Double plating is a suitable option for periprosthetic distal femur fracture compared to single plate fixation and distal femoral arthroplasty

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Aims
The purpose of this study was to compare reoperation and revision rates of double plating (DP), single plating using a lateral locking plate (SP), or distal femoral arthroplasty (DFA) for the treatment of periprosthetic distal femur fractures (PDFFs).

Methods
All patients with PDFF primarily treated with DP, SP, or DFA between 2008 and 2022 at a university teaching hospital were included in this retrospective cohort study. The primary outcome was revision surgery for failure following DP, SP, or DFA. Secondary outcome measures included any reoperation, length of hospital stay, and mortality. All basic demographic and relevant implant and injury details were collected. Radiological analysis included fracture classification and evaluation of metaphyseal and medial comminution.

Results
A total of 111 PDFFs (111 patients, median age 82 years (interquartile range (IQR) 75 to 88), 86% female) with 32 (29%) Su classification 1, 37 (34%) Su 2, and 40 (37%) Su 3 fractures were included. The median follow-up was 2.5 years (IQR 1.2 to 5.0). DP, SP, and DFA were used in 15, 66, and 30 patients, respectively. Compared to SP, patients treated with DP were more likely to have metaphyseal comminution (47% vs 14%; p = 0.009), to be low fractures (47% vs 11%; p = 0.009), and to be anatomically reduced (100% vs 71%; p = 0.030). Patients selected for DFA displayed comparable amounts of medial/metaphyseal comminution as those who underwent DP. At a minimum follow-up of two years, revision surgery for failure was performed in 11 (9.9%) cases at a median of five months (IQR 2 to 9): 0 DP patients (0%), 9 SP (14%), and 2 DFA (6.7%) (p = 0.249).

Conclusion
Using a strategy of DP fixation in fractures, where the fracture was low but there was enough distal bone to accommodate locking screws, and where there is metaphyseal comminution, resulted in equivalent survival free from revision or reoperation compared to DFA and SP fixation.

Take home message
- Double plating through a single approach offers a reliable surgical treatment strategy for periprosthetic distal femur fractures, including for low subtypes.
- Double plating resulted in a more anatomical fracture reduction compared to single plating.
- This technique can be suitable in cases that were previously treated with distal femoral arthroplasty.

Bone & Joint Open

Introduction

Periprosthetic distal femur fractures (PDFFs) around total knee arthroplasties (TKAs) are severe complications associated with a similar mortality rate as hip fractures.[1,2] Due to a longer life expectancy in an ageing society, the total number of TKAs and subsequently PDFFs is surging,[3] occurring in up to 2.5% of cases after primary TKA and up to 3.8% following revision TKA. Nonoperative treatment is rarely indicated, and associated with a poor prognosis; surgical treatment is the mainstay of care.[4] However, the optimal surgical treatment between fixation and revision arthroplasty and how this should be determined remains unclear. Numerous studies have compared lateral locking plate fixation to intramedullary nailing and to distal femoral arthroplasty (DFA), with a subsequent meta-analysis concluding only minimal differences in outcome with better knee flexion in the open reduction internal fixation (ORIF) group.[4] The systematic review was limited by the low-quality evidence of the included studies and the short follow-up data available. The heterogeneity and complexity of these injuries and patients has made performing randomized controlled trials to answer these questions difficult.[3]

Though DFA facilitates immediate weightbearing postoperatively and precludes fracture nonunion,[5] implant costs are high and the risks considerable, including refracture, implant loosening, and infection. DFA should be used with caution in patients with significant life expectancy.[6,7] Fracture fixation, where possible, is favoured in younger patients but has its own risks, including infection, refracture, fixation failure, or nonunion,[6-8] especially when using a single plating technique (SP). In fractures at risk of fixation failure with a SP technique, such as fractures with medial/metaphyseal comminution or very distal fractures, double plate (DP) constructs can help accommodate comminution or impaired bone quality, preserve bone stock, convert cantilever to on-axis fixation, and can avoid a large revision to DFA. However, clinical evidence for double plating is sparse, with most studies lacking a control group.[9-14] No previous study compared double plating to both single plating and DFA.

