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ORIGINAL ARTICLE

Patients with periprosthetic femoral fractures are older adults who are commonly diagnosed with osteoporosis

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Abstract

Summary This study focused on individuals aged ≥ 50 years with periprosthetic femoral fractures (PFF). When compared to those with native hip fractures, patients with PFF were older, had a higher BMI, and demonstrated a greater number of comorbidities. Given the high frequency of osteoporosis risk factors and the BMD results, PFF should be classified as osteoporotic fractures.

Introduction To compare patients presenting with periprosthetic femoral fractures (PFF) to patients with native hip fractures with a special focus on bone mineral density (BMD) measurements, in order to reinforce the hypothesis that PFF are osteoporotic fractures.

Methods A retrospective, single-centre, observational study of all patients aged ≥ 50 years with low-energy PFF identified at the Lille University Hospital from January 1, 2016, to December 31, 2022, was conducted. The PFF group was compared to a group of patients with native hip fractures hospitalized during the same period. To compare the T-score data, we used a linear mixed model that considered a predefined adjustment for age, sex, and BMI. Adjusted means ± standard error of the mean (SEM) are derived from the mixed model.

Results Among 71 patients with PFF (78.9% female, median (IQR) age 81 (72–88) years), osteoarthritis (57.8%) was the primary indication for hip surgery. Compared with the native hip fracture group ($n = 117$), patients in the PFF group were significantly older ($p = 0.002$), had a significantly greater BMI ($p = 0.043$), and had a higher history of multiple falls (54.3% vs. 26.1%, $p < 0.001$). A greater frequency of previous low-energy fractures (69.0% vs. 44.0%, $p < 0.001$) and an increased prescription of anti-osteoporosis medications (26.8% vs. 11.1%, $p = 0.006$) in patients with PFF were found. Adjusted T-scores differed between the two groups at the lumbar spine (mean adjusted ± SEM, − 0.5 ± 0.2 (PFF group) vs. − 1.2 ± 0.2 (comparator group), $p = 0.008$) but not at the femoral neck or at the total hip.

Conclusion Low-energy PFF should be considered as an osteoporotic fracture and treated accordingly.

Keywords Bone mineral density · Fracture liaison service · Osteoporosis · Periprosthetic femoral fractures · Periprosthetic fractures

Introduction

The increase in life expectancy and the growing demand from patients for enhanced joint mobility and an improved quality of life have resulted in an increasing number of total joint arthroplasties (TJA). The numbers of total hip arthroplasty (THA) and total knee arthroplasty (TKA) surgeries are expected to increase by 300% and 400%, respectively, by 2040, reaching approximately 4 million interventions per year by 2030 in the USA [1, 2].

Despite the high prevalence of TJA, complications, including periprosthetic fractures (PPF), remain. Periprosthetic femoral fractures (PFF) represent the second most

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common cause of revision following THA [3, 4]. Periprosthetic fractures are defined as fractures occurring around an orthopedic implant, either a TJA or any other internal fixation device (e.g., hip resurfacing or gamma nail). This outcome affects up to 18% of patients following primary TJA, with an annual increased risk of 13% in the UK over the last few years [1, 2, 5, 6].

Mortality is broadly similar to osteoporotic fractures, with a 1-year mortality rate of 10–36% for PFF [2, 7–10]. It also represents a major public health burden, with a PFF costing approximately $40,000 in the USA [2]. Orthopedists are thus well aware of this complication and have conducted several studies to identify potential risk factors for PPF. Some of these are specific to the surgical procedure itself, such as an uncemented stem [3, 11], but most are actually similar to those associated with osteoporosis, including age, sex, history of low-energy fracture, and rheumatoid arthritis [1, 3, 11]. Moreover, PPF is predominantly a consequence of low-energy trauma [12, 13], and patients undergoing TJA are typically over 60 years of age; therefore, they are at higher risk of osteoporosis [1].

