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ORIGINAL ARTICLE • KNEE - ARTHROPLASTY

Revision knee arthroplasty using a distal femoral replacement prosthesis for periprosthetic fractures in elderly patients

Ehab Girgis[1] · **Christoph McAllen**[1] · **Jonathan Keenan**[1]

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Abstract
Purpose Distal femoral periprosthetic fractures above a total knee replacement in elderly patients are technically challenging to treat. Bone quality is often poor, the fractures comminuted, and post-operative mobilisation is difficult. This study assesses the clinical, radiological and functional outcome of revision knee distal femoral replacement (DFR) in these fractures.
Methods We identified 14 patients over 70 years of age (70–94) who underwent DFR for periprosthetic fractures above a knee replacement. All the 14 fractures were classified as Su type III. Clinical and radiological records were retrospectively reviewed. The mean of clinical follow-up was 27 months (8–46). Functional outcome was assessed using Oxford Knee Score and EQ-5D (UK English Version) score at a mean time of 35 months (20–65). The Knee Society patient category score was also evaluated.
Results The median post-operative knee flexion was 100° (range 90°–135°). Nine patients (64%) returned to their pre-fracture level of mobility or better. The median post-operative Oxford Knee Score was 27 (range 4–40). The median EQ-5D was 11 (range 6–12). Cognitive impairment negatively impacted the functional outcome in four patients. One patient died early post-operatively, and two patients had complications.
Conclusions DFR led to satisfactory outcome in our patients with a relatively low complication rate. In our experience, revision knee distal femoral replacement is an appropriate method to treat elderly patients who sustained periprosthetic Su et al. type III distal femoral fractures in association with poor bone stock, caused by osteoporosis and/or comminution.

Keywords Periprosthetic supracondylar fracture · Distal femoral replacement · Revision total knee replacement · Elderly

Introduction

The treatment of very distal femoral periprosthetic fractures in elderly patients is a difficult and increasingly encountered problem. These fractures are often comminuted, and bone quality is often poor. It is difficult to predict whether internal fixation of such fractures will be stable enough to allow early post-operative weight bearing. There is limited current evidence about the results of distal femoral replacement (DFR) prosthesis in elderly patients with periprosthetic distal femoral fractures. There are concerns about implant longevity and complications, mainly derived from the use of the older generations of hinged endoprosthesis designs [1].

The spectrum of treatment of periprosthetic supracondylar femoral fractures in the elderly patients varies from the use of plaster cast or hinged brace at one end of the spectrum to the use of DFR endoprosthesis at the other. Herrera et al. [2] in a systematic review of 415 cases of periprosthetic supracondylar fractures found that the relative risk reductions for non-union and revision surgery for retrograde nails and locking plates were significantly lower when compared with non-operative treatment. Cast or brace immobilisation for displaced fractures had an unacceptable high rate of non-union and mal-union [3, 4]. In addition, they may result in marked loss of the knee range

✉ Ehab Girgis
ehab.girgis@nhs.net

[1] Department of Trauma and Orthopaedic Surgery, Derriford Hospital, Plymouth, UK

of movement [5, 6] and high risk of complications of prolonged immobilisation [5]. This method of treatment is now considered historical especially with the availability of modern implants and is indicated only in medically unfit patients with undisplaced fractures [5, 7].

Current options commonly used to treat these fractures are the retrograde intramedullary nail and the distal femoral locking plate [7]. However, in elderly patients with periprosthetic supracondylar femoral fractures, the bone stock in the distal fragment can be too deficient to allow good distal locking screw or bolt purchase when either a locking plate or retrograde intramedullary nail is used.

Revision knee replacement using distal femoral replacement (DFR) has been used to treat such complex fractures in small case series with variable results. Some reported very good outcome with low risk of complications [8–10], and others reported relatively high complication rate and advised its use as a salvage operation [11, 12]. Berend and Lombardi [8] used rotating-hinge DFR in non-tumour cases in 37 patients with average age 76 years including 13 periprosthetic fractures with overall implant survivorship 87% at 4 years. The selection of the patient and the fracture that require this type of replacement is controversial with some studies advocate the use of locking plates in these fractures [13, 14].