The aim of this retrospective single-centre cohort study was to compare the outcomes of patients with PDFFs treated with DP, SP, and DFA. The primary outcome measure was revision for failure. The authors hypothesized that DP yields comparable results to DFA, and might be superior to SP in appropriately selected patients with very distal fractures or significant comminution.

Methods

The study was conducted following local institutional review board approval and the Declaration of Helsinki.[15] The data were analyzed following the STROBE statement for retrospective cohort studies.[16]

Patient inclusion

The institutional, prospectively followed trauma database was queried for all patients with PDFF between January 2008 and December 2022, with a minimum follow-up of one year postoperatively. The institution was a university teaching hospital and tertiary referral centre (Royal Infirmary of Edinburgh, UK) for a population of approximately 800,000 people aged over 16 years.

The inclusion criteria were all patients treated for PDFF with: 1) DP, SP, or DFA; 2) from 2008 to 2022; and 3) who had been followed up within the local area (Scotland, UK). Exclusion criteria were: 1) patients not living locally, with no clinical or radiological follow-up; or 2) formal disagreement with study participation.

Primary outcomes

The primary outcome measure was revision surgery for failure.

Secondary outcomes

Secondary outcome measures included reoperation surgery for any reason, mortality, medical or orthopaedic/surgical complications defined as early (< six weeks) or late (> six weeks), and length of hospital stay.

Patient evaluation

All demographic data including age, sex, BMI, American Society of Anesthesiologists (ASA) grade,[17] and comorbidities (osteoporosis, bisphosphonate use, diabetes (including insulin-dependency), and steroid use) were collected from the electronic patient record. All injury-related data and follow-up information were included with length of hospital stay, last clinical appointment, patient's death, and medical and surgical complications. Surgical complications requiring return to theatre were classified as either revision surgery for failure, or other reoperations.

A total of 111 operatively managed PDFFs in 111 patients were identified. Initial treatment was with DP in 15 (Figures 1 to 3), SP in 66, and DFA in 30. Median follow-up was 2.5 years (interquartile range (IQR) 1.2 to 5.0). Seven consultant orthopaedic surgeons (CEHS, MM among them) were involved in the treatment of all patients. Basic demographic data are given in Table I. No significant differences in patient demographics were identified between groups.

Surgical details

Time to surgery, surgical treatment strategy, and implant details were collected. The time from TKA implantation to fracture was calculated and TKA design noted.

The surgical technique involved spinal and/or general anaesthesia with prophylactic antibiotics and tranexamic acid. Tourniquets were not used. Single lateral locking plates (SP) were placed either using a short lateral minimally invasive plate osteosynthesis (MIPO) type approach with targeting of proximal screws placed percutaneously, or through an extensile lateral parapatella approach or direct lateral approach to femur.[18] DP was performed through a single midline incision and either an extensile lateral or medial parapatella approach with proximal screws targeted percutaneously. The lateral locking plate used was a 4.5 large fragment distal femur PeriLoc plate (Smith and Nephew, UK). DFA was performed through an extensile medial patrapatella approach using a GMRS implant (Stryker, USA). The wound was usually closed in layers with sutures or clips to skin as per surgeon's preference. Weightbearing was typically unrestricted postoperatively for all constructs.

Radiological evaluation

All radiological imaging was analyzed including available CT scans, and fractures were classified using the Su et al[19] and

Fig. 1
Anteroposterior and lateral views of a periprosthetic distal femur fracture in a 73-year-old female around a standard total knee arthroplasty treated with double plating. The coronal plane CT image confirms no additional sagittal plane split in the distal fragment, and sufficient bone stock to enable fixation. Post fixation radiographs are shown here at seven months.

Fig. 2
Double plating of a periprosthetic distal femur fracture of a 78-year-old female around a hinged total knee arthroplasty. The anteroposterior and lateral radiographs demonstrate the fracture preoperatively and at five months postoperatively.

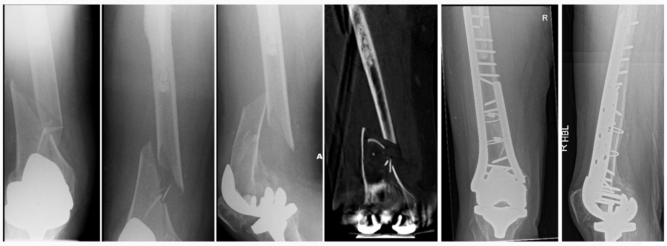

Fig. 3
Double plating for treatment of an interprosthetic distal femur fracture of an 88-year-old female with anatomical reduction and satisfactory healing. The anteroposterior and lateral radiographs and coronal CT demonstrate metaphyseal comminution preoperatively, but no sagittal split. Postoperative radiographs (taken at 47 months) demonstrate union.

