Background: Revision total hip arthroplasty is frequently accompanied by bone loss. The purpose of this study is to evaluate mid- to long-term results of revision total hip arthroplasty for massive femoral bone loss using cementless modular, fluted, tapered stems.

Methods: During the period of 2007 to 2015 at a single hospital, 34 hips (33 patients) underwent primary revision surgery with cementless modular, fluted, tapered stems due to massive bone loss, and patients with prosthetic joint infection (PJI) or tumours were excluded. The hips were revised with the LINK MP (Waldemar Link, Hamburg, Germany) prosthesis. Bone loss was categorized by the Paprosky classification for prosthesis loosening and Vancouver classification for peri-prosthetic fracture. All revision bearing surfaces were ceramic-on-ceramic (CoC). Clinical outcomes, radiographic outcomes and survivorship were evaluated.

Results: The mean follow-up was 9.1±2.5 years (range, 5-13 years). The Harris hip score was 43.6±11.5 preoperatively and maintained at 86.5±6.6 at the time of latest follow-up ($p<0.\ 05$). The X-ray showed bone ingrowth fixation in 30 hips (88%), fibrous stable fixation in 3 hips (9%) and instability in 1 hip (3%). The average stem subsidence was 3.9±2.2 mm (range, 1 to 10 mm). The survivorship of prostheses with re-revision for any reason was 95% (95% CI, 12.0 to 13.0) at the 10-year follow-up. Three (9%) re-revisions were needed, including 1 for aseptic loosening, 1 for dislocation and 1 for infection.

Conclusions: The mid- to long-term results of revision total hip arthroplasty with the cementless modular, fluted, tapered stem (LINK MP stem) are encouraging for massive femoral bone loss.

Introduction

Over the past few decades, the number of revision total hip arthroplasty (RTHA) procedures performed has gradually increased following the large cohort of total hip arthroplasties (THAs)[1]. Furthermore, it has been predicted that the demand for RTHAs will be dramatically amplified by over 137% worldwide by 2030 [2-5]. Aseptic loosening and peri-prosthetic fracture are two common causes of failure THA[6], which are associated with osteoclast-mediated bone resorption at the peri-prosthesis area[7]. Sustained osteolysis around the implant triggers massive bone loss and therefore fails to compress and solidly fix the implant[8]. In such a situation, RTHA is required to reconstruct damaged bone and restore the bone stock.

A variety of strategies have been applied to treat massive femoral bone loss in RTHA, including cemented stems[9], uncemented long stems[10], cylindrical stems[11], monoblock tapered stems[12] and bone grafting[13]. Nevertheless, the effect of these reconstruction techniques is limited and unsatisfactory in long-term results[14-16].

Cementless modular, fluted, tapered stems are another option for massive femoral bone defects in RTHA[17] and exhibit several beneficial characteristics. For example, the tapered distal design is easier to engage a short isthmic segment compared with cylindrical distal geometry[11]; moreover, the modular design allows adjustment of the leg length, anteversion and offset to optimize stability and reduce the potential risk of dislocation for specific patients[18]. Furthermore, the grit-blasted titanium surface facilitates bone growth and attenuates thigh pain and stress shielding[19]. However, concerns about junctional fractures of the modular stem have been raised and reported by a few authors[20, 21]. Several studies of RTHA with modular, fluted, tapered stems obtained good results at short- to mid-term follow-up[22-24]. However, few reports of the long-term results of the LINK MP modular prosthesis are available, and survivorship of the junction of the modular stem is worth further investigation.

Therefore, the purpose of this retrospective study was to evaluate the mid- to long-term clinical and radiographic results of modular, fluted, tapered, stem (LINK MP stem) in massive bone defect RTHA and long-term survivorship of the modular junction.

Materials And Methods

Patients

This was a retrospective study of patients who underwent primary RTHA with femoral proximal massive bone loss using LINK MP cementless modular, fluted, tapered stem (Waldemar Link, Hamburg, Germany). The preoperative bone defect was categorized by the Paprosky classification[25] for prosthesis loosening and Vancouver classification[26] for peri-prosthetic fracture. Patients whose bone loss classification met Paprosky type II, III or IV and Vancouver type B2 or B3 were included. Thirty-seven patients underwent RTHA with LINK MP stem from Jan 2007 to Jan 2015; however, 4 patients were lost to follow-up within 5 years after surgery. Therefore, we ultimately enrolled 33 consecutive patients (34 hips) with massive femoral bone defects after primary THA (Table I). The primary THA indications included osteoarthritis, femoral head necrosis, femoral neck fracture, developmental dysplasia of the hip (DDH), and ankylosing spondylitis. There were 17 males and 16 females; among these patients, 27 (79%) were Paprosky types II, III and IV, and 7 (21%) were Vancouver types B2 and B3 (Figures 1 and 2). The mean body mass index (BMI) was 23.7±3.7 kg/m^2 (range, 18 to 31 kg/m^2). The minimum follow-up was 5 years (mean 9.1 years; range, 5 to 13 years). The follow-up of 14 (41%) patients exceeded 10 years. All revision-bearing surfaces were ceramic-on-ceramic (CoC).