The aim of this retrospective study was to assess the clinical, radiological and functional outcome of a third-generation distal femoral rotating-hinge endoprosthesis in periprosthetic fractures above knee replacement.

Materials and methods

After institutional approval, the electronic database of our operative theatres was searched for Global Modular Replacement System (GMRS, Stryker, Newbury, UK) in knee surgery that was done between 2009 and 2014. We identified 22 patients who had GMRS endoprosthesis around the knee during this period. We excluded eight patients who had GMRS endoprosthesis for other indications than periprosthetic supracondylar fractures. There were 14 patients who underwent GMRS distal femoral replacement for periprosthetic distal femoral fractures. Retrospective review of the medical and radiographic records of these 14 patients included the patients' demographics, fracture criteria, operative notes, complications, follow-up documentation, clinical, functional and radiographic assessment.

Patient characteristics

There were 12 females and two males with a mean age of 82 years (range 70–94 years). Seven fractures were in the right distal femur and seven in the left. All patients have had significant, often multiple, comorbidities including osteoporosis, obesity, cardiovascular disease, cognitive impairment and concomitant arthritis. This was reflected in the ASA (American Society of Anaesthesiologists) grade being II in five patients, III in seven patients and IV in two patients. Seven patients had the diagnosis of osteoporosis and were already on treatment at the time of the fracture. Five patients had early or diagnosed dementia at the time of the fracture. The mean time since the primary total knee replacement (TKR) was 10.5 years (range 1 month–27 years). Twelve were cruciate-retaining TKR, and two were cruciate-substituting. Ten patients had the distal femoral replacement (DFR) for acute periprosthetic distal femoral fractures. Three patients had previous internal fixation using Less Invasive Stabilisation System locking plate (LISS, Synthes) and then developed non-union and plate failure including one infected non-union. The locking plates failed at average of 6 months (3–9 months) when patients were allowed weight bearing for the first time post-operatively. One patient had temporary bridging external fixator to allow transfer from another country to our hospital prior to the DFR (Table 1).

Fracture characteristics

The mechanism of injury was a simple fall in 12 patients, fall from electric mobility chair in one patient and motor vehicle accident in one patient who sustained multiple injuries. Su et al. [5, 15] classification (Table 2) of supracondylar periprosthetic fractures was used as it provides guidance for surgical treatment and has good inter-observer reliability and intra-observer reproducibility [7, 15]. All the radiographs of the 14 periprosthetic distal femoral fractures in our patients showed Su classification type III fractures and radiological signs of osteopenia. Pre-operative CT scanning was done in eight patients to assess for comminution and fracture pattern. This contributed to the decision on the choice of the treatment method. Eleven fractures were multi-fragmentary, included severe comminution in eight and small comminution in three. There was no obvious comminution in the other three fractures.

Surgical management

Tourniquet was used only in three operations (21%) with mean time 113 minu (range 90–130 min). Seven operations were carried out by a consultant with experience in both revision arthroplasty and trauma surgery and the other seven by a supervised senior fellow. Extended midline incision including the old scar and medial parapatellar approach were used in all operations. The lack of sufficient bone attached to the femoral component to enable