However, few studies have investigated the bone mineral density (BMD) of patients presenting with PPF. They mostly found an elevated prevalence of low BMD, indicative of underlying osteopenia or osteoporosis [2, 14]. In recent studies, osteoporosis, defined by a T-score ≤ -2.5, was present in up to 78% of patients before PPF [2, 14] and osteoporosis/osteopenia, defined by a T-score ≤ -1, was present in 50–86% of patients prior to TJA [15–18]. Moreover, some studies have demonstrated bone loss within a few months following TJA [19, 20].

However, studies on PPF are usually based on a limited sample size, and data on BMD remain scarce. To the best of our knowledge, no previous study has compared the characteristics of patients with PFF to those with native hip fractures, particularly BMD. Therefore, we aimed to compare patients presenting with PFF to patients with native hip fractures with a special focus on BMD measurements to better characterize patients with PFF and reinforce the hypothesis that PFF are osteoporotic fractures.

Patients and methods

Study design

We conducted a retrospective, single-centre, observational study of all patients with PFF identified at Lille University Hospital from January 1, 2016, to December 31, 2022. This research project was approved by the local Medical Research Ethics Committee.

Study population

Inclusion criteria were adults of both sexes with PFF, aged 50 years or over, and hospitalized at the Lille University Hospital for a low-energy PFF using the *International Classification of Diseases 10 th Revision* (ICD- 10 M96.6 code) and/or the Fracture Liaison Service (FLS) database [21, 22]. PFF was defined as a fracture around a surgically implanted femoral device [13]. Only patients with a PFF and bone densitometry using DXA available in the year before or after the fracture were included.

The exclusion criteria were PFF related to bone metastases, high-energy PFF, atypical PFF, periprosthetic joint infection, periprosthetic osteolysis, or wear.

The PFF group was compared to a group of patients with native hip fractures hospitalized at Lille University Hospital from January 1, 2016, to December 31, 2022. In the comparator group, only patients seen by the FLS who had bone densitometry performed using DXA were included.

Study assessment

All data were collected by one rheumatologist (VH) using a standardized data collection instrument by full reading of the computerized medical files of patients with PFF and native hip fractures.

Medical file

Age, sex, body mass index (BMI), comorbidities (Charlson Comorbidity Index (CCI)), current medications, and risk factors for osteoporosis were collected, including current or past smoking, current or past alcohol abuse ($\geq$ 3 units of alcohol per day for men and $\geq$2 units for women), family history of hip fracture, premature menopause (< 45 years), and current and past glucocorticoid exposure. History of low-energy fracture, multiple falls (at least two falls in the last year), and anti-osteoporosis medications (AOM) were also collected (i.e., bisphosphonates, denosumab, and teriparatide).

The WHO criteria were used to define osteoporosis (T-score ≤ -2.5) and osteopenia (T-score between -1.0 and -2.5) for each site (lumbar spine, femoral neck, and total hip). FRAX® scores were also calculated using femoral neck BMD measurements.

Almost all of bone densitometry were performed at the Lille University Hospital (~ 90%), and the rest were performed outside the Lille University Hospital. During the study period, two Hologic© scanners were available at the Lille University Hospital (HOLOGIC Discovery A S/N 81360 and HOLOGIC Horizon W S/N 300869 M). The

following reference curves were used: for women, the Isos, Ofely, and Genset (IOG) curve for the lumbar spine (established from three French populations) [23] and the National Health and Nutrition Examination Survey (NHANES) curve for the hip [24, 25]; for men, the Bone Mineral Density in Childhood Study (BMDCS) curve for the lumbar spine [26] and the NHANES curve for the hip [24, 25].

Statistical analysis

Categorical variables are expressed as numbers (percentage), while continuous variables are expressed as means (standard deviation, SD) in the case of normal distribution or medians (interquartile range) otherwise. Normality of distribution was assessed using histograms and the Shapiro–Wilk test.