Operative Techniques

For the surgical approach, the patient was placed in the lateral position with a posterolateral approach along the previous incision in all operations. Then, the loosened implant was extracted, and the residual tissues in the femoral canal and acetabulum were debrided completely. At the same time, the removed tissue was tested for pathology and bacteriology. The extended trochanteric osteotomy (ETO) was performed in situ[27], such as severe femoral prosthesis subsidence or extensive femoral proximal osteolysis to avoid trochanteric fracture and eccentric reaming. After revision of the acetabulum, we prepared the femoral canal for implantation using hand reaming. Then, we applied trial segments to optimize the leg length, anteversion and soft tissue tension in a satisfactory position. Finally, the prosthesis was implanted, and hip joint activities were tested again. If there was no risk for dislocation, the incision was closed and bandaged under pressure. In addition, cerclage wires, structural autografts or allografts were used for femoral reconstruction. All RTHAs were performed by one single experienced orthopaedic surgeon.

Rehabilitation

The methods of enhanced recovery after surgery were applied to permit patients to recover faster and more effectively[28]. Tranexamic acid was used before and after surgery to reduce blood loss, and the drainage tube was removed within 48 h after the surgery. Routine anticoagulant therapy was applied for at least 14-35 days to prevent lower limb deep vein thrombosis (DVT). Physical therapists guided patients to exercise muscle strength and passive knee motion on the same day after surgery. Under the supervision of the physical therapist, they started to exercise actively, stand near the bedside and walk with a walker twice daily for 30 minutes each time. Full weight-bearing with a walker was required for 6 weeks.

Clinical and Radiographic Evaluation

Clinical outcomes were assessed by Harris Hip Scores (HHS)[29] and visual analogue scale (VAS) scores[30] preoperatively and at 3 days, 1 month, 6 months, and 1 year postoperatively and every 2 or 3 years thereafter. The maximum range of hip motion (ROM) was measured by a goniometer. Additionally, the presence of complications and survivorship of the femoral stem were investigated[31]. The possible issues associated with the RTHA procedure were analysed. The standard anteroposterior view of the bilateral hip and lateral view of the operative hip were taken for each patient. All imaging data were displayed and measured via the picture archiving and communication system (PACS, Neusoft Medical Information System, Shenyang, China). The radiographic evaluation included femoral stem fixation, the range of femoral stem subsidence, stress shielding, restoration of bone, integrin of allograft bone and the leg length discrepancy. Specifically, femoral stem fixation was classified as stable, fibrous stable and unstable[32]. The range of subsidence of the femoral stem was assessed using the distance from the tip of the greater trochanter to the stem shoulder[33]. The degree of stem subsidence exceeding 5 mm was considered significant[34]. The stress shielding was divided into four levels according to the Gruen zones[35]. Restoration of bone was calculated by the ratio of the width of the cortical bone to its outside diameters, which was measured at 1 cm distal to the inferior margin of the lesser trochanter[36]. The integrin of allograft bone was judged by the trabeculae between the grafted and the host bones[37]. The leg length discrepancy was required to correct to within 10 mm[38]. All radiographs were measured by two observers who were blinded to the patients' recovery.

Statistical Analysis

Continuous variable data were statistically analysed with the use of an independent-sample t test, and the mean and standard deviation were determined for each measurement, shown as ($\bar{x} \pm s$). Additionally, the 95% confidence interval, range and percentage were calculated for partial data. A Kaplan-Meier analysis was used to assess survivorship. P values of <0.05 were considered significantly different.

Results

Clinical Results

Clinical evaluation showed that the HSS scores improved significantly from an average of 43.6 points (range, 17 to 67) preoperatively to 86.5 points (range, 67 to 97) at the last follow-up in all patients, which showed a significant difference (Table II). Consistently, the VAS scores for these patients decreased from a mean preoperative 7.1 points (range, 6 to 9) to 1.1 points (range, 0 to 3) postoperatively. With respect to the comparison of pre- and postoperative HSS and VAS scores between the prosthesis loosening group and peri-prosthesis fracture group by the criteria of Paprosky and Vancouver, we found that the postoperative functional results were similar in patients of both groups. The postoperative function part of the HSS scores improved dramatically compared with that before surgery ($p<0.05$). Twenty-four (89%) patients in the Paprosky group felt satisfied with the surgery, while all 7 (100%) patients in the Vancouver group felt satisfied. No patients were disappointed with the RTHA. The operative results, including operative duration, length of incision, drainage volume, drainage duration, blood loss, blood transfusion, bone graft, ETO, and auxiliary fixation, are shown in Table III. The mean hospital stay was 15.4 days.

Radiographic Results

Overall, radiographic evaluation demonstrated that 30 (88%) femoral stems remained stable, while 3 (9%) stems attained stable fibrous fixation. Moreover, 1 (3%) stem displayed unstable fixation (Table IV). For the range of femoral stem subsidence, the mean subsidence of all stems was 3.9 mm (range, 1 to 10). Of these, 5 (19%) stems in the Paprosky group and 1 (14%) stem in the Vancouver group subsided over 5 mm, but all subsidence stabilized after 1 year without further progression. In addition, 1 out of 34 stems (3%) developed severe stress shielding accompanied by thigh pain, which required nonsteroidal anti-inflammatory drugs (NSAIDs) for relief. The integrin of allograft bone was satisfactory with enough osteointegrin in all cases. The averaged leg length discrepancy in all patients was 3.3 mm (range, 0 to 10), and we attempted to correct all cases exceeding 10 mm to 10 mm.

