European Review for Medical and Pharmacological Sciences 2024; 28: 1375-1383

Comparison of clinical data between the proximal femoral bionic nail (PFBN) and hip replacement for the treatment of femoral intertrochanteric fracture

Z.-H. SUN[1], D. CHEN[2], K.-W. CHU[1], Y. SHI[1], B. HONG[1], Y. CHEN[1], L. LIU[1]

[1]Department of Orthopedics, Jinzhai County People's Hospital, Liuan, China
[2]Department of Orthopedics, China-Japan Friendship Hospital, Beijing, China

Z.-H. Sun and D. Chen contributed equally to this study

Abstract. – OBJECTIVE: The aim of this study was to compare the difference between proximal femoral bionic nail (PFBN) and hip replacement (HR) for femoral intertrochanteric fracture.

MATERIALS AND METHODS: A retrospective analysis of the differences in operative time, length of stay, postoperative Harris score, and postoperative mortality between patients with femoral intertrochanteric fracture treated by PFBN and HR admitted to Jinzhai County People's Hospital from October 2020 to September 2022 was performed.

RESULTS: A total of 56 patients with femoral intertrochanteric fracture, 26 with PFBN and 30 with HR, were included in the study. There were no differences in the length of surgery, pre- and post-operative hemoglobin, or post-operative Harris score at 3 months between the two groups. Compared to the HR group, the PFBN group had a lower total cost, shorter hospital stays, and lower mortality but a longer ambulation time, with a difference of 3.36 weeks.

CONCLUSIONS: PFBN may be a promising new treatment for femoral intertrochanteric fracture.

Key Words:
Proximal femoral bionic nail (PFBN), Hip replacement (HR), Femoral intertrochanteric fracture, Harris.

Abbreviations

HR: Hip Replacement; PFBN: Proximal Femoral Bionic Nail; PFN: Proximal Femoral Nail.

Introduction

Hip fractures are one of the most common fractures in older people[1-3]. Femoral intertrochanteric fractures are frequent in hip fractures, accounting for approximately 54% of all hip fractures, with an age of onset 5-10 years higher than that of femoral neck fractures. Femoral intertrochanteric fractures are more closely associated with osteoporosis and have higher postoperative complications[4,5].

In 1838, Frederick Oldfield Ward first proposed the concept of the Ward's Triangle of the proximal femur, which is of great importance in understanding the distribution of tension and pressure trabeculae in the proximal femur, in mechanical conduction and in guiding the design of internal fixations[6]. Based on Ward's Triangle, in 2021, Yanbin et al[7] proposed the Proximal Femur N Triangle Theory and the Design Concept of Proximal Femur Bionic Nail (PFBN).

The PFBN is a new generation of intramedullary fixation for the proximal femur based on "Zhang's N triangle theory" (Figure 1). Compared to the traditional proximal intramedullary nail