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Characteristics and risk factors of UCS fracture subtypes in periprosthetic fractures around the hip

RESULTS FROM THE NATIONAL PERIPROSTHETIC FRACTURE STUDY

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Aims
Periprosthetic fractures (PPFs) following hip arthroplasty are complex injuries. This study evaluates patient demographic characteristics, management, outcomes, and risk factors associated with PPF subtypes over a decade.

Methods
Using a multicentre collaborative study design, independent of registry data, we identified adults from 29 centres with PPFs around the hip between January 2010 and December 2019. Radiographs were assessed for the Unified Classification System (UCS) grade. Patient and injury characteristics, management, and outcomes were compared between UCS grades. A multinomial logistic regression was performed to estimate relative risk ratios (RRR) of variables on UCS grade.

Results
A total of 1,104 patients were included. The majority were female (57.9%; n = 639), ethnically white (88.5%; n = 977), used mobility aids (67%; n = 743), and had a median age of 82 years (interquartile range (IQR) 74 to 87). A total of 77 (7%) had pain prior to the PPF. The most common UCS grade was B2 (33%; n = 368). UCS type D fractures had the longest length of stay (median 19 days (IQR 11 to 26)), highest readmission to hospital (21%; n = 9), and highest rate of discharge to step-down care (52%; n = 23). Multinomial regression suggests that uncemented femoral stems are associated with a reduced risk of UCS C (RRR 0.36 (95% confidence interval (CI) 0.2 to 0.7); p = 0.002) and increased risk of UCS A (RRR 3.3 (95% CI 1.9 to 5.7); p < 0.001), compared to UCS B fracture.

Conclusion
The most common PPF type in elderly frail patients is UCS B2. Uncemented stems have a lower risk of UCS C fractures compared to cemented stems. A national PPF database is needed to further identify correlation between implants and fracture subtypes.

Cite this article: *Bone Jt Open* 2023;4-9:659–667.

Keywords: Periprosthetic, Fracture, UCS, Cemented, Uncemented

Introduction
The survivorship of a hip arthroplasty exceeds 90% at ten years postoperatively.[1] An increasing number of total hip arthroplasties (THAs) are being performed every year according to the National Joint Registry (NJR) for England, Wales, and Northern Ireland.[1] Due to this, there has been a recent rapid increase in the burden and incidence of periprosthetic fractures (PPFs) around hip prosthesis.[2,3] PPFs are associated with 30-day mortality rates ranging between 3% and 5%, with similar morbidity and mortality to that of well-recognized femoral neck fractures.[4,5] The rising incidence of hip PPFs requires significant economic resources to manage

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doi: 10.1302/2633-1462.49.BJO-2023-0065.R1

Bone Jt Open 2023;4-9:659–667.

them. The mean cost of treating a single PPF around the hip in a UK teaching hospital is estimated to be £23,469 (range £615 to £223,000).[6]

Risk factors associated with the occurrence of hip PPFs include female sex, age, rheumatoid arthritis, and osteoporosis.[7-9] Uncemented femoral stems have been linked with a higher overall incidence of PPFs compared to cemented implants, while cemented taper slip design stems are associated with a higher risk of PPF compared to the cemented composite beam design.[10] Despite what is currently known in the literature regarding risk factors, PPF subtypes vary significantly in their stability and therefore appropriate management. Recently, the Unified Classification System (UCS) was introduced to classify all possible fracture subtypes around arthroplasties of major joints.[11] This classification system has been shown to have excellent inter- and intraobserver agreement.[12]

Little is currently known about the characteristics and risk factors associated with the different UCS fracture subtypes. Previous cohort studies concluded that the choice of cemented femoral stem may influence risk of revision for PPFs, and that the Exeter stem is associated with a higher risk of type B fractures compared to the Lubinus stem.[13,14] Thien et al[15] investigated implant design in a large registry-based study, and concluded that the shape and surface finish of the femoral stem and its fixation is associated with the risk of PPF. More recently, Jain et al[16] concluded that male sex was associated with a reduction in odds of sustaining a UCS C fracture, while Karam et al[17] described a burst and spiral fracture pattern associated with cemented stems and a clamshell pattern associated with uncemented stems. However, most of the studies included a small population, accounted for a limited number of covariates in their analyses, or compared purely cemented stems. To date, no relationship has been established between UCS fracture grade and femoral stem cementing type (cemented versus uncemented). In addition, limited information is available comparing patient demographic characteristics, outcomes, and uncemented component designs and their relationship with UCS grade of fracture.

In this study, we aimed to describe the characteristics, management strategies, and outcomes of the different UCS fracture grades in hip PPFs. In addition, we evaluated the patient-, injury mechanism-, and implant-related risk factors associated with each UCS fracture grades.

Methods

Using a multicentre trainee-led collaborative research model, we included adult patients who presented with a PPF between 1 January 2010 and 31 December 2019. Data were collected from 29 NHS trusts in the UK. Skeletally immature patients, iatrogenic intraoperative PPFs, isolated acetabular fractures, and suspected tumour cases were excluded. PPFs sustained intraoperatively were excluded because the majority are managed immediately when recognized.