Table 1 Patients' data

Patient	Age	Sex	Type of TKR	Mechanism of injury	Knee Society patient category score	Previous periprosthetic fracture fixation	ASA grade	Medical comorbidities
1	75	F	CR	Fall	C	Yes LISS plate Infected non-union	2	SLE, Obesity, Chronic anaemia, HTN
2	88	F	CS	Fall	C	No	2	HTN, Hypothyroid, O. A., CKD
3	80	F	CR	Fall	C	No	3	Dementia, RA, HTN, Lung fibrosis
4	91	F	CR	Fall	C	No	2	Dementia, Polyarthritis
5	84	F	CR	Fall	C	No	2	Osteoporosis, Fragility fractures, IHD
6	75	F	CR	Fall	C	Yes LISS plate Non-union	3	HTN, AF, Obesity, H.H., Chronic back pain
7	80	F	CR	Fall	C	No	3	RA, Osteoporosis, anaemia, CKD, Hypothyroidism, DM, severe low back pain
8	76	F	CR	Fall	A	Yes LISS plate Non-union	2	Osteoporosis, Obesity, HTN
9	70	F	CS	Fell off mobility scooter	B	Yes Temporary external fixator	3	Morbid Obesity, IHD, acute UTI
10	85	F	CR	Fall	B	No	3	Dementia, AF, CCF, IHD, HTN, acute UTI
11	84	F	CR	Fall	B	No	3	Dementia, HTN, IHD
12	78	M	CR	RTA	C	No	4	CKD, HTN, IHD, Polytrauma
13	94	M	CR	Fall	C	No	4	HTN, CKD, PVD, DM, Vascular Dementia, Chronic anaemia, recurrent UTI
14	84	F	CR	Fall	A	No	3	Osteoporosis, HTN, Crohn's disease

ASA American Society of Anaesthesiologists; *F* female; *M* male; *CR* cruciate retaining; *CS* cruciate substituting; *LISS* less invasive stabilisation system; *RTA* road traffic accident; *SLE* systemic lupus erythematosus; *HTN* hypertension; *O. A.* osteoarthritis; *CKD* chronic kidney disease; *RA* rheumatoid disease; *IHD* ischaemic heart disease; *AF* atrial fibrillation; *H. H.* hiatus hernia; *DM* diabetes mellitus; *UTI* urinary tract infection; *CCF* congestive cardiac failure; *PVD* peripheral vascular disease

Table 2 Su et al. [5, 15] classification of supracondylar periprosthetic femoral fractures

Type 1	Fracture line is proximal to the femoral component
Type 2	Fracture starting at the level of the upper edge of the femoral component and extending proximally
Type 3	Fracture in which any part of the fracture line is distal to the tip of the anterior flange of the femoral component

stable internal fixation was confirmed intra-operatively before proceeding with DFR. Distal femoral Global Modular Replacement System (GMRS, Stryker) was used in all patients with Modular Rotating-Hinge (MRH) tibial baseplate and polyethylene tibial inserts.

For later rotational orientation of the femoral endoprosthesis, a longitudinal diathermy mark was made on the anterior cortex of the femur above the resection level in line with the prosthetic trochlear groove [1] after provisional reduction of the fracture. The resection length was measured from the prosthetic distal femoral condyles to a level above the fracture that can be reproduced by the available implants. In addition, the old meniscal scar, patellar height above the joint line and comparison with the other limb were used to guide restoring the joint line level [16]. After careful subperiosteal dissection of the distal

femur, the osteotomy was performed perpendicular to the shaft whilst protecting the posterior and medial structures in order to resect the distal fractured femur with the attached femoral component. Hand reamers were utilised to progressively ream the femoral canal in order to reduce the risk of intra-operative fracture. Removal of the tibial component followed by proximal tibial recut and canal reaming were performed. The selected stem diameter was either the same size or 1 mm smaller than the reamed canal size [17, 18]. Trial components were assembled and used initially to check the ease of stems insertion, correct rotation, proper prosthesis length, joint line level and patellar tracking. We used the 65-mm replacement length of the distal femoral component which has a built-in 6° valgus offset in the 14 patients including three who required the additional use of extension pieces due to the proximal extension of the fracture (Fig. 1). Cemented stemmed tibial baseplate with at least 80-mm-long stem was used in all operations, but in four the cement was applied only proximally. The cemented femoral stems used were either 102 or 127 mm long to help reduce the risk of aseptic loosening [18]. Patellar resurfacing was carried out in two revisions to improve patellar tracking.