Complications

Overall, we observed that 3 (9%) intraoperative fractures (Figure 3) happened when the LINK stem was inserted, and 4 (12%) fractures occurred during the removal of the initial stem (Table V). All fractures were treated with plates, single cortical screws or cerclage wires for stable fixation. Three (9%) cases with infection were observed after revision, of which 1 case was treated by intravenous antibiotics and debridement, 1 case was treated by the vacuum sealing drainage (VSD) method, and 1 case needed re-revision. Three (9%) patients in the Paprosky group and 3 (9%) patients in the Vancouver group had lower limb vein thrombosis, which was successfully treated by routine anticoagulant therapy. One (3%) patient in the Vancouver group was observed with artery thrombosis, which was treated with a strainer. One (3%)

dislocation case happened in the Paprosky group, and re-revision was needed for reduction. No non-union ETO occurred in either group. One (3%) case of aseptic loosening took place 5 years after revision.

Survivorship

Overall, 3 (9%) re-revisions were needed, including 1 for aseptic loosening, 1 for dislocation and 1 for infection. There was no modular junction fracture in our study. As shown in Figure 4, the overall cumulative Kaplan-Meier survivorship with re-revision for any reason as the end-point was 95% at 10 years after surgery and 74% (95% CI, 12.0 to 13.0) at 13 years follow-up. The subgroup analysis of Kaplan-Meier survivorship is shown in Figure 5.

Discussion

Revision THA with massive bone defects indicates a complex challenge to perform and reconstruct the bone stock. Numerous different designs of prostheses, including cemented stems[9], uncemented long stems[10], cylindrical stems[11], and monoblock tapered stems[12], have been applied to treat this problem during RTHA. For Paprosky types I, II, and IIIA bone defects, these strategies have been associated with acceptable long-term results; however, for severe bone loss, such as Paprosky type IIIB, IV and Vancouver types B2 and B3, modular fluted tapered stems were considered to have the potential advantage of achieving long-term fixation[16]. In our study, we focused on the strategy of the LINK MP stem, which has exhibited satisfactory short- to mid-term results in previous studies[24, 39, 40], whereas the long-term results in functional restoration, pain relief, complications, and survivorship of stem have been less frequently reported.

HSS scores is the major tool used to evaluate the clinical outcome of hip surgery and incorporates dimensions of pain, function, deformity and activity[29]. The pain and function scores contribute to over 90% of the HSS, which required doctors not only to focus on the surgery but also to manage the patients during the whole perioperative period from the preoperative plan to rehabilitation. In our study, the average HSS after RTHA improved dramatically and reached 86.5 points at the last follow-up, which is higher than that in previous studies, with 77 and 78 points at the latest follow-up[38, 39]. We believe that the better functional outcomes in our study were associated with adequate reconstruction of extensive bone defects, reduced intervention in muscular attachments of the hip, the use of ceramic-to-ceramic surfaces in all patients and emphasized rehabilitation to enhance patient recovery after surgery.

The subsidence of the femoral stem was considered one of the most common risks for re-revision[41]. Moreover, the design of modular stems is commonly accompanied by early subsidence[42]. Van Houwelingen et al. demonstrated that 6 out of 48 (12.5%) cases of substantial stem subsidence (>5 mm) happened with a mean subsidence of 12.3 mm and achieved stability during the first year after RTHA[42]. Abdel et al. showed that 12 (2.4%) patients underwent stem subsidence >5 mm, and one of them exhibited progressive subsidence[43]. In our study, the average subsidence of the stem was 3.9 mm (range, 1 to 10), and 6 out of 34 (18%) cases subsided over 5 mm, which was higher than that in a previous study and met the features of the modular stem. Additionally, early weight-bearing and lower bone mass and quality might trigger stem subsidence in our study. However, no stem demonstrated progressive subsidence 1 year postoperatively. The risk of increased subsidence was affected by several factors. First, inappropriate and undersized stem diameter was found to be the key factor for progressive subsidence; therefore, the choice of a larger stem size and an increased 1-2 reamer size was suggested[41]. Second, the MP stem was designed with a 3° bow that accommodated the canal filling to provide better initial stability[40]. Moreover, the assistance of intraoperative fluoroscopy could help surgeons evaluate endosteal contact and implant position to avoid progressive subsidence.

Dislocation was another severe complication after RTHA. A high rate of dislocation was related to low femoral offset and deficient soft tissue. Weiss et al. showed that 17 (19%) dislocations occurred after RTHA within a minimum of 5 years of follow-up[39]. Wang et al. indicated that 2 of 58 (3.4%) hips dislocated after RTHA and that one patient needed further re-revision[24]. In our study, the number of dislocation cases was 1 (2.9%), which was lower than that in a previous study. The low rate of dislocation might be attributed to the modular design of the implant, which permitted adjustments of version and offset, good protection of the hip abductor mechanism during the surgical procedures and use of the largest possible head size.