Comparisons between patients presenting with PFF to patients presenting with native hip fractures were performed using Chi-square tests (or Fisher's exact tests when expected cell frequency was <5) for categorical variables and Mann–Whitney U or Student's t-tests (regarding the normality of distributions) for continuous variables.

To compare T-scores, we used a linear mixed model that considered a predefined adjustment for age, sex, and BMI. The validity of the linear mixed models was assessed by examining the residuals. Adjusted means ± standard errors of the mean (SEM) are derived from the mixed model.

Statistical analysis was performed using a two-tailed α level of 0.05. Data were analyzed using the SAS software package (version 9.4; SAS Institute, Cary, NC, USA).

Results

Patient selection

From January 1, 2016, to December 31, 2022, 517 of 613 patients with PPF identified using the ICD- 10 M96.6 code and/or the FLS database were eligible for inclusion in this study, and 115 were excluded (Fig. 1). Among patients with PPF ($n=$ 5 17), 389 (75.2%) had PFF and 71 had available bone densitometry data and were compared to a group of 117 patients with native hip fractures identified using the FLS database.

Demographic data and baseline characteristics

Among 71 patients with PFF (78.9% female, median (IQR) age 81 (72–88) years), the primary indication for hip surgery was osteoarthritis ($n=41$, 57.8%), followed by hip fracture ($n=25$, 35.2%) (Table 1). The underlying reason was unknown for the remaining patients ($n=5$, 7%). Fifty-five PFF were proximal around THA, and 16 were well below the stem.

The patients in the PFF group were significantly older ($p=0.002$) and had a significantly higher BMI ($p=0.043$). Among the clinical risk factors for osteoporosis, patients presenting with PFF had more corticosteroids exposure (18.3% versus 7.0%, $p=0.017$), less history of family hip fracture (4.3% vs. 13.6%, $p=0.041$), and higher history of