All patients except the polytrauma patient were allowed active range of movement of the knee and full weight bearing on the first post-operative day if tolerated. Cell saver was used in seven operations and re-transfusion drain in two. All patients required heterologous blood transfusion. The mean combined intra-operative and post-operative blood transfusion was 2.3 units (range 1–4 units). All patients had VTE prophylaxis using enoxaparin for 2–6 weeks post-operatively and foot pumps in the early post-operative period. The median of the duration of surgery was 120 min (range 75–180 min) after exclusion of two patients who required additional plate removal. The mean post-operative hospital stay in 12 patients was 14 days (range 8–31 days).

Outcome measures

The clinical outcome including presence of knee pain, instability, extension lag and knee range of movement was evaluated in the follow-up clinics. The mean clinical follow-up time was 27 months (range 8–46 months). This excludes two patients who were discharged after their first follow-up due to frailty. The post-operative mobility, use of walking aid, post-operative residence and change in independence were also assessed. The functional outcome was evaluated using Oxford Knee Score (OKS), EuroQol-5D (UK English Version) general health questionnaire and the Knee Society patient category score [19]. The questionnaire was sent to the patients as part of virtual clinic at a mean of 35 months (range 20–65 months) post-operatively. We excluded patients with dementia from the functional outcome scoring as they were unable to complete to the score questions accurately. All post-operative and follow-up radiographs were assessed for signs of radiological

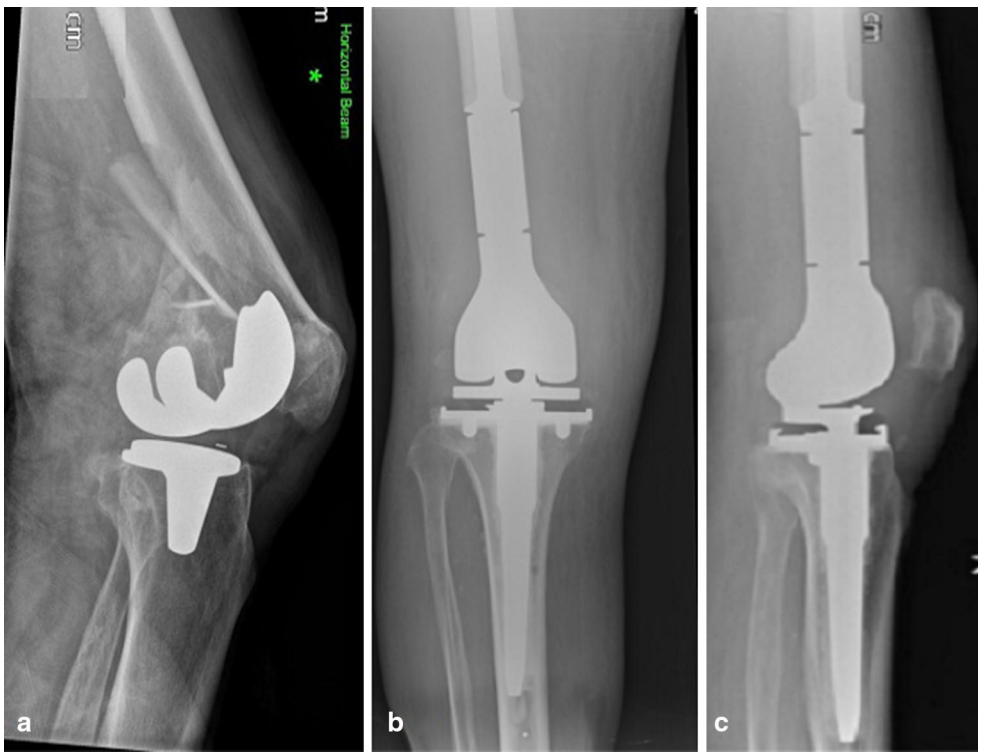

Fig. 1 Pre-operative lateral radiograph of severely comminuted very distal periprosthetic femoral fracture with proximal extension (**a**). Post-operative antero-posterior (**b**) and lateral (**c**) radiographs of rotating-hinge distal femoral replacement including an extension piece attached to the stem

loosening. The mean time of the latest radiological follow-up was 28 months (range 6–58 months).