The study methodology was published prior to commencing the study.[18] Each participating hospital obtained local trust site governance approval. This study was registered as a service evaluation. Data collection was performed through REDCap, an online secure software platform that supports data capture for research studies.[19,20] A minimum of 80% of data variables must have been completed by participating sites in order for data to be accepted for analysis.

Data on patient demographic characteristics, fracture characteristics, management strategies, and outcomes were collected retrospectively. The PPF database was subsequently filtered and only patients with a PPF involving a total hip arthroplasty (THA) or hip hemiarthroplasty were included. The type of femoral stem implant was categorized by participating sites according to cementing (cemented versus uncemented), type of stem, collar, and implant brand. The PPFs were further assessed via radiographs and categorized according to the UCS grade. UCS grades were classified as AG (greater trochanter fracture), AL (lesser trochanter fracture), B1 (fracture around a stable stem), B2 (fracture around a loose stem, with good bone stock), B3 (fracture around a loose stem with poor bone stock), C (fracture distal to the implant and cement mantle), D (fracture between hip and knee arthroplasties, closer to the hip), and E (fracture involving the pelvis and femur).[11] Patients with missing data on UCS grade were excluded from the analysis.

Statistical analysis. Categorical variables were presented as totals and percentages. Continuous variables were presented as means and medians. Patient demographic characteristics, injury characteristics, type of implant, management methods, and outcomes were compared between the UCS grades using chi-squared or Fisher's exact test for discrete variables, and Kruskall-Wallis or analysis of variance tests for continuous variables. Multinomial logistic regression models were developed to identify the correlation between independent variables and the different UCS grades (dependent variables), compared to a reference outcome defined as UCS grade B. Independent variables with > 10% missing data were not included in the regression model. Statistical significance was defined as $p < 0.05$. Stata v. 17 (StataCorp, USA) was used to perform the statistical analyses.

Results

Patients. Out of 1,667 patients in the PPF study database, a total of 1,104 patients met the inclusion criteria. Table I describes the demographic characteristics of this population. In summary, the majority were female (57.9%; n = 639), white in ethnicity (89%), and with a median age of 82 years (interquartile range (IQR) 74 to 87). The most common type of fracture was a UCS B (73%; n = 810), of

Table I. Study population characteristics.

		UCS								