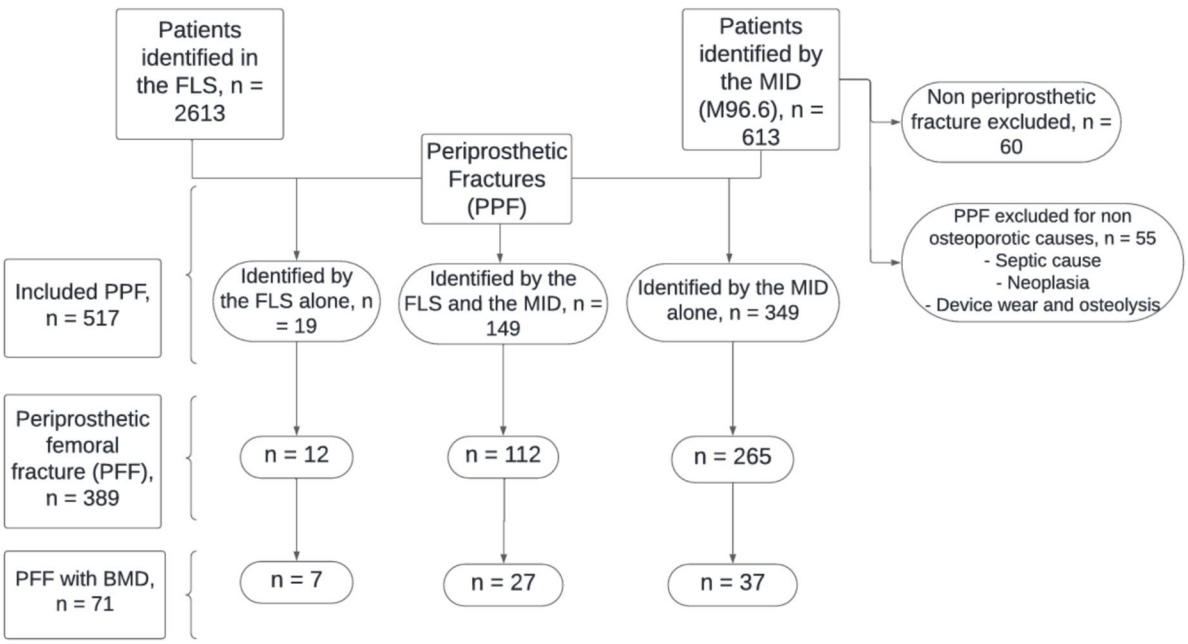

Fig. 1 Flowchart. BMD, bone mineral density; FLS, Fracture Liaison Service; MID, Medical Information Department; PFF, periprosthetic femoral fracture; PPF, periprosthetic fractures

Table 1 Demographic data and baseline characteristics

Characteristics	*N*	Native hip fractures *N* = 117	*N*	Periprosthetic femoral fractures *N* = 71	*p*-value
Female	117	87 (74.4)	71	56 (78.9)	0.48
Age (years)	117	75.0 (67.0 to 84.0)	71	81.0 (72.0 to 88.0)	**0.002**
Height (m)	116	1.6 ± 0.1	68	1.6 ± 0.1	0.26
Weight (kg)	116	63.0 (56.0 to 73.5)	69	64.0 (58.0 to 77.2)	0.30
BMI (kg/m^2)	116	24.2 (21.4 to 27.3)	68	26.1 (22.1 to 30.7)	**0.043**
Osteoporosis risk factors					
Former or current smokers	117	32 (28.1)	71	22 (31.0)	0.67
Alcohol abuse	116	11 (9.5)	71	12 (16.9)	0.13
Premature menopause (< 45 years)	75	18 (24.0)	46	13 (28.3)	0.60
Family history of hip fracture	110	15 (13.6)	70	3 (4.3)	**0.041**
Corticosteroids exposure (current or prior)	115	8 (7.0)	71	13 (18.3)	**0.017**
Multiple falls*	115	30 (26.1)	70	38 (54.3)	**< 0.001**
Previous anti-osteoporosis medication	117	13 (11.1)	71	19 (26.8)	**0.006**
Previous fragility fracture	116	51 (44.0)	71	49 (69.0)	**< 0.001**
Vertebrae	116	11 (9.5)	71	24 (33.8)	**< 0.001**
Wrist	116	16 (13.8)	71	13 (18.3)	0.41
Shoulder	116	9 (7.8)	71	17 (23.9)	**0.002**
Hip	116	9 (7.8)	71	25 (35.2)	**< 0.001**
Ankle	116	7 (6.0)	71	5 (7.0)	0.77
Pelvis	116	3 (2.6)	71	5 (7.0)	0.16
Multiple prior fragility fractures (≥ 2)	116	15 (12.9)	71	31 (43.7)	**< 0.001**

Values are expressed as numbers (%) for qualitative variables and mean ± SD or median (IQR) for quantitative variables

SD standard deviation, *IQR* interquartile range, *BMI* body mass index

*At least two falls in the last year

multiple falls (54.3% vs. 26.1%, $p < 0.001$). A significantly higher number of patients in the PFF group had a history of low-energy fracture (69.0% vs. 44.0%, $p < 0.001$), main sites being the hip (35.2%) and vertebrae (33.8%). Moreover, a history of AOM use was significantly more frequent in patients presenting with PFF (26.8% vs. 11.1%, $p = 0.006$).

As shown in Table 2, patients in the PFF group exhibited a greater prevalence of comorbidities. Subsequently, patients in the PFF group exhibited a significantly greater CCI median (5.0 (4.0; 7.0) vs. 4.0 (3.0; 5.5), $p < 0.001$) as well as a higher number of drug prescriptions and risk of polypharmacy (number of treatments ≥ 5) (Supplementary Table 1).

Bone densitometry

Comparisons of the BMD results and FRAX® scores between the two groups are presented in Table 3.