Results

Clinical outcome

The median maximum post-operative knee flexion at last follow-up was 100° (range 90°–135°). Eleven patients, who had not developed complications, reported no or little pain in the knee at last follow-up.

Complications

Two patients had complications. One had vascular injury of the superficial femoral artery intra-operatively caused by the presence of excessive scar tissue at the infected non-union site following locking plate fixation. This required emergency femoro-popliteal bypass with return of the normal circulation of the limb. The same patient has had patello-femoral maltracking post-operatively that mainly affected the standing from the sitting position but did not require further surgery. The other patient developed delayed low-grade deep joint infection four months post-operatively. Knee culture demonstrated enterobacter which was the same organism that was grown from a post-operative urine infection, suggesting haematogenous spread. This was treated by debridement, implant retention and exchange of the polyethylene components followed by long-term suppressive antibiotics. This was the only patient who required re-operation.

Mortality

One patient aged 94 years died 16 days post-operatively from broncho-pneumonia which developed two weeks after surgery despite being mobilised under physiotherapy supervision in the post-operative period. Four other patients died during follow-up between 9 and 50 months post-operatively from causes unrelated to the DFR operation.

Radiological assessment

One patient had early subsidence of the femoral stem that did not progress in follow-up radiographs and has remained asymptomatic. The patient who developed deep infection had a small area of bone resorption at the junction of the distal medial femur and the endoprosthesis. There were no signs of progressive loosening in the radiographs of the other patients (Fig. 2).

Functional outcome

The median post-operative OKS was 27 (range 4–40). The median EuroQol-5D descriptive system (EQ-5D) was 11 (range 6–12). The median of the EuroQol visual analogue scale (EQ VAS) was 45 (range 15–90). Nine patients scored category C on the Knee Society patient category