Fakler et al[20] classification systems. The presence of medial comminution or metaphyseal comminution was noted, as was the quality of postoperative anatomical reduction. All radiographs were analyzed by three readers (CEHS, MM, PK) and consensus was reached.

Statistical analysis

All data were analyzed with R Studio version 2023.12.1 (R Foundation for Statistical Computing, Austria). Parametrical data were given as mean and standard deviation (SD), while non-parametrical data were given as median and IQR. Distribution was analyzed using the Kruskal-Wallis test and through visual analysis of the distribution after plotting. Parametrical continuous data were compared using the *t*-test for independent samples, while non-parametrical continuous data were evaluated using the Mann-Whitney U test. For very small samplze sizes, the Mann-Whitney U exact test was used. Comparison of two separate groups was achieved using the chi-squared or Fisher's exact test, as appropriate. Survival analysis was conducted using Kaplan-Meier survival curves. A p-value < 0.05 was considered significant.

Results

Fracture features and classifications are detailed in Table II. In general, the initial fracture configuration was more comparable between DP and DFA rather than between DP and SP. The Su classification differed between all three groups: DFA and DP were used for more distal fractures, while SP was mainly used for more proximal fractures. Analyses of the reduction revealed less anatomical reduction for SP compared to DP (p = 0.030). Fractures with metaphyseal comminution were less likely to be treated with SP than either DP (p = 0.009) or DFA (p < 0.001). There was no difference in metaphyseal comminution presence between fractures treated with DP or DFA (p = 0.750). Medial comminution was comparable between all three groups with no statistically significant difference.

Details of TKA implant types and surgical complications are given in Table III. All TKA implants were cemented. Revision surgery for failure was necessary in zero patients (0%) following DP, nine patients (14%) following SP, and two patients (6.7%) following DFA (p = 0.249; Figure 4 and Table III). The most common surgical complication was nonunion, which occurred exclusively in the SP group. The reason for revision in the SP group was nonunion for all cases, whereas the reasons in the DFA group included a periprosthetic fracture and implant loosening (Table IV). Reoperation for any reason was necessary in one (6.7%), 12 (18%), and two (6.7%) patients following DP, SP, and DFA, respectively. Indications for reoperation other than failure included irritating metalwork in one DP and one SP, and washout and debridement for wound infection in two SP. The time to revision for failure was significantly longer after DFA, with a median of 64 months (IQR 55 to 74) compared to three months (IQR 1 to 6) for SP (Table III).

Risk factor analysis did not reveal any significant associations with revision for failure from the demographic and radiological features examined (Table V).

A high number of postoperative complications were seen, with a rate of 62% for early medical complications and 23% for all surgical complications (Table VI). The early medical complications are presented in Table VII, with anaemia and pneumonia being the most common complications. Late medical complications after six weeks were death (1.8%), urinary tract infection (1.8%), anaemia (0.9%), general deterioration (0.9%), and heart failure (0.9%). Early surgical complications included periprosthetic fracture (SP), infection

Table I. Demographic data for all three groups: distal femoral arthroplasty, double plating, and single plating.