The median time to BMD was 4 months (interquartile range (IQR) 1–10). Almost half of the hip BMD measurements (femoral neck and total hip) were missing in the PFF group ($n = 33$, 46.5%) mainly because of bilateral THA ($n = 25$, 35.2%). Lumbar spine BMD measurements were missing in five patients (7.0%) due to multiple vertebral fractures ($n = 2$, 2.8%), not reported in the medical record ($n = 2$, 2.8%), or arthrodesis ($n = 1$, 1.4%).

BMD osteoporosis (43.6% vs. 29.6%) and osteopenia (47.9% vs. 42.2%) were significantly more frequent in the comparator group ($p = 0.001$).

Table 4 illustrates the comparisons of T-scores between the two groups after adjustment for age, sex, and BMI. The adjusted T-scores differed between the two groups at the lumbar spine (mean adjusted ± SEM, −0.5 ± 0.2 (PFF group) vs. −1.2 ± 0.2 (native hip fractures group), $p = 0.008$) but not at the femoral neck or at the total hip.

Discussion

Main findings

Upon comparing patients with PFF and those with native hip fractures, we observed that patients with PFF were of advanced age, had a higher BMI, and exhibited a greater

Table 2 Comorbidities

Comorbidities	Hip fractures $N = 117$	Periprosthetic femoral fractures $N = 71$	p-value
CCI	4.0 (3.0 to 5.5)	5.0 (4.0 to 7.0)	**< 0.001**
Digestive system diseases	20 (17.2)	22 (31.0)	**0.029**
Cirrhosis	1 (0.9)	2 (2.8)	NA
Peptic ulcer disease	2 (1.7)	6 (8.5)	0.055
Gastritis	2 (1.7)	2 (2.8)	NA
Esophagitis	1 (0.9)	3 (4.2)	NA
Cardiovascular diseases	78 (67.2)	59 (83.1)	**0.017**
HTA	64 (55.2)	47 (66.2)	0.14
Peripheral vascular disease	13 (11.2)	5 (7.0)	0.35
Stroke	15 (12.9)	14 (19.7)	0.21
Coronary artery disease	12 (10.3)	9 (12.7)	0.62
Arrhythmia	25 (21.6)	26 (36.6)	**0.025**
Dyslipidemia	41 (35.3)	28 (39.4)	0.57
Pulmonary diseases	20 (17.2)	23 (32.4)	**0.017**
COPD	8 (6.9)	13 (18.3)	**0.016**
Asthma	3 (2.6)	4 (5.6)	NA
Sleep apnea syndrome	7 (6.0)	4 (5.6)	1.00
Endocrinological diseases	34 (29.3)	18 (25.4)	0.56
T2DM	24 (20.7)	10 (14.1)	0.26
Dysthyroidism	19 (16.4)	6 (8.5)	0.12
Obesity	10 (8.6)	21 (29.6)	**< 0.001**
Neurological diseases	23 (19.8)	28 (39.4)	**0.003**
Parkinson's disease	2 (1.7)	1 (1.4)	NA
Epilepsy	4 (3.4)	4 (5.7)	0.48
Impaired cognitive function	7 (6.0)	17 (23.9)	**< 0.001**
Walking disorders**	2 (1.7)	19 (26.8)	**< 0.001**
Depression	10 (8.6)	18 (25.4)	**0.002**
Chronic kidney disease	6 (5.2)	12 (16.9)	**0.008**
Rheumatologic diseases	50 (43.1)	69 (97.2)	**< 0.001**
Inflammatory rheumatic diseases	2 (1.7)	11 (15.5)	**< 0.001**
Scoliosis	9 (7.8)	4 (5.6)	0.77
Osteoarthritis	24 (20.7)	55 (77.5)	**< 0.001**
Dermatological diseases	11 (9.5)	7 (9.9)	0.93
Neoplasia	23 (19.8)	18 (25.4)	0.38