Variable	**Total**	**AG**	**AL**	**B1**	**B2**	**B3**	**C**	**D**	**E**	**p-value**
Patients, n (%)	1,104	94 (8.5)	19 (1.7)	337 (30.5)	368 (33.3)	105 (9.5)	136 (12.3)	44 (4)	1 (0.1)	
Age, years										0.058*
Mean (SD)	80 (10.6)	80 (10.2)	84.9 (6.0)	79.7 (11.6)	79.3 (10.3)	79.7 (10.3)	81.9 (10.3)	81.1 (8.7)	84	
Median (IQR)	82 (74 to 87)	81.5 (73 to 88)	86 (85 to 89)	82 (74 to 88)	81 (73 to 86)	82 (74 to 87)	83 (76 to 89)	82.5 (80 to 86.5)	84	
Sex, n (%)										0.002†
Female	639 (57.9)	49 (52.1)	16 (84.2)	190 (56.4)	196 (53.3)	61 (58.1)	93 (68.4)	33 (75)	1 (100)	
Male	465 (42.1)	45 (47.9)	3 (15.8)	147 (43.6)	173 (47)	43 (41)	43 (31.6)	11 (25)	0	
Ethnicity, n (%)										0.495†
White	977 (88.5)	84 (89.4)	18 (94.7)	292 (86.6)	329 (89.4)	91 (86.7)	123 (90.4)	39 (88.6)	1 (100)	
Asian	4 (0.4)	0	0	4 (1.2)	0	0	0	0	0	
Mixed	2 (0.2)	1 (1.1)	0	0	1 (0.3)	0	0	0	0	
Black	6 (0.5)	2 (2.1)	0	0	2 (0.5)	0	2 (1.5)	0	0	
Other	2 (0.2)	0	0	0	2 (0.5)	0	0	0	0	
Unknown	113 (10.2)	7 (7.4)	1 (5.3)	41 (12.2)	34 (9.2)	14 (13.3)	11 (8.1)	5 (11.4)	0	
AMTS										0.142*
Mean (SD)	8.1 (2.9)	8.2 (2.7)	6.2 (3.1)	8 (3.0)	8.2 (2.9)	8.1 (2.8)	8.1 (3.1)	8.1 (2.9)	10	
Median (IQR)	10 (7 to 10)	10 (7 to 10)	7 (3 to 8)	10 (7 to 10)	10 (8 to 10)	9 (8 to 10)	10 (8 to 10)	10 (7 to 10)	10	
ASA grade, n (%)										0.174†
I	26 (2.4)	0	0	12 (3.6)	9 (2.4)	4 (3.8)	1 (0.7)	0	0	
II	351 (31.8)	34 (36.2)	2 (10.5)	117 (34.7)	118 (32.1)	33 (31.4)	32 (23.5)	15 (34.1)	0	
III	599 (54.3)	44 (46.8)	16 (84.2)	172 (51)	198 (53.8)	57 (54.3)	86 (63.2)	25 (56.8)	1 (100)	
IV	109 (9.9)	11 (11.7)	0	29 (8.6)	37 (10.1)	11 (10.5)	17 (12.5)	4 (9.1)	0	
Missing	19 (1.7)	5 (5.3)	1 (5.3)	7 (2.1)	6 (1.6)	0	0	0	0	
BMI, kg/m^2										0.006*
Mean (SD)	26.3 (5.6)	26 (4.9)	22.8 (5)	25.4 (5.4)	26.7 (5.4)	26.9 (5.8)	26.7 (5.9)	30.3 (7.8)		
Median (IQR)	25.8 (22 to 29)	26 (22 to 29)	22 (19 to 27)	25 (22 to 28)	26 (23 to 30)	26 (22 to 31)	26 (23 to 29)	32 (21 to 38)		
Missing	411 (37.2)	22	6	131	148	39	39	25	1	
Mobility status, n (%)										< 0.001†
Independent	352 (31.9)	20 (21.3)	2 (10.5)	131 (38.9)	127 (34.5)	39 (37.1)	25 (18.4)	8 (18.2)	0	
Uses stick(s)	381 (34.5)	39 (41.5)	10 (52.6)	110 (32.6)	124 (33.7)	30 (28.6)	47 (34.6)	21 (47.7)	0	
Uses frame/walker	331 (30)	31 (33)	5 (26.3)	79 (23.4)	112 (30.4)	33 (31.4)	56 (41.2)	14 (31.8)	1 (100)	
Wheelchair user	25 (2.3)	3 (3.2)	1 (5.3)	11 (3.3)	1 (0.3)	2 (1.9)	6 (4.4)	1 (2.3)	0	
Bed-bound	6 (0.5)	0	1 (5.3)	2 (0.6)	1 (0.3)	0	2 (1.5)	0	0	
Unknown	9 (0.8)	1 (1.1)	0	4 (1.2)	3 (0.8)	1 (1)	0	0	0	
CCI										0.005*
Mean (SD)	4.9 (1.9)	4.9 (1.8)	6.7 (2.5)	4.8 (2)	4.8 (1.9)	4.6 (1.7)	5.1 (1.9)	5.4 (1.7)	4	
Median (IQR)	5 (4 to 6)	4 (4 to 6)	6 (5 to 8)	5 (4 to 6)	5 (4 to 6)	5 (4 to 6)	5 (4 to 6)	5 (4 to 6.5)	4	
Bisphosphonate use, n (%)	167 (15.1)	11 (11.7)	4 (21.1)	52 (15.4)	50 (13.6)	7 (6.7)	31 (22.8)	12 (27.3)	0	0.007†