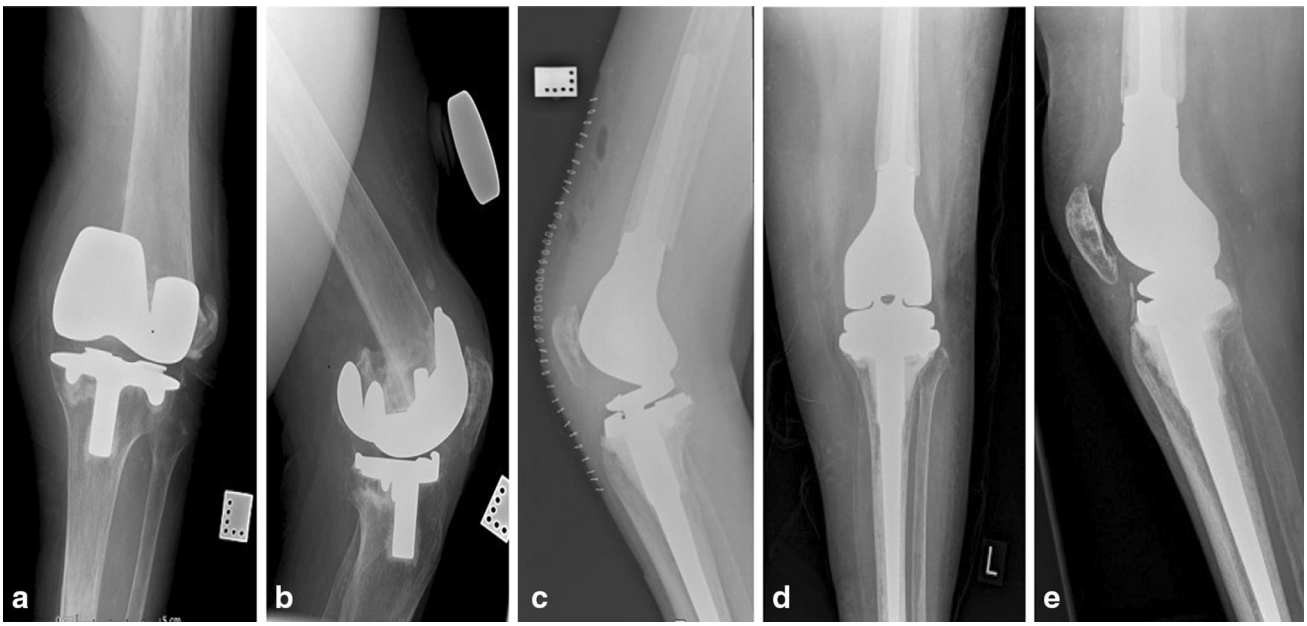

Fig. 2 Antero-posterior (**a**) and lateral (**b**) radiographs of periprosthetic fracture with loose prosthesis in a rheumatoid patient. Post-operative lateral radiograph (**c**). Antero-posterior (**d**) and lateral (**e**) radiographs at 18 months post-operatively with no signs of loosening

Table 3 Functional outcome

Patient	Cognitive and Musculo-skeletal problems	Pre-operative mobility and walking aid	Post-operative mobility and walking aid	Pre-fracture walking distance	Post-operative walking distance	Oxford Knee Score	EQ-5D and EQ VAS	Pre-operative residence	Post-operative residence
1	SLE, polyarthritis	Frame	Frame or 4 wheel-trolley	1/2 mile	300 yards	17	11 45	Home	Home
2	O. A.	One stick	Frame	200 yards	200 yards	23	N/A	Home	Home
3	Dementia[a], RA	Frame	Frame	40 yards	40 yards	N/A	N/A	Home	Residential Home
4	Dementia[a], Polyarthritis	Unknown	Frame	Unknown	30–40 yards	N/A	N/A	Home	Nursing Home
5	Osteoporosis, previous fragility fractures	Frame	Frame or wheelchair	Unknown	20 yards	36	10 15	Home	Home
6	Chronic back pain	Wheelchair	No walking aid	30 yards	200–300 yards	32	11 35	Home	Home
7	RA, severe low back pain, Osteoporosis	Gutter frame or wheelchair	Wheelchair	10 yards	Transfer only	4	11 60	Home	Residential home
8	Osteoporosis	No walking aid	No walking aid	1-2 miles	1/2 mile	40	6 90	Home	Home
9	Bilateral club feet	1 stick or mobility scooter	2 crutches or wheelchair	30 yards	30 yards	4	12 60	Home	Home
10	Dementia[a]	1 stick	1 stick or no walking aid	Indoors	Indoors	N/A	N/A	Sheltered home	Nursing Home
11	Dementia[a]	Frame	Frame	Indoors	20 yards	N/A	N/A	Home	Residential Home
12	Polytrauma, partial spinal cord injury	1 stick	Wheelchair	Unknown	Unable to walk	36 Had no knee problem	12 30	Home	Home
13	Dementia	1 stick	Frame	30 yards	20 yards	N/A	N/A	Home	Post-operative death
14	Osteoporosis	1 or 2 sticks	No walking aid	Unknown	100 yards	N/A	N/A	Home	Home

SLE systemic lupus erythematosus; *O. A.* osteoarthritis; *RA* rheumatoid arthritis; *N/A* not applicable or not available

[a] Patients with dementia were not included in the functional scoring questionnaire

score indicating that they had multiple joint arthritis or medical infirmity [19]. Nine patients (64%) returned to their pre-fracture mobility or even better either walking independently or using their usual walking aid. One polytrauma patient reported no problems following his knee operation, but his mobility was severely affected by weakness in the legs, due to partial spinal cord injury and ipsilateral fracture dislocation of the hip. Another patient used a wheelchair due to disabling low back pain and polyarthritis. All other patients were able to walk at least indoors, and most of them regained their pre-fracture outdoors walking distance. Eight patients (57%) eventually returned to their pre-fracture residence. Five patients moved from their own residence to a care home, four of them due to their cognitive problems and one due to severe chronic low back pain and advanced rheumatoid disease (Table 3).