Values are expressed as numbers (%) for qualitative variables and median (IQR) for quantitative variable

NA not applicable, *IQR* interquartile range, *CCI* Charlson Comorbidity Index, *T2DM* type 2 diabetes mellitus, *COPD* chronic obstructive pulmonary disease

**Any chronic walking disability, including neurological disorders such as ataxia, polyneuropathy, orthopaedic, and rheumatologic conditions including claudication, inducing a risk of fall

prevalence of comorbidities. Clinical risk factors for osteoporosis include a greater prevalence of low-energy fractures, a higher history of multiple falls, and an increased prescription of AOM in patients with PFF. BMD measurements at the total hip and femoral neck did not demonstrate statistically significant differences between the two groups; however, significantly lower values were observed at the lumbar spine in the native hip fractures group. Overall, patients with PFF had less frequent T-score osteoporosis than patients with native hip fractures.

Comparison with other studies

The demographic characteristics and comorbidities of the patients in our cohort were broadly similar to previous studies [2, 5, 12, 14]. Zhao et al. [27] and Agarwal et al. [28]

Table 3 BMD results and FRAX® scores

Characteristics		Native hip fractures $N = 117$		Periprosthetic femoral fractures $N = 71$	*p*-value
All sites	117		71		**0.001**
Osteoporosis		51 (43.6)		21 (29.6)	
Osteopenia		56 (47.9)		30 (42.2)	
Normal		10 (8.5)		20 (28.2)	
Lumbar spine	112		66		**0.027**
Osteoporosis		20 (17.9)		7 (10.6)	
Osteopenia		49 (43.8)		20 (30.3)	
Normal		43 (38.4)		39 (59.1)	
Total hip	100		37		0.44
Osteoporosis		29 (29.0)		9 (24.3)	
Osteopenia		56 (56.0)		19 (51.3)	
Normal		15 (15.0)		9 (24.3)	
Femoral neck	99		38		0.27
Osteoporosis		45 (45.4)		13 (34.2)	
Osteopenia		48 (48.5)		20 (52.6)	
Normal		6 (6.1)		5 (13.2)	
FRAX® scores	102		37		
Hip fracture		5.5 (2.3 to 12.0)		7.6 (2.5 to 11.0)	0.46
MOF		15.0 (8.7 to 26.0)		18.0 (11.0 to 24.0)	0.69

Values are expressed as numbers (%) for qualitative variables and median (IQR) for quantitative variables

BMD bone mineral density, *MOF* major osteoporotic fracture (hip, vertebra, proximal humerus, and distal forearm/wrist), *IQR* interquartile range

Table 4 Comparison of T-scores between patients with periprosthetic femoral fractures and those with native hip fractures

Measurement sites	*N*	Native hip fractures ($N = 117$)	*N*	Periprosthetic femoral fractures ($N = 71$)	*p*-value
Femoral neck T-score*	98	− 2.3 ± 0.1	37	− 2.0 ± 0.1	0.08
Total hip T-score*	99	− 1.8 ± 0.1	36	− 1.7 ± 0.2	0.49
Lumbar spine T-score*	111	− 1.2 ± 0.2	63	− 0.5 ± 0.2	**0.008**

Values are expressed as adjusted means ± SEM

SEM standard error of the mean

*Results are adjusted for age, sex, and BMI

showed that a history of low-energy fractures is frequent in patients with PFF. Accordingly, we identified a significantly higher prevalence of low-energy fractures in the PFF group than that in the native hip fractures group. T-score osteoporosis has been repeatedly described as a predominant risk factor for PFF [20, 29]. T-score osteoporosis was identified in 20% of patients prior to PFF by Seward et al. [12] and in 29.3% of patients by Whiting et al. [2]. These figures using DXA scans are consistent with our findings (29.6%). However, some studies have reported a higher prevalence of osteoporosis with the help of BMD measurements using computed tomography at the lumbar spine [2, 30].