Characteristic	Overall (n = 111)	DFA (n = 30)	DP (n = 15)	SP (n = 66)	p-value
Median age, yrs (IQR)	82 (75 to 88)	83 (76 to 87)	78 (73 to 88)	83 (77 to 88)	0.742*
Female, n (%)	96 (86)	25 (83)	13 (87)	58 (88)	0.792†
Side, n (%)					0.613†
Right	66 (59)	21 (70)	9 (60)	36 (55)	
Left	44 (40)	9 (30)	6 (40)	29 (44)	
Bilateral	1 (0.9)	0 (0)	0 (0)	1 (1.5)	
ASA grade, n (%)					0.079†
I	2 (1.9)	2 (7.7)	0 (0)	0 (0)	
II	38 (36)	13 (50)	7 (47)	18 (28)	
III	55 (52)	9 (35)	6 (40)	40 (62)	
IV	10 (9.4)	2 (7.7)	2 (13)	6 (9.2)	
V	1 (0.9)	0 (0)	0 (0)	1 (1.5)	
Osteoporosis, n (%)	53 (50)	18 (67)	5 (33)	30 (47)	0.086‡
Bisphosphonates, n (%)	25 (24)	6 (23)	4 (27)	15 (23)	0.947†
Diabetes, n (%)	14 (13)	4 (15)	4 (27)	6 (9.4)	0.153†
Insulin dependence, n (%)	2 (1.9)	0 (0)	1 (6.7)	1 (1.6)	0.326†
Steroid use, n (%)					0.569†
Yes	12 (11)	2 (7.7)	2 (13)	8 (13)	
No	83 (79)	20 (77)	11 (73)	52 (81)	
Inhaler	10 (9.5)	4 (15)	2 (13)	4 (6.3)	

*Kruskal-Wallis rank sum test.
†Fisher's exact test.
‡Pearson's chi-squared test.
ASA, American Society of Anesthesiologists; DFA, distal femoral arthroplasty; DP, double plating; IQR, interquartile range; SP, single plating.

(SP), and wound dehiscence (DFA). Late surgical complications are presented in Table VIII.

Discussion

The main finding of this study was that of 15 patients whose PDFF was manged with DP, none required revision surgery for failure, compared to nine cases (14%) of SP and two (6.7%) of DFA. Though this difference was not significant, it demonstrates that dual plating is a safe technique in this group of patients, and was not associated with any early failures to a median of 2.5 years. The overall reintervention rate (including removal of irritating metalwork) was one (6.7%) for DP, 12 (18%) for SP, and two (6.7%) for DFA. Treatment failure was not significantly associated with any of the measured demographic features. Analysis of radiological data revealed that metaphyseal comminution and low fracture types were more commonly treated with DP or DFA than with SP. Despite DP being used to fix these more complex fracture patterns, patients treated with DP were significantly more likely to be anatomically reduced compared to patients treated with unilateral SP, and none went on to fail.

DP for distal femur fracture was introduced by Sanders et al[21] in 1991, initially focusing on fractures of native femora. The body of literature has expanded vastly over the last few years; a recent systematic review identified 24 studies including 436 cases of DP for femur fractures without TKA.[22] The advantage of DP over SP is a stronger biomechanical construct and a theoretical reduction of construct failure.[23–26] This is especially so for varus collapse after lateral locking plate fixation (amplified by medial or metaphyseal comminution) as DP converts off-axis lateral locking plate cantilever fixation to on-axis fixation. In contrast, a potential disadvantage of DP is a theoretical risk of nonunion because of reduced fracture mobility or soft-tissue stripping, which might impair the healing process.[27–30] One often cited criticism of DP is impaired blood supply postoperatively. In a recent cadaveric study, Rollick et al[31] revealed that DP did not significantly diminish the blood supply of the distal femur. The authors described the decrease in blood supply as 21% for SP and 25% for DP, which did not yield a statistically relevant difference.

As in the native distal femur, DP for PDFF has gained some popularity in recent years. Yet, the literature is limited to small case series, mostly without a control group.[9-14] Further, no previous study has compared the results of DP, SP, and DFA all together.[9-14] One study compared native distal femur fractures with PDFFs, demonstrating satisfactory results in both groups.[12] A recent randomized control trial from Egypt comparing DP and DFA (15 patients per group) found similar

Table II. Fracture features and classification.

Characteristic	DFA (n = 30)	DP (n = 15)	SP (n = 66)	p-value*
Metaphyseal comminution, n (%)	15 (52)	7 (47)	9 (14)	< 0.001
Medial comminution, n (%)	8 (28)	2 (13)	9 (14)	0.288
Su classification, n (%)				< 0.001
1	1 (3.4)	3 (20)	28 (43)	
2	2 (6.9)	5 (33)	30 (46)	
3	26 (90)	7 (47)	7 (11)	
Fakler classification, n (%)†				
A1	1 (3.4)	3 (20)	26 (39)	
A2	3 (10)	4 (27)	25 (38)	
A3	17 (59)	7 (47)	9 (14)	
A4	4 (14)	0 (0)	0 (0)	
B1	0 (0)	0 (0)	1 (1.5)	
B2	0 (0)	0 (0)	1 (1.5)	
B3	0 (0)	0 (0)	1 (1.5)	
C1	0 (0)	0 (0)	1 (1.5)	
C2	0 (0)	1 (6.7)	1 (1.5)	
C3	3 (10)	0 (0)	0 (0)	
C4	1 (3.4)	0 (0)	0 (0)	
U	0 (0)	0 (0)	1 (1.5)	
Anatomical reduction	0 (N/A)	13 (100)	42 (71)	0.030