*Kruskal-Wallis test.
†Chi-squared test
AMTS, Abbreviated Mental Test Score; ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index; IQR, interquartile range; PPF, periprosthetic fracture; SD, standard deviation.

which type B2 (33.3%; n = 368) was the most prevalent. Patients with a UCS AL fracture were older (median age 86 years (IQR 85 to 89)), mostly female (84%; n = 16), with a lower median AMTS score (median 7 (IQR 3 to 8)), a higher CCI score (median 6 (IQR 5 to 8)), and lower BMI (median 22 kg/m^2 (IQR 19 to 27)) compared to other UCS

Table II. Periprosthetic fracture characteristics.

		UCS								
Variable	**Total**	**AG**	**AL**	**B1**	**B2**	**B3**	**C**	**D**	**E**	**p-value***
Patients, n (%)	1104	94 (8.5)	19 (1.7)	337 (30.5)	368 (33.3)	105 (9.5)	136 (12.3)	44 (4)	1 (0.1)	
Open fracture, n (%)	10 (0.9)	0	0	5 (1.5)	3 (0.8)	1 (1)	1 (0.7)	0	0	0.905
Evidence of infection around PPF, n (%)	17 (1.5)	1 (1.1)	0	6 (1.8)	6 (1.6)	1 (1)	3 (2.2)	0	0	0.964
Pain on hx prior to PPF, n (%)	77 (7)	7 (7.4)	0	15 (4.5)	31 (8.4)	12 (11.4)	9 (6.6)	3 (6.8)	0	0.238
Implant, n (%)										0.068
THA	905 (82)	79 (84)	11 (57.9)	272 (80.7)	298 (81)	89 (84.8)	114 (83.8)	41 (93.2)	1 (100)	
Hemiarthroplasty	199 (18)	15 (16)	8 (42.1)	65 (19.3)	70 (19)	16 (15.2)	22 (16.2)	3 (6.8)	0	
Femoral stem, n (%)										< 0.001
Cemented	793 (71.8)	44 (46.8)	9 (47.4)	239 (70.9)	275 (74.7)	71 (67.6)	118 (86.8)	37 (84.1)	0	
Uncemented	299 (27.1)	48 (51.1)	9 (47.4)	95 (28.2)	88 (23.9)	33 (31.4)	18 (13.2)	7 (15.9)	1 (100)	
Missing	12 (1.1)	2 (2.1)	1 (5.3)	3 (0.9)	5 (1.4)	1 (1)	0	0	0	
Cemented femoral stems, n (%)										< 0.001
Taper slip	656 (82.7)	28 (66.7)	5 (55.6)	213 (91.4)	227 (85)	48 (69.6)	99 (86.8)	36 (97.3)	0	
Composite beam	115 (14.5)	14 (33.3)	4 (44.4)	20 (8.6)	40 (15)	21 (30.4)	15 (13.2)	1 (2.7)	0	
Composite beam										
Type of stem, n (%)										
Anatomical sagittal bow	34 (29.6)	6 (42.9)	1 (25)	1 (5)	11 (27.5)	3 (14.3)	11 (73.3)	1 (100)	1 (100)	< 0.001
Straight stem	81 (70.4)	8 (57.1)	3 (75)	19 (95)	29 (72.5)	18 (85.7)	4 (26.7)	0	0	
Collared implant, n (%)	47 (40.9)	4 (28.6)	2 (50)	10 (50)	16 (40)	7 (33.3)	8 (53.3)	0	0	0.741
Uncemented femoral stem										
Type of stem, n (%)										
Proximal loading	240 (83)	41 (93.2)	6 (85.7)	79 (83.9)	72 (81.8)	27 (84.4)	11 (61.1)	4 (66.7)	1 (100)	0.157
Diaphyseal loading	44 (15.2)	3 (6.8)	1 (14.3)	14 (15.1)	15 (17.1)	4 (12.5)	6 (33.3)	1 (16.7)		
Distally locked	5 (1.7)	0		1 (1.1)	1 (1.1)	1 (3.1)	1 (5.6)	1 (16.7)		
HA coating of stem, n (%)										
No coating	46 (17.5)	7 (16.7)	1 (25)	12 (14.5)	17 (20.2)	1 (3.7)	6 (35.3)	1 (20)	1 (100)	0.322
Proximal coated	111 (42.2)	17 (40.5)	1 (25)	35 (42.2)	35 (41.7)	15 (55.6)	7 (41.2)	1 (20)		
Fully coated	106 (40.3)	18 (42.9)	2 (50)	36 (43.4)	32 (38.1)	11 (40.7)	4 (23.5)	3 (60)		
Unknown	36 (12)									
Modular stem, n (%)	67 (22.4)	7 (14.6)	0	28 (29.5)	17 (19.3)	5 (15.2)	7 (38.9)	3 (42.9)	0	0.008
Implant with anatomical sagittal bow, n (%)	38 (12.7)	4 (8.3)	1 (11.1)	12 (12.6)	13 (14.8)	3 (9.1)	3 (16.7)	2 (28.6)	0	0.118
Collared implant, n (%)	86 (28.8)	23 (47.9)	5 (55.6)	25 (26.3)	16 (18.2)	11 (33.3)	6 (33.3)	0	0	< 0.001

*Chi-squared test/Fisher's exact test.
HA, hydroxyapatite; hx, history; PPF, periprosthetic fracture; THA, total hip arthroplasty.

subtypes. BMI was higher in UCS D (median 32 kg/m^2 (IQR 21 to 38)) compared to other fracture subtypes (p = 0.006, Kruskal-Wallis test). Bisphosphonate use was more prevalent in fractures distal to the cement mantle (22.8% (n = 32) in UCS C, 27.3% (n = 12) in UCS D) (p = 0.007, chi-squared test).

PPF characteristics. Table II describes the injury and implant characteristics. A total of 77 patients (7%) had pain prior to presentation, of which 31 (40%) resulted in a B2 fracture. A total of 155 (20%) of cemented femoral stems resulted in a UCS C or D fracture, compared to 25 (8%) of uncemented stems. In addition, a higher proportion of uncemented compared to cemented stems resulted in a UCS A fracture (19% (n = 57) vs 7% (n = 53), respectively).

Of the PPFs involving a cemented femoral stem, taper slip prosthesis was more prevalent than composite beam stems (82.7% (n = 656) vs 14.5% (n = 115), respectively). Overall, 74.3% of taper slip stems (n = 488) versus 70.4% of composite beam stems (n = 81) resulted in a UCS type B fracture. The majority of UCS B fractures in composite beam stems involved a straight stem design (81%; n = 66), while the majority of UCS C fractures in composite beam stems involved an anatomical sagittal bow design (73.3%; n = 11). The different brands of cemented stems did not significantly differ between the UCS subtypes.

A total of 299 (27%) sustained a PPF around an uncemented femoral stem. The majority of PPFs involving an uncemented femoral stem were proximal loading (83%; n = 240) and proximally coated (42.2%; n = 111). Overall, 75% of PPFs involving a modular uncemented stem resulted in a UCS B fracture (n = 50), while 15% resulted in a UCS C or D fracture (n = 10). The highest proportion

Table III. Management of periprosthetic fractures.