The leg length discrepancy is vital for patients during the process of functional recovery and is related to back pain[44] and gait correction[45]. Weiss et al. showed that 33 (52%) patients had leg length discrepancies greater than 5 mm, and even 2 (3%) of these patients had leg length diversity over 30 mm[39]. Restrepo et al. demonstrated that leg length was corrected within 5 mm in 95 (78%) of the patients[38]. The mean difference in leg length in our study was 3.3 (range, 0 to 10) mm, and the leg length discrepancy in 28 (82%) patients was within 5 mm, which was better than previous results. The balance of both leg lengths intraoperatively could be adjusted by modular stem, which was an important advantage of the modular design.

Intraoperative femoral fracture was not uncommon during RTHA. Wang et al. observed that 10 out of 58 (17%) intraoperative femoral fractures happened during RTHA, which might be attributed to their lack of use of extended trochanteric osteotomy (ETO)[24]. ETO was reported to decrease the potential risk of intraoperative fracture during RTHA[46]. In addition, Ovesen et al. revealed that 4 (3%) fractures were detected intraoperatively[23]. Brown et al. showed that 4 out of 58 (7%) patients had intraoperative femoral fracture due to severe bone loss without adequate supportive bone[17]. The percentage of intraoperative femoral fracture in our research was 21%, which was higher than the proportion in previous studies. Consequently, more attention should be paid to prevent fracture during RTHA, for example, reaming by hand to centralize within the canal. Moreover, cerclage wire was considered a useful tool to protect the intact femur and avoid fracture. Furthermore, an appropriate stem size with routine fluoroscopy was helpful to reduce the risk of fracture intraoperatively.

Modular junction fracture has been regarded as a potential risk for the design of modular stems. Several studies have already reported such a situation. Lakstein et al. revealed that 6 out of 165 (3.6%) stems had a fracture at the junction of the modular implant[47]. The analysis of risk factors including excessive body weight, inadequate bone support, osteolysis, loosening and undersized prostheses were reported to lead to junction fracture. Van Houwelingen et al. demonstrated that 5 out of 48 (10.4%) patients experienced stem fracture of the modular junction with the standard ZMRÒ design[42]. The poor proximal femoral bone stock was identified as the vital factor for junction fracture in this study. Notably, Rodriguez et al. recorded 1 fractured stem in a Paprosky type IIIB patient [40]. The heavy weight and inappropriate size of the stem contributed to stem fracture. In our study, no case of junction fracture was observed, which might be due to the good bone reconstruction around the femoral proximal canal at the modular junction followed by adequate diaphyseal fit and no excessive BMI of patients, therefore indicating the long-term survivorship of the modular stem under adequate bone reconstruction.

Most patients in our study sustained bone grafting, which was beneficial for large metaphyseal bone loss to improve bone regeneration. In contrast, Wang et al. illustrated that none of their patients received bone grafts, and no patients had fatigue junction fractures during 3-7 years of follow-up[24]. However, we still suggest that bone grafts should be applied to patients with massive bone defects during RTHA to accelerate new bone formation and provide adequate support for implants.

There were some limitations of our study. First, our study was a retrospective study, which means that bias related to review and data was unavoidable, although we attempted to review each record precisely and objectively. Further prospective randomized controlled trials are essential. Second, the number of cohorts for RTHA with extensive bone loss was still not large enough, which might decrease the incidence of complications. Moreover, this study focused on only one type of stem without comparison to other alternative prostheses for massive femoral bone loss RTHA, which might be accompanied by selection bias. Finally, this was a single-centre study, and all operations were performed by a single surgeon. Future multicentre design with a large cohort is needed for further investigation.

In conclusion, the mid- to long-term outcomes of revision total hip arthroplasty with the cementless modular, fluted, tapered stem (LINK MP stem) are inspiring for massive proximal femoral bone defects.

Conclusions

The mid- to long-term results of revision total hip arthroplasty with the cementless modular, fluted, tapered stem (LINK MP stem) are encouraging for massive femoral bone loss.

Abbreviations

PJI: prosthetic joint infection; CoC: ceramic-on-ceramic; RTHA: revision total hip arthroplasty; THAs: total hip arthroplasties; DDH: developmental dysplasia of the hip; BMI: body mass index; ETO: extended trochanteric osteotomy; DVT: deep vein thrombosis; HHS: Harris Hip Scores; VAS: visual analogue scale; ROM: range of hip motion; PACS: picture archiving and communication system

Declarations

Authors' contributions

Kai Zheng: collection of data, data analysis and writing for manuscript. Ning Li and Weicheng Zhang: collection of data and data analysis. Jun Zhou: critical comments and help in writing of the manuscript. Yaozeng Xu: planning of study and performing surgery. Dechun Geng: Planning of study and supervisor of the study.

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Availability of data and materials

The corresponding author, Dr. Dechun Geng, had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Ethics approval and consent to participate

The study was approved by the ethics committee of First Affiliated Hospital of Soochow University. Due to the retrospective nature of the study, informed consent was waived.