*Fisher's exact test.
†Due to the number of groups, calculation of a p-value was not possible.
DFA, distal femoral arthroplasty; DP, double plating; N/A, not applicable; SP, single plating.

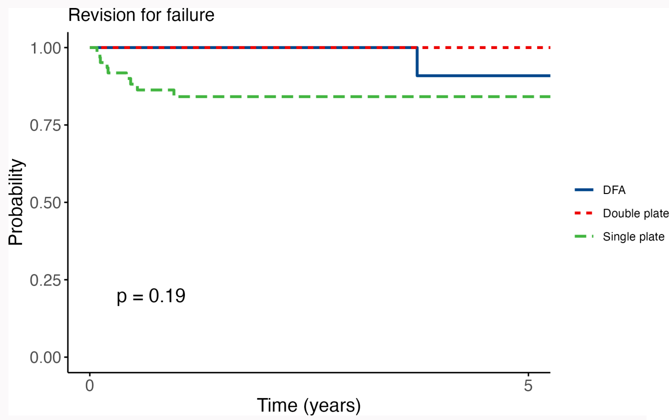

Fig. 4
Kaplan-Meier survival curve of all three groups over a duration of five years. DFA, distal femoral arthroplasty.

complication rates and revision surgeries, but significantly better range of motion in the DP group at a minimum follow-up of 12 months.[32] No primary outcome was defined, and the study was not powered. Their data were comparable to the current study, in that medical complication rates were similar across all three groups. Consistent with the current study, previous studies have demonstrated union rates of 87% to 100% following DP.[9-14] None of the patients treated with DP in this study underwent revision for failure (nonunion or refracture), which is an important finding because PDFF patients are typically elderly and frail, and would be potentially unfit for a second operation.

Though DFA removes nonunion as a mode of failure, it is associated with high-stakes complications, including infection rates of 3% to 14%, more extensive surgery with substantial bone and blood loss, the ongoing risk of periprosthetic refracture, and a long-term risk of aseptic loosening.[6,7] Aseptic loosening, or other mid- to long-term mechanical failure, is often under-reported in fracture studies where follow-up is short, and this potentially skews results in favour of DFA.[33] When DFAs fail, total femoral arthroplasty mega-prostheses may be required as a last surgical resort for the usually large amount of bone loss at that stage.[34] Contrary to this, after surgical fixation and uneventful healing of PDFF, the patient can be discharged from the service and, potentially, no further follow-up would be necessary in the future.[35] The main disadvantages of fixation remain nonunion and construct failure.[36] Medial or metaphyseal comminution, very low fractures, osteoporotic bone, and severe bone loss have been described as potential risk factors for fixation failure.[5,9–14,29] The risk of construct failure was diminished by the more advanced use of locking plates.[37] Augmented fixation with combined constructs such as nail-plate,[38,39] or double plates, have demonstrated significantly higher construct strength.[23,26,40] Further, a stronger fixation construct allows early weightbearing, and multiple studies have shown that immediate unrestricted weightbearing is safe after PDFF fixation.[5] This somewhat negates the argument of DFA being advantageous purely because it allows immediate weightbearing – fixation constructs facilitate this too.