		UCS								
Variable	**Total**	**AG**	**AL**	**B1**	**B2**	**B3**	**C**	**D**	**E**	**p-value**
Patients, n (%)	1,104	94 (8.5)	19 (1.7)	337 (30.5)	368 (33.3)	105 (9.5)	136 (12.3)	44 (4)	1 (0.1)	
Treatment method, n (%)										< 0.001*
Conservative	131 (11.9)	69 (73.4)	13 (68.4)	29 (8.6)	11 (3)	6 (5.7)	2 (1.5)	1 (2.3)	0	
ORIF	585 (53)	17 (18.1)	5 (26.3)	268 (79.5)	109 (29.6)	28 (26.7)	123 (90.4)	35 (79.6)	0	
Revision arthroplasty	189 (17.1)	3 (3.2)	1 (5.3)	18 (5.3)	113 (30.7)	42 (40)	6 (4.4)	6 (13.6)	0	
ORIF + revision arthroplasty	199 (18)	5 (5.3)	0	22 (6.5)	135 (36.7)	29 (27.6)	5 (3.7)	2 (4.6)	1 (100)	
Revision with endoprosthesis	29 (2.6)	1 (1.1)	0	3 (0.9)	8 (2.2)	12 (11.4)	1 (0.7)	4 (9.1)	0	
Time from presentation to surgery, days										
Mean (SD)	4.5 (6.6)	7.7 (17.5)	4.7 (4.9)	4 (3.9)	5.2 (7.6)	4.5 (4)	3 (3.5)	4.7 (11.5)	3	0.001†
Median (IQR)	3 (2 to 5)	4 (2 to 6)	2.5 (1 to 8)	3 (2 to 5)	4 (2 to 6)	3 (2 to 6)	2 (1 to 3)	2 (1 to 4)	3	
Speciality of operating surgeon, n (%)										< 0.001*
Arthroplasty surgeon	819 (84.2)	23 (92)	6 (100)	252 (81.8)	330 (92.4)	87 (87.9)	88 (65.7)	33 (76.7)	0	
Trauma/general/other	146 (15)	2 (8)	0	52 (16.9)	26 (7.3)	12 (12.1)	45 (33.6)	8 (18.6)	1 (100)	
Unknown	8 (0.8)	0	0	4 (1.3)	1 (0.3)	0	1 (0.7)	2 (4.7)	0	

*Chi-squared test.
†Kruskal-Wallis test.
IQR, interquartile range; ORIF, open reduction and internal fixation; SD, standard deviation.

of collared uncemented stems was seen in UCS A fractures (49%; n = 28).

Management of UCS grades. Table III describes management methods of the different UCS grades. Most B1 and C fractures underwent fixation (79.5% (n = 268) and 90.4% (n = 123), respectively), while the majority of B2 and B3 fractures underwent revision arthroplasty (67.4% (n = 148) and 67.6% (n = 71), respectively). Overall, 29.6% of UCS B2 fractures (n = 109) and 26.7% of UCS B3 fractures (n = 28) underwent fixation. A total of 29 patients (3%) underwent revision with an endoprosthesis, of which 12 (41%) were for a UCS B3 fracture. The mean time from presentation to surgery was 4.5 days (standard deviation (SD) 6.6). Patients with a UCS AG fracture had a longer wait to surgery at a mean of 7.7 days (SD 17.5); p < 0.001, analysis of variance). The majority of surgically treated patients were operated on by an arthroplasty surgeon (84.2%; n = 819).

Outcomes of UCS grades. Table IV describes outcomes of the UCS fracture grades. In-hospital mortality did not significantly differ between fracture subtypes (p = 0.366, chi-squared test/Fisher's exact test). The median length of stay (LOS) was significantly different between the fracture subtypes (p < 0.001, Kruskal-Wallis test), with the longest duration of stay seen in UCS D fractures (median 19 days (IQR 11 to 26)). A total of 72 (6.5%) were readmitted to hospital within 30 days, with the highest proportion of readmissions seen in UCS D fractures (20.5%; n = 9). More than one-third of patients (35%; n = 361) were discharged to step-down or interim care. The highest proportion of patients discharged to step-down care was seen in UCS C fractures (41.4%; n = 53).

Effect of covariates on UCS grade. A multinomial logistic regression analysis was modelled to evaluate the predictors of UCS subtypes (Table V). The use of mobility aids was associated with a higher risk of sustaining a UCS type C fracture compared to a B fracture. The risk of sustaining a UCS type C fracture for wheelchair users is 11 times that of patients who mobilize independently (RRR 11.7 (95% CI 2.4 to 57.9); p = 0.002). Patients with a hemiarthroplasty around which the PPF has occurred are at a decreased risk of sustaining a UCS type C fracture, relative to a type B fracture, than patients with a THA (RRR 0.5 (95% CI 0.2 to 0.95); p = 0.037). In addition, uncemented femoral stems overall are at a decreased risk of fractures distal to the tip of the stem, relative to a type B fracture, than cemented stems. The risk of sustaining a UCS type C fracture in uncemented stems is 0.36 times that of cemented stems (RRR 0.36 (95% CI 0.2 to 0.7); p = 0.002). Uncemented femoral stems were also associated with an increased risk of UCS A fractures, relative to a type B fracture, than cemented stems (RRR 3.3 (95% CI 1.9 to 5.7); p < 0.001). The overall pseudo R^2 of the model was 0.22.

Discussion

To the best of our knowledge, this is the largest study comparing the characteristics between the different UCS grades of hip PPFs. In general, the majority of our population are elderly, frail, with similar mortality rates

Table IV. Outcomes.