Patients with PFF have a greater prevalence of prior AOM than those with native hip fractures. Nevertheless, the proportion of patients who received AOM (26.8%) was comparable to that reported by Whiting et al. (26.3%) [2] and Ritter et al. (22.5%) [14]. Regarding the prescription of AOM between the two groups (26.8% vs. 11.1%), this discrepancy can be attributed to the fact that an initial exclusion criterion for the Lille University Hospital FLS comprised individuals already treated by AOM, potentially introducing a recruitment bias in the native hip fractures group. It is also possible that as the PFF group had a higher prevalence of previous fragility fractures, they were more likely to be treated.

Clinical implications

The results of this study demonstrate that patients presenting with PFF often exhibit osteoporosis, as defined

clinically (history of low-energy fracture and/or prescription of AOM) or through BMD measurements. Based on the aforementioned findings, it can be reasonably proposed that low-energy PFF can be considered osteoporotic fractures. Therefore, it is advisable to initiate AOM and subsequently arrange follow-up consultation with a bone specialist.

There is a need for the primary prevention of osteoporosis in patients undergoing THA, particularly in women and older patients. Despite the undeniable osteoporosis gap [31], osteoporosis can be diagnosed and prevented relatively easily. It is essential that patients aged ≥ 50 years undergo an evaluation of their risk factors for osteoporosis and a DXA examination, ideally before surgery or a few months later. This approach would allow for the identification of individuals who may benefit from AOM. Regarding TKA, a recent study evaluates a novel, simple bone health screening protocol composed of patient sex, age, fracture history, and FRAX risk to identify patients for preoperative DXA [32]. The study included 100 patients (68 females and 32 males). T-score osteoporosis was observed in 16 patients, while 43 had clinical osteoporosis (T-score ≤ − 2.5, elevated BMD-adjusted FRAX risk, or prior hip/spine fracture) showing the effectiveness of this preoperative screening protocol [32].

Strengths and limitations

This study was based on a relatively large sample over a 7-year period. The use of the Medical Information Department to create a register based on the ICD- 10 M96.6 code allowed more systematic recruitment. Another strength of this study is the comparison group. To the best of our knowledge, no previous study has compared patients with PFF to those with native hip fractures. Nevertheless, it represents the most appropriate comparison group for determining whether PFF can be defined as an osteoporotic fracture. There are only a few studies on PFF, especially regarding the bone densitometry results [2, 4, 33].

This study had some limitations. This was a single-centre retrospective study, leading to potential bias. There were a number of missing data because most of the patients in the PFF group did not undergo a dedicated consultation with a rheumatologist via the FLS, unlike patients in the native hip fractures group, all included via the FLS, and data were retrieved through systematic medical record screening. Moreover, the definition of PPF is somewhat vague in the literature, primarily due to the existence of different classifications (Vancouver [13], Unified Classification System for Periprosthetic Fractures (UCPF) [34], Dorr [35]), the increasing number of distinct implants, and localization options for orthopedic devices. The use of disparate criteria in the literature to identify patients with PPF poses a significant challenge for the comparison of studies.

Conclusion

Low-energy PFF should be considered as an osteoporotic fracture and treated accordingly. Given the challenges associated with the management of PFF, it is imperative that bone specialists collaborate with orthopedists to improve the primary prevention of osteoporosis prior to TJA. In addition, research has indicated that AOM, such as bisphosphonates, may reduce bone loss following TJA [27, 31], thereby contributing to the prevention of PFF. Finally, further studies are required to investigate a recently proposed entity called atypical PFF [36, 37].

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Data availability Data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflicts of interest Julien Paccou has received honoraria from Amgen, MSD, Eli Lilly, Kyowa-Kirin, Theramex, and Pfizer. Cécile Philippoteaux received honoraria from Amgen, Galapagos, Kyowa-Kirin, AbbVie, and Eli Lilly. None of the remaining authors declares any conflict of interest.

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