Across all groups, our revision rate for failure was 9.9%, and for any reoperation was 14%. Reoperation rates were lower following DP and DFA (6.7% for both) than in a recently published systematic review comparing DFA and SP, but were higher for SP at 18%.[4] The authors included 58 studies with 1,484 cases comparing ORIF (44 studies, 1,212 cases) and DFA (14 studies, 272 cases), which revealed a comparable revision rate of 14% for DFA and 15.4% for ORIF. Further, the systematic review revealed comparable complication rates between the two groups, with slightly better functional results after ORIF.[4]

The results of this study strongly suggest that DP can be used safely for low PDFFs with metaphyseal comminution, provided there is enough bone distally attached to a well-fixed femoral component to obtain screw fixation. The analysis revealed that DP and DFA were similarly used for both fracture configurations, with a low revision rate for failure in both techniques. Interestingly, when comparing DP to SP, a more anatomical reduction was achieved, which is one of the main principles of the AO in order to achieve sustainable long-term

Table III. Implant types and surgical complications.

Characteristic	Overall, n = 111	DFA, n = 30	DP, n = 15	SP, n = 66	DP vs SP	DP vs DFA	SP vs DFA
Revision for failure, n (%)	11 (9.9)	2 (6.7)	0 (0)	9 (14)	0.198*	0.545*	0.494*
Median time to revision for failure, mths (IQR)	5 (2 to 9)	64 (55 to 74)	N/A	3 (1 to 6)	1.000*	1.000*	0.036†
Any reoperation, n (%)	15 (14)	2 (6.7)	1 (6.7)	12 (18)	0.444*	1.000*	0.213*
Median time to revision, mths (IQR)	7 (2 to 37)	64 (55 to 74)	9 (9 to 9)	5 (2 to 16)	0.769†	1.000*	0.088†
Median follow-up, yrs (IQR)	2.5 (1.2 to 5.0)	3.1 (1.2 to 5.8)	2.4 (2.0 to 4.2)	2.5 (0.9 to 4.3)	0.336‡	0.833†	0.272‡
Median length of stay, days (IQR)	12 (8 to 17)	12 (9 to 19)	13 (6 to 17)	12 (8 to 16)	1.00 ‡	0.570‡	0.378‡
Mortality 30 days	3 (2.7%)	0 (0%)	1 (6.7%)	2 (3.0%)	0.464*	0.333*	1.000*
Mortality 1 year	20 (18%)	4 (13%)	2 (13%)	14 (21%)	0.723*	1.000*	0.359§
Median time from arthroplasty, yrs (IQR)	9.0 (5.0 to 11.0)	10.0 (6.8 to 11.0)	8.0 (4.8 to 11.8)	9.0 (5.0 to 12.0)	0.644‡	0.507‡	0.660‡
Implant design, n (%)					0.725*	0.647*	0.070*
Constrained	7 (6.4)	4 (14)	1 (6.7)	2 (3.1)			
CR	99 (91)	25 (86)	14 (93)	60 (92)			
PS	3 (2.8)	0 (0)	0 (0)	3 (4.6)			
Cable fixation used, n (%)	27 (24)	0 (0)	2 (13)	25 (38)	0.069§	0.106*	< 0.001§

*Fisher's exact test.
†Mann-Whitney U exact test
‡Mann-Whitney U test.
§Pearson's chi-squared test.
CR, cruciate-retaining; DFA, distal femoral arthroplasty; DP, double plating; IQR, interquartile range; PS, posterior-stabilized; SP, single plating.

Table IV. Revisions and reoperations.

Group	Age, yrs	Su	Fakler	Indication surgery	Failure	Anatomical reduction	Time to reoperation, mths
DFA	79	3	A3	Loosening	Yes		45
DFA	81	3	C4	Periprosthetic fracture	Yes		83
DP	74	3	A3	Irritating metalwork	No	Yes	9
SP	60	3	B3	Infection	No	Yes	28
SP	79	2	A2	Infection	No	Yes	48
SP	71	1	A2	Irritating metalwork	No	No	49
SP	71	2	A2	Nonunion	Yes	No	6
SP	79	2	A1	Nonunion	Yes	Yes	2
SP	79	1	A1	Nonunion	Yes	No	1
SP	87	2	A2	Nonunion	Yes	Yes	7
SP	75	3	A3	Nonunion	Yes	No	1
SP	75	2	A2	Nonunion	Yes	Yes	12
SP	83	1	A1	Nonunion	Yes	Yes	1
SP	73	1	A1	Nonunion	Yes	Yes	5
SP	87	1	A1	Nonunion	Yes	Yes	3

DFA, distal femoral arthroplasty; DP, double plating; SP, single plating.

Table V. Univariable analysis of predictors for failure.