		UCS								
Variable	**Total**	**AG**	**AL**	**B1**	**B2**	**B3**	**C**	**D**	**E**	**p-value**
In-hospital mortality, n (%)	59 (5.3)	0	1 (5.3)	18 (5.3)	24 (6.5)	7 (6.7)	8 (5.9)	1 (2.3)	0	0.366*
Total length of stay (days)										< 0.001†
Mean (SD)	22.3 (54.9)	16.7 (21.3)	20.9 (32.6)	25.3 (93.3)	20 (16.6)	22.1 (34.7)	26.3 (26.3)	20.9 (15.1)	14	
Median (IQR)	14 (9 to 23)	11 (6 to 17)	12.5 (7 to 20)	13 (9 to 21)	15 (10 to 24)	16 (10 to 24)	16.5 (10 to 32)	19 (11 to 26)	14	
SSI postoperatively, n (%)										0.265*
Superficial	26 (2.7)	0	2 (33.3)	10 (3.2)	12 (3.4)	1 (1)	0	1 (2.3)	0	
Deep	26 (2.7)	2 (8)	1 (16.7)	9 (2.9)	8 (2.2)	2 (2)	4 (3)	0	0	
Dislocation, n (%)	49 (4.4)	4 (4.3)	1 (5.3)	10 (3)	18 (4.9)	10 (9.5)	2 (1.5)	4 (9.1)	0	0.040*
Readmission within 30 days, n (%)	72 (6.5)	8 (8.5)	0	19 (5.6)	26 (7.1)	6 (5.7)	4 (2.9)	9 (20.5)	0	0.026*
Discharge destination, n (%)										
Usual place of residence	683 (65.4)	71 (75.5)	14 (77.8)	220 (69.2)	216 (62.8)	66 (67.4)	75 (58.6)	20 (46.5)	1 (100)	0.010*
Sheltered accommodation	2 (0.2)	0	0	1 (0.3)	1 (0.3)	0	0	0	0	
Residential home	59 (5.7)	4 (4.3)	0	11 (3.5)	15 (4.4)	4 (4.1)	17 (13.3)	8 (18.6)	0	
Nursing home	102 (9.8)	11 (11.7)	2 (11.1)	25 (7.9)	27 (7.9)	11 (11.2)	18 (14.1)	8 (18.6)	0	
Community hospital	173 (16.6)	8 (8.5)	2 (11.1)	51 (16)	73 (21.2)	14 (14.3)	18 (14.1)	7 (16.3)	0	
Acute hospital	11 (1.1)	0	0	2 (0.6)	8 (2.3)	1 (1)	0	0	0	
Hospice	2 (0.2)	0	0	1 (0.3)	1 (0.3)	0	0	0	0	
Other	12 (1.2)	0	0	7 (2.2)	3 (0.9)	2 (2)	0	0	0	
Return to theatre, n (%)	22 (2)	3 (3.2)	1 (5.3)	4 (1.2)	9 (2.5)	0	3 (2.2)	2 (4.6)	0	0.174*

*Chi-squared test.
†Kruskal-Wallis test.
IQR, interquartile range; SD, standard deviation; SSI, surgical site infection.

as the neck of femur fracture population, as previously suggested.[21,22] The most common UCS fracture subtype in our population was B2, denoting a loose stem with good bone stock, a finding that is consistent in multiple other studies.[17,23,24] Pain prior to sustaining a PPF, which may possibly correlate with stem loosening, was most prevalent in patients that sustained a B2 and B3 fracture. Being aware of the impending risk of fracture in patients with pain or loose prosthesis is of utmost importance.

Several implant related characteristics, such as mode of fixation of the femoral stem and stem design, were significantly different in the various UCS fracture subtypes. A significant difference was identified between cemented and uncemented stems in their association with UCS fracture grade, a finding that has not been previously reported in other studies. A higher proportion of cemented femoral stems were present in UCS C and D fractures, while a higher proportion of uncemented stems were present in UCS B fractures. Previous data have shown that the cumulative probability of a PPF in uncemented implants is 1.6% at ten years, increasing to 13.2% at 29 years after surgery, possibly because uncemented implants have been implanted for longer in younger patients and may have been loose prior to sustaining the PPF.[25] For uncemented implants, UCS B fractures were the most prevalent, followed by UCS A type fractures. For cemented implants, though UCS B was again the most prevalent, UCS C fractures were more common than UCS A fractures. This may be due to differences in stem geometry and loading mechanisms, as well as poor bone quality and advanced age in patients who underwent a cemented THA.

In uncemented femoral stems, significant differences in UCS grade of fracture existed in modular stems and in collared versus collarless stems. Modular uncemented femoral stems are routinely reserved for complex and revision hip procedures because they allow more surgical flexibility.[26] Failure at the modular junction of these implants has been a topic of debate, especially with older generations of the stems. Previous reports have also analyzed implant fractures, which were limited to the level of the modular junction.[27-29] Our more recent

Table V. Multinomial logistic regression: predictors of Unified Classification System (UCS) subtypes compared to UCS B.