Consent for publication

Not applicable

Competing interests

All authors declare that they have no competing interests.

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Tables

TABLE I Demographic Data

Parameter	Value
Age* (yr)	63.9±11.7 (range, 27 to 88)
Height* (cm)	161.7±7.9 (range, 140 to 180)
Weight* (kg)	62.0±10.1 (range, 46 to 80)
Body mass index* (kg/m^2)	23.7±3.7 (range, 18 to 31)
Side† (n=34)	18 (53%)
Left	16 (47%)
Right	
Sex† (n=33)	
Female	16 (48%)
Male	17 (52%)
Primary THA indication†	
Osteoarthritis	8 (24%)
Femoral head necrosis	6 (18%)
Femoral neck fracture	10 (29%)
Developmental Dysplasia of the Hip	7 (21%)
Ankylosing spondylitis	2 (6%)
Else#	1 (3%)
Interval period from THA to RTHA†	9.9±3.3 (range, 2 to 16)
Diagnosis† (n=34)	
Loosening	27 (79%)
Peri-prosthesis fracture	7 (21%)
Paprosky classification†	
II	7 (21%)
IIIA	11 (31%)
IIIB	7 (21%)
IV	2 (6%)
Vancouver classfication	3 (9%)
B2	4 (12%)
B3	
Mean follow-up*	9.1±2.5 (range, 5 to 13)

*The values are given as the mean and the standard deviation, with the range in parentheses. †The value is given as the number of hips, with the percentage in parentheses. #Else: acetabulum fracture

TABLE II Clinical Data at Preoperative and Mean 9.1 years Postoperative

Parameters	Preop.*		Postop.*		P Value	
	Paprosky II/III/IV	Vancouver B2/B3	Paprosky II/III/IV	Vancouver B2/B3	Preop.*	Postop.*
HSS score†(points) Overall	43.6 (17 to 67) [39.6 to 47.6]		86.5 (67 to 97) [84.2 to 88.8]		**0.001**	
Pain	17.4 (0 to 30) [14.8 to 20.0]	18.6 (10 to 20) [15.1 to 22.1]	41.4 (30 to 44) [39.6 to 43.2]	41.1 (40 to 44) [39.3 to 43.0]	0.56	0.46
Function	21.6 (10 to 35) [19.2 to 24.0]	18.6 (10 to 25) [13.4 to 23.7]	38.1 (30 to 45) [36.7 to 39.5]	39.7 (38 to 40) [39.0 to 40.4]	**0.002**	**0.02**
Deformity	2.5 (1 to 4) [2.2 to 2.7]	2.7 (1 to 3) [2.0 to 3.4]	3.4 (2 to 5) [3.2 to 3.7]	3.6 (3 to 4) [3.1 to 4.1]	0.83	1.00
Activity	2.6 (1 to 4) [2.3 to 2.9]	2.0 (11 to 3) [1.5 to 2.5]	1.1 (1 to 2) [3.1 to 3.5]	3.1 (3 to 4) [2.8 to 3.5]	0.22	0.85
Subtotal	44.1 (17 to 67) [39.2 to 48.9]	41.9 (30 to 50) [34.3 to 49.4]	86.2 (67 to 97) [83.4 to 89.1]	87.6 (85 to 92) [85.0 to 90.1]	**0.01**	**0.01**
VAS score†(points) Overall	7.1 (6 to 10) [6.8 to 7.5]		1.1 (0 to 3) [0.8 to 1.4]		0.36	
Subtotal	7.1 (6 to 9) [6.7 to 7.5]	7.3(6 to 8) [6.6 to 8.0]	1.1 (0 to 3) [0.8 to 1.5]	1.0 (0 to 2) [0.5 to 1.5]	0.66	0.18
Satisfaction (no. of hips)§						
Satisfeid	-	-	24 (89%)	7 (100%)	-	-
General	-	-	3 (11%)	0 (0%)	-	-
dissatisfied	-	-	0 (0%)	0 (0%)	-	-

*Preop. = preoperative, Postop. = postoperative, HSS=Harris Hip score, VAS=visual analogue scale . †The value is given as the mean, with the range in parentheses and the 95% CI in brackets. §The values are given as the number of hips, with the percentage in parentheses.

TABLE III Operative Data

Parameters	Paprosky II/III/IV	Vancouver B2/B3	Total
Operative Duration† (min)	192.9±70.1(range,115 to 335)	165.3±21.8(range,132 to 189)	187.2±63.9(range,113 to 335)
Length of Incision† (cm)	19.5±5.2 (range, 10 to 28)	18.9±5.2 (range, 14 to 30)	19.4±5.2 (range, 10 to 30)
Drainage Volume† (ml)	164.5±134 (range, 11 to 580)	166.4±63.9 (range, 90 to 260)	164.9±122 (range, 11 to 580)
Drainage Duration†(hrs)	53.3±12.2 (range, 24 to 72)	51.4±9.1 (range, 48 to 72)	52.9±11.4 (range, 24 to 72)
Blood loss (ml)	1129±734(range,200 to 3000)	842.9±287(range,400 to1200)	1070±673(range,200 to3000)
Blood transfusion (ml)	948.1±735 (range, 0 to 2900)	521.4±376(range, 0 to 950)	860.3±694(range, 0 to 2900)
Bone graft*	20 (74%)	7 (100%)	27 (79%)
ETO*	10 (37%)	0 (0%)	10 (29%)
Auxiliary fixation*#	10 (37%)	6 (86%)	16 (47%)
Hospital Stay† (days)	15.6±6.3 (range, 7 to 37)	15.0±6.2 (range, 9 to 28)	15.4±6.2 (range, 7 to 37)