Characteristic	Revision for failure No (n = 100)	Revision for failure Yes (n = 11)	p-value
Treatment, n (%)			0.249*
Distal femoral arthroplasty	28 (28)	2 (18)	
Double plate	15 (15)	0 (0)	
Single plate	57 (57)	9 (82)	
Median age, yrs (IQR)	83 (75 to 88)	79 (75 to 82)	0.244†
Side, n (%)			0.200*
Right	62 (62)	4 (36)	
Left	37 (37)	7 (64)	
Bilateral	1 (1.0)	0 (0)	
Female, n (%)	86 (86)	10 (91)	1.000*
ASA grade, n (%)			0.911*
1	2 (2.1)	0 (0)	
2	34 (35)	4 (44)	
3	50 (52)	5 (56)	
4	10 (10)	0 (0)	
5	1 (1.0)	0 (0)	
Osteoporosis, n (%)	49 (51)	4 (44)	1.000‡
Bisphosphonates, n (%)	23 (24)	2 (22)	1.000*
Diabetes, n (%)	14 (15)	0 (0)	0.604*
Insulin dependence, n (%)	2 (2.1)	0 (0)	1.000*
Steroid use, n (%)			0.677*
Yes	12 (13)	0 (0)	
No	75 (78)	8 (89)	
Inhaler, n (%)	9 (9.4)	1 (11)	
Metaphyseal comminution, n (%)	28 (29)	3 (27)	1.000*
Medial comminution, n (%)	15 (15)	4 (36)	0.098*
Su classification, n (%)			0.789*
1	28 (29)	4 (36)	
2	33 (34)	4 (36)	
3	37 (38)	3 (27)	
Anatomical reduction, n (%)	49 (78)	6 (67)	0.433*

*Fisher's exact test.
†Mann-Whitney U test.
‡Pearson's chi-squared test.
ASA, American Society of Anesthesiologists; IQR, interquartile range.

outcome measures.[41] High rates of medical complications were observed across all techniques, reflecting the frail elderly population who sustain these fractures, but rates did not differ across surgical treatment strategies. Getting it right the first time and avoiding reoperation is imperative in frail elderly patients, who may not be fit for further surgery. Some fractures are not reconstructable, and implants are unstable, in which case DFA is the only option. Larger, multicentre studies are required to clarify the indications for and efficacy of DP in PDFF management and how this compares to DFA.

Table VI. Complications overview.

Complication, n (%)	Overall (n = 111)	DFA (n = 30)	DP (n = 15)	SP (n = 66)	p-value
Medical (early)	69 (62)	18 (60)	7 (47)	44 (67)	0.340*
Medical (late)	8 (7.2)	1 (3.3)	0 (0)	7 (11)	0.366†
Surgical (early)	3 (2.7)	1 (3.3)	0 (0)	2 (3.0)	1.000†
Surgical (late)	22 (20)	8 (27)	2 (13)	12 (18)	0.583†

*Pearson's chi-squared test.
†Fisher's exact test.
DFA, distal femoral arthroplasty; DP, double plating; SP, single plating.

Table VII. Early medical complications.

Characteristic, n (%)	Overall (n = 111)	DFA (n = 30)	DP (n = 15)	SP (n = 66)	p-value
Anaemia	37 (33)	7 (23)	3 (20)	27 (41)	0.119*
Pneumonia	18 (16)	5 (17)	3 (20)	10 (15)	0.873†
Delirium	12 (11)	3 (10)	2 (13)	7 (11)	0.911†
UTI	11 (9.9)	3 (10)	0 (0)	8 (12)	0.530†
AKI	10 (9.0)	3 (10)	0 (0)	7 (11)	0.568†
Death	6 (5.4)	1 (3.3)	1 (6.7)	4 (6.1)	1.000†
DVT	2 (1.8)	2 (6.7)	0 (0)	0 (0)	0.088†
Cellulitis	2 (1.8)	0 (0)	0 (0)	2 (3.0)	1.000†
Myocardial infarction	2 (1.8)	0 (0)	0 (0)	2 (3.0)	1.000†

*Pearson's chi-squared test.
†Fisher's exact test.
AKI, acute kidney injury; DFA, distal femoral arthroplasty; DP, double plating; DVT, deep vein thrombosis; SP, single plating; UTI, urinary tract infection.