Subtype	RRR (95% CI)	p-value
UCS A		
Type of femoral stem		
Cemented (reference)	1	
Cementless	3.3 (1.9 to 5.7)	< 0.001
Mobility prior to PPF		
Independent	Reference	
Uses stick	3 (1.4 to 6.4)	0.004
Uses frame/walker	2.7 (1.1 to 6.6)	0.034
Wheelchair user	7.5 (1.3 to 41.8)	0.022
Dementia	2.8 (1.03 to 7.6)	0.043
Mechanism of injury		
Fall < 2 m	Reference	
MVC	9.1 (1.3 to 65.3)	0.028
UCS C		
Type of femoral stem cementing		
Cemented	Reference	
Cementless	0.36 (0.2 to 0.7)	0.002
Mobility prior to PPF		
Independent	Reference	
Uses stick	2 (1.1 to 4.4)	0.036
Uses frame/walker	3 (1.4 to 6.5)	0.005
Wheelchair-bound	11.7 (2.4 to 57.9)	0.002
Diabetes	0.3 (0.2 to 0.7)	0.008
Implant around PPF		
THA	Reference	
Hip hemiarthroplasty	0.5 (0.2 to 0.95)	0.037
UCS D		
Type of femoral stem cementing		
Cemented	Reference	
Cementless	0.3 (0.08 to 0.89)	0.032
Sex		
Female	1	
Male	0.2 (0.1 to 0.7)	0.011
Mobility prior to PPF		
Independent	Reference	
Uses stick	6.3 (1.4 to 27.6)	0.015
Prior PPF in the past	13 (2.4 to 71.7)	0.003
Parkinson's disease	9.8 (1.4 to 70.1)	0.023
Dementia	7.4 (1.2 to 47.4)	0.035
Rheumatoid disease	5.6 (1.4 to 22.6)	0.016
Metastatic cancer	16 (2.6 to 97.4)	0.003
Mechanism of injury		0.002
Fall < 2 m	Reference	
Fall > 2 m	12.5 (2.6 to 60.1)	

CI, confidence interval; PPF, periprosthetic fracture; RRR, relative risk ratio; THA, total hip arthroplasty; UCS, Unified Classification System.

results demonstrate that 15% of PPFs involving a modular stem resulted in a fracture distal to the tip of the stem. In addition, 7.7% of our population (n = 86) sustained a PPF around a collared uncemented stem. The highest proportion of PPFs involving a collared uncemented implant in our population are seen in UCS A (49%). Collared implants are associated with overall less risk of PPFs, less subsidence, and reduced propagation of calcar fractures as suggested by previous research.[30]

Most UCS A fractures in our population were managed conservatively (72.5%), most UCS B1 were managed with fixation (80%), most UCS B2 and B3 were managed with revision (67% and 68%, respectively), and most UCS C and D were managed with fixation (90% and 80%, respectively). This is expected and consistent with treatment principles and findings from previous studies.[16,31]

This is the largest study so far comparing outcomes in different UCS fracture subtypes since the introduction of this classification system. Total LOS, dislocation, readmission to hospital, and discharge destination were significantly different between the UCS fracture grades. Patients with a UCS D fracture had the longest median LOS, highest proportion of hospital readmission rates, and highest proportion of patients who were discharged to step-down or interim care. This may be related to the weightbearing status of those patients, complications associated with decreased mobility, and the higher BMI in this group.

Our study has several limitations. First, a proportion of participating centres withdrew from the study due to difficulty acquiring detailed information, particularly from centres without electronic patient records, which may have resulted in selection bias. Obtaining the true incidence of PPFs was not achievable. The centres that did participate had minimal missing data, and this could have resulted in data bias because they may have had more advanced medical record systems, allowing for easier data collection. Despite our rigorous attempts in the multivariable analysis, residual confounding might still be present due to missing information such as time from index procedure to fracture, and information on radiological position of the original arthroplasty implants prior to the PPF. We acknowledge that a calcar fracture propagating to a UCS B2 postoperatively is treated differently from a longstanding femoral stem with poly wear, lysis, and fracture. We have also included patients with PPFs around a THA and a hemiarthroplasty, which may have introduced heterogeneity in our population. However, the implant around which the PPF has occurred was accounted for in the multinomial regression analyses. Finally, interpretation of radiological images as per the UCS for PPFs is subject to inter- and intraobserver variability, even though the intraobserver agreement was 0.920 for the experts, and 0.772 for the pre-experts, as suggested by Vioreanu et al.[12]

In conclusion, patients with PPFs around the hip are frail with high mortality rates, consistent with those seen in patients with femoral neck fractures. Several patient- and implant-related characteristics are associated with certain UCS fracture subtypes. Although UCS type B fractures are the most common fracture pattern in both cemented and uncemented stems, UCS A fractures are more common in uncemented stems, and UCS C fractures in cemented stems. A national PPF database that records patient characteristics and implant name is needed. This would help to further identify trends and correlation between implants and fracture subtypes, and may also help to monitor specific patients at risk of PPFs who could benefit from revision surgery prior to sustaining a fracture.

Take home message

- Patients with periprosthetic fractures (PPFs) around the hip are similar to the neck of femur fracture population.
- Uncemented femoral stems are associated with a reduced risk of Unified Classification System (UCS) C and increased risk of UCS A fractures.
- A national PPF database is currently needed.

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- A. Mahmood: Funding acquisition, Resources, Supervision, Visualization, Writing – review & editing.