†The value is given as the mean and the standard deviation, with the range in parentheses. *The value is given as the number of hips, with the percentage in parentheses. #Auxiliary fixation: plates, single cortical screws or cerclage wires

TABLE IV Radiographic Data			
Parameters	Paprosky II/III/IV	Vancouver B2/B3	Total
Femoral stem fixation†			
Stable	25 (92%)	5 (71%)	30 (88%)
Fibrous fixation	1 (4%)	2 (29%)	3 (9%)
Unstable	1 (4%)	0 (0%)	1 (3%)
Subsidence†	3.8±2.4 (range, 1 to 10)	4.1±1.8 (range, 2 to 7)	3.9±2.2 (range, 1 to 10)
≤5 mm	22 (81%)	6 (86%)	28 (82%)
>5 mm	5 (19%)	1 (14%)	6 (18%)
Integrin of allograft bone†	27 (100%)	7 (100%)	34 (100%)
Leg length discrepancy*(mm)	2.7±2.4 (range, 0 to 10)	5.7±2.7 (range, 1 to 9)	3.3±2.7 (range, 0 to 10)
≤5 mm	24 (89%)	4 (57%)	28 (82%)
>5 mm	3 (11%)	3 (43%)	6 (18%)

*The values are given as the mean and the standard deviation, with the range in parentheses. †The value is given as the number of hips, with the percentage in parentheses.

TABLE V Complications			
Parameters	Paprosky II/III/IV	Vancouver B2/B3	Total
Intraoperative fracure†			
Inserting stem	2 (7%)	1 (14%)	3 (9%)
Removing stem	3 (11%)	1 (14%)	4 (12%)
Infection†	2 (7%)	1 (14%)	3 (9%)
Thrombosis†	3 (11%)	3 (43%)	6 (18%)
Vein	0 (0%)	1 (14%)	1 (3%)
Artery			
Dislocation†	0 (0%)	1 (14%)	1 (3%)
ETO nonunion†	0 (0%)	0 (0%)	0 (0%)
Postop. Peri-prosthesis fracture†	0 (0%)	0 (0%)	0 (0%)
Aseptic loosening†	1 (4%)	0 (0%)	1 (3%)
Modular junction Fracture†	0 (0%)	0 (0%)	0 (0%)

ETO= extended trochanteric osteotomy. Postop.=postoperative. *The values are given as the mean and the standard deviation, with the range in parentheses. †The value is given as the number of hips, with the percentage in parentheses.