Besides DP for PDFF, a nail-plate construct (NP) has also been popularized recently and needs to be considered for similar reasons to DP. Recently, Kontakis and Giannoudis[42] summarized the contemporary literature, which is comparably sparse, including a total of 69 cases across six studies, albeit with favourable results. Comparable with DP, NP also provides improved resistance to axial and torsional loads that could be used for earlier mobilization and weightbearing, which could subsequently lead to earlier recovery. The nail and the plate could theoretically be interconnected, which seems advantageous for osteoporotic bone. The published studies reported a higher union rate when compared to conventional techniques. Nevertheless, disadvantages must also be outlined, including the necessity for an open box TKA design to implant a nail in a retrograde way, the difficulty of anatomically reducing a fracture using a rod, and the potentially higher costs of nails compared to plates. Nevertheless, as DP for PDFF, NP could be a reliable alternative to SP or DFA. No study has compared NP to DP thus far.[42]

Table VIII. Late surgical complications.

Characteristic, n (%)	Overall (n = 111)	DFA (n = 30)	DP (n = 15)	SP (n = 66)	p-value*
Chronic wound problems	2 (1.8)	1 (3.3)	1 (6.7)	0 (0)	0.162
Heterotopic ossification	2 (1.8)	2 (6.7)	0 (0)	0 (0)	0.088
Knee stiffness	1 (0.9)	1 (3.3)	0 (0)	0 (0%)	0.405
Infection	3 (2.7)	1 (3.3)	0 (0)	2 (3.0)	1.000
Irritating metalwork	2 (1.8)	0 (0)	1 (6.7)	1 (1.5)	0.324
Loosening	1 (0.9)	1 (3.3)	0 (0)	0 (0)	0.405
Nonunion	9 (8.1)	0 (0)	0 (0)	9 (14)	0.050
Pain	1 (0.9)	1 (3.3)	0 (0)	0 (0)	0.405
Reduced mobility	1 (0.9)	1 (3.3)	0 (0)	0 (0)	0.405
Refracture	1 (0.9)	1 (3.3)	0 (0)	0 (0)	0.405

*Fisher's exact test.
DFA, distal femoral arthroplasty; DP, double plating; SP, single plating.

Another important factor to discuss is the economic burden of revision TKA for fracture in the light of these new techniques. Unfortunately, to the best of our knowledge, no study has analyzed any possible economic advantages or disadvantages of DP or NP over SP or DFA thus far. One could hypothesize that implant costs are lower for DP compared to DFA, and could also assume that the recovery is quicker because of an overall less invasive surgery when using DP. As outlined previously, patients can fully weightbear following DP, which is comparable to DFA. One could further assume that, if the fracture has healed, no further intervention is required. However, DFA could lead to another revision in the future, due to loosening or other complications related to complex nature of revision TKA. Unfortunately, those data are not available at the time of writing.

The present study was inherently limited by the data quality of a retrospective cohort analysis. Nonetheless, the nationwide radiological system enabled adequate follow-up data pertaining to revision, and national hospital numbers to readmission and mortality. Patient-reported outcome measures (PROMs) were not recorded. A prospective study including PROMs is indicated, though attempts at a randomized multicentre UK study has previously not been feasible due to the difficulties of randomization and follow-up of mainly elderly patients.[4] Another limitation was that the decision for fracture fixation or TKA revision was made by the treating consultant, which makes a retrospective comparison between the groups difficult. We have tried to interpret and examine any such decisions by examining medial or metaphyseal comminution in addition to applying standard classification systems. Further, retrospectively assessing postoperative weightbearing was challenging due to variations in standards among different surgeons. The elderly population exhibited a limited ability to perfectly execute the rehabilitation programme, particularly in terms of weightbearing.

To summarize, DP is a safe option for the management of PDFFs even in low fractures and in the presence of medial or metaphyseal comminution. DP was associated with more anatomical reductions than SP, even in more complex fractures, with reoperation rates similar to DFA with no revisions for failure. Further studies should examine the specific indications and fracture patterns that require DFA instead of DP.

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Data sharing

The datasets generated and analyzed in the current study are not publicly available due to data protection regulations. Access to data is limited to the researchers who have obtained permission for data processing. Further inquiries can be made to the corresponding author.

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