Funding statement:
- The authors disclose receipt of the following financial or material support for the research, authorship, and/or publication of this article: this work was supported by the Queen Elizabeth Hospital Birmingham (QEHB) Charity Trauma Research and Ed-

ucation Fund, who helped with set-up costs. The funding source was not involved in the study design, data collection, analysis, or writing of the manuscript.

ICMJE COI statement:
- A. Mahmood is the president of the British Trauma Society.

Data sharing:
- The data that support the findings for this study are available to other researchers from the corresponding author upon reasonable request.

Acknowledgements:
- We are grateful for the hard work of the Birmingham centre for observational and prospective studies (BiCOPS) in managing the data. We are also grateful for the hard work of Brett Ellis and Charlotte Thornewell for their support in setting up resources for this project.

Ethical review statement:
- This study was registered as a service evaluation and therefore exempt from IRB approval. This study was approved in each of the participating hospitals local governance department as a service evaluation.

The PPF Study Collaborative:
- Varun Dewan, The Birmingham Orthopaedic Network, Birmingham, UK; Jerome Davidson, Mohammed Al-Azzawi, Christian Smith, Mothana Gawad, St Thomas Hospital, London, UK; Ioannis Palaiologos, Rory Cuthbert, Warran Wignadasan, The Whittington Hospital, London, UK; Daniel Banks, James Archer, Abdulrahman Odeh, New Cross Hospital, Wolverhampton, UK; Thomas Moores, Muaaz Tahir, Margaret Brooks, Walsall Manor Hospital, Walsall, UK; Gurdeep Biring, Stevan Jordan, Zain Elahi, Mohammed Shaath, Stoke Mandeville Hospital, Aylesbury, UK; Manoj Veettil, Chiranjit De, Sandwell General Hospital, West Bromwich, UK; Mohit Bansal, Akshdeep Bawa, Ahmed Mattar, Varun Tandra, Audrina Daadipour, Ahmed Taha, Princess Royal University Hospital, Orpington, UK; Shafat Gangoo, Sriram Srinivasan, Mandishona Tarisai, James Paget Hospital, Norfolk, UK; Basil Budair, Krishna Subbaraman, Farrukh Khan, Austin Gomindes, Arjun Samuel, Queen Elizabeth Hospital, Birmingham, UK; Niel Kang, Karan Kapur, Elizabeth Mainwaring, Hannah Bridgwater, Andre Lo, Addenbrooke's Hospital, Cambridge UK; Usman Ahmed, Tahir Khaleeq, Princess Royal Hospital, Telford, UK; Ahmed El- Bakoury, Ramy Rashed, Hazem Hosny, Rathan Yarlagadda, Jonathan Keenan, Ahmed Hamed, Derriford Hospital, Plymouth, UK; Bryan Riemer, Arham Qureshi, Vatsal Gupta, University Hospital Coventry & Warwickshire, Coventry, UK; Matthew Waites, Sabri Bleibleh, David Westacott, Russell's Hall Hospital, Dudley, UK; Jonathan Phillips, Jamie East, Daniel Huntley, Royal Devon and Exeter Hospital, Exeter, UK; Saqib Masud, Yusuf Mirza, Sandeep Mishra, Morriston Hospital, Swansea, UK; David Dunlop, Mohamed Khalefa, Balakumar Balasubrama-nian, Mahesh Thibbaiah, Olivia Payton, Royal Orthopaedic Hospital, Birmingham, UK; James Berstock, Krisna Deano, Royal United Hospital, Bath, UK; Khaled Sarraf, Kartik Logishetty, George Lee, Hariharan Subbiah- Ponniah, St Mary's Hospital, Lon-don, UK; Nirav Shah, Aakaash Venkatesan, James Cheseldene-Culley, Joseph Ayatha-mattam, Worthing Hospital, Worthing, UK; Samantha Tross, Sukhwinder Randhawa, Faisal Mohammed, Ramla Ali, Ealing Hospital, Southall, UK; Jonathan Bird, Kursheed Khan, University Hospital Lewisham, London, UK; Muhammad Adeel Akhtar, Andrew Brunt, Panagiotis Roupakiotis, Victoria Hospital, Kirkcaldy, UK; Padmanabhan Subramanian, Nelson Bua, Barnet General Hospital, Barnet, UK; Mounir Hakimi, Samer Bitar, Majed Al Najjar, Ajay Radhakrishnan, Charlie Gamble, Salford Royal Hospital, Salford, UK; Andrew James, Catherine Gilmore, Dan Dawson, Ulster Hospital, Belfast, UK; Rajesh Sofat, Mohamed Antar, Aashish Raghu, Lister Hospital, Stevenage, UK; Sam Heaton, Waleed Tawfeek, Christerlyn Charles, Yeovil District Hospital, Yeovil, UK; Henry Burnand, Sean Duffy, Luke Taylor, Bristol Royal Infirmary, Bristol, UK; Laura Magill, Rita Perry, Michala Pettitt, Kelvin Okoth, Thomas Pinkney, The Birmingham Centre for Observational and Prospective Studies (BiCOPS), University of Birmingham, Birmingham, UK.

Open access funding:
- The open access fee was self-funded.