Figures

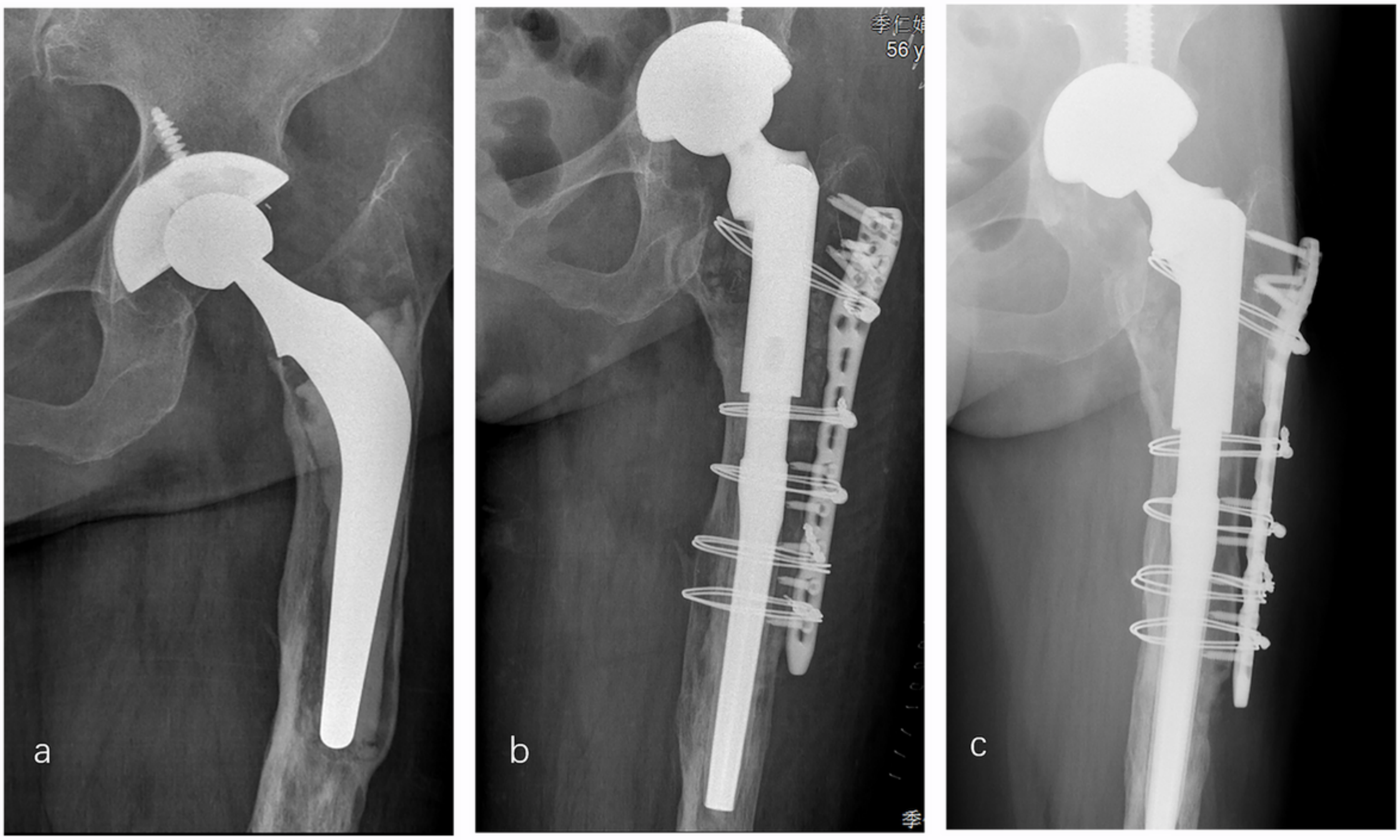

Figure 1

Radiographs of a 56-year-old woman who underwent hip revision 4 years after THA. a. Radiograph before revision, showing a loosened cemented stem. b. Radiograph postoperative with the MP Link modular prosthesis. c. Radiograph at 10 years postoperatively. The patient obtained a good clinical outcome with no subsidence of the stem.

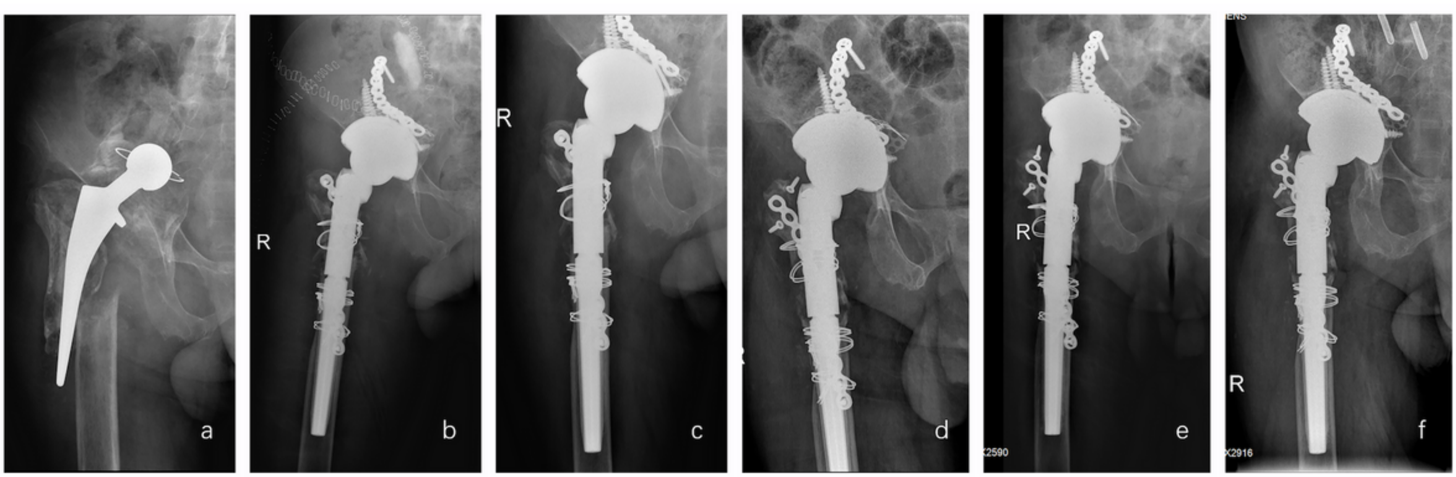

Figure 2

Radiographs of a 60-year-old man who underwent hip revision 8 years after THA. a. Radiograph before revision, showing a peri-prosthesis fracture. b. Radiograph postoperative with a plate and cerclage wire. c.

Radiograph at 1 years postoperatively. d. Radiograph at 3 years postoperatively. e. Radiograph at 5 years postoperatively. f. Radiograph at 8 years postoperatively

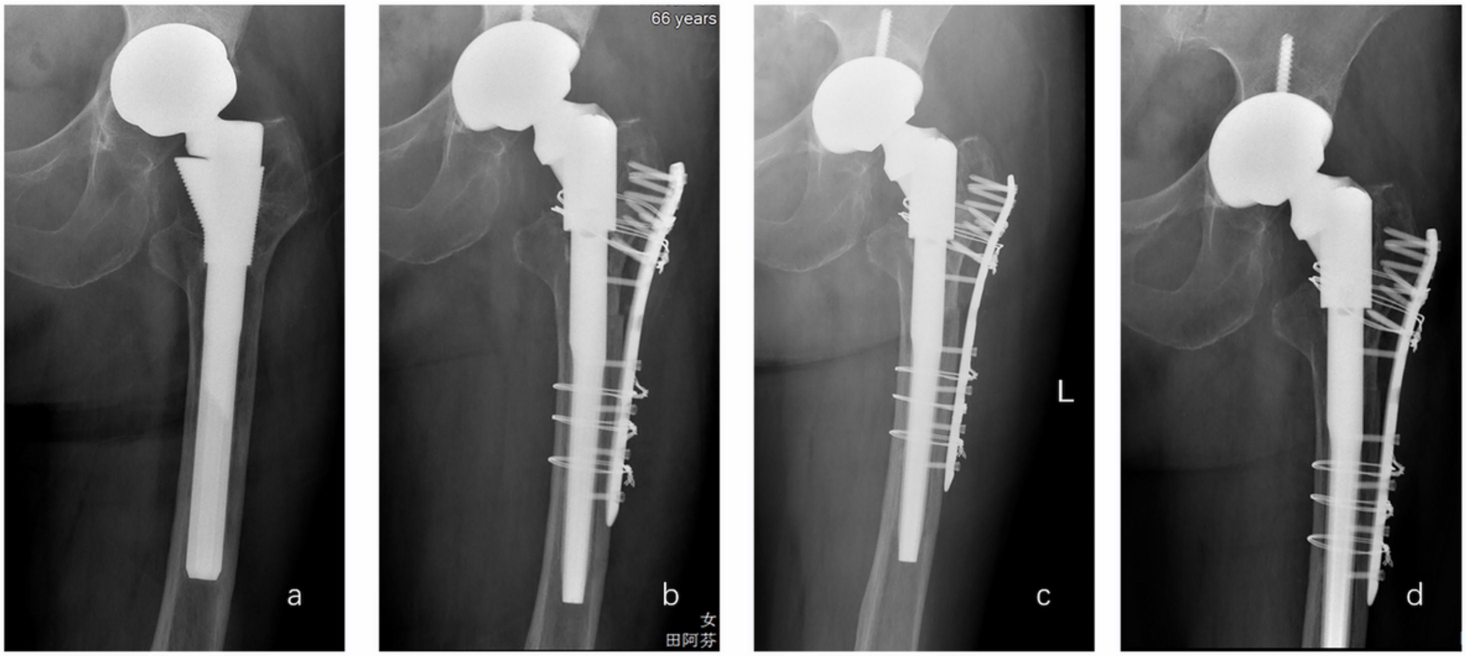

Figure 3

Radiographs of a 67-year-old female who underwent hip revision 10 years after THA. a. Radiograph before revision, showing a loosened cementless stem. b. Radiograph postoperative with an intraoperative fracture when removed the initial stem. c. Radiograph at 5 years postoperatively. d. Radiograph at 10 years postoperatively.

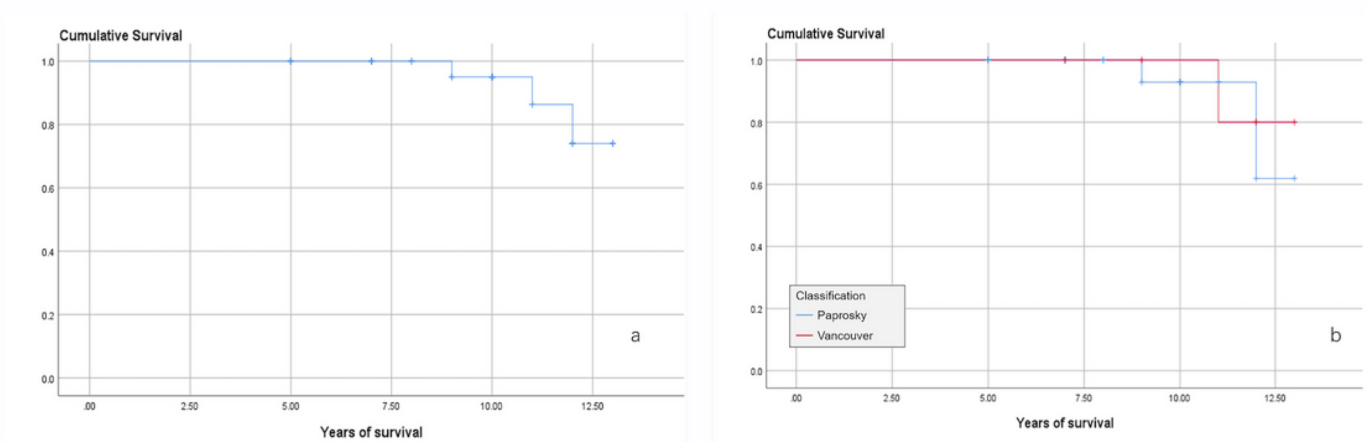

Figure 4

a. Kaplan-Meier overall survival rate. b. Kaplan-Meier survival rate according to the classification (Paprosky & Vancouver)