Discussion

The very distal periprosthetic femoral fractures (Su classification type III) are challenging to manage especially in elderly patients who have osteoporotic bones adding to the localised osteoporosis caused by stress shielding as a result of the presence of the femoral component over the years [5, 7]. The poor bone stock, often associated with comminution, in Su type III fractures was the main indication

for DFR in our patients rather than the loosening of the prosthesis. Most patients in our study were frail and elderly with multiple comorbidities including cognitive problems and limited mobility before sustaining the periprosthetic fracture. Most of the patients had pre-fracture low functional demands with either household mobility or community mobility with walking aids. They have, however, achieved good clinical outcome with pain-free range of movement and stable knees other than the two patients who developed complications.

The advantages of DFR are that it allows early mobilisation, faster recovery and early weight bearing post-operatively [3]. It also does not rely on bone healing which is compromised in this age group. There is less concern about the medium-term complication of aseptic loosening in distal femoral replacement [1, 7] considering the age and the functional demands of these patients and the better design of the third-generation rotating-hinge implants. These implants are characterised by a high range of tibial rotation to reduce the risk of loosening and deep trochlear groove to improve patellar tracking [1].

The current methods of treating supracondylar femoral fractures are internal fixation or revision arthroplasty. The retrograde intramedullary nails are mainly indicated in high supracondylar fractures, i.e. Su type I and some of type II fractures, if the femoral component allows nail placement whilst the locking plates are mainly indicated in Su type II and some of type III fractures [5].

For very distal fractures, Streubel et al. [13] recommended the use of lateral locking plates reporting results similar to those of the more proximal fractures; however, five patients (15%) developed non-unions in 33 patients. Kim et al. [14] reported only one non-union in 21 patients with Su et al. type III fractures treated with lateral locked plating using minimally invasive percutaneous plate osteosynthesis (MIPPO) technique. This was combined with medial plating in two-thirds of patients, bone graft or substitute in one-third and teriparatide in two-thirds of their patients. However, the average age of the patients in these two series is 9.5 years younger than the mean of age in our patients.

Revision knee arthroplasty using distal femoral replacement is indicated in elderly sedentary patients when there is poor bone stock in Su type III fractures [3, 7]. Mortazavi et al. [11] reviewed 22 knees in 20 patients using DFR for periprosthetic fractures and reported ten post-operative complications with five patients requiring additional surgery. Jassim et al. [12] reviewed 11 periprosthetic distal femoral fractures who had distal femoral replacement (GMRS, Stryker) and reported seven patients who developed some form of complication. Both studies recommended the use of DFR as a salvage procedure in these fractures.

Limitations of our study are that it is a retrospective review of a small number of patients and with no control group. However, previously published studies on the use of DFR in periprosthetic supracondylar femoral fractures were similar sized retrospective case series (Level IV evidence) [8–12]. Another limitation is the relatively short-term follow-up. A review article by Harrison et al. [1] found that most of the published literature on the use of DFR in periprosthetic fractures reported short-term follow-up <48 months. This is expected in the elderly patients especially that many of them suffer from cognitive impairment or physical frailty which makes long-term or even medium-term follow-up difficult or impractical [1, 20].

In our experience, revision knee distal femoral replacement is an appropriate method to treat elderly patients who have sustained periprosthetic Su et al. type III distal femoral fractures in association with poor bone stock, caused by osteoporosis and/or comminution. Barring complications, use of DFR, allowed early mobilisation, weight bearing and a good functional outcome. We had a relatively low complication rate compared to previously published series.

Compliance with ethical standard

Conflict of interest Ehab Girgis and Christoph McAllen have nothing to disclose. Jonathan Keenan reports other from Smith & Nephew, outside the submitted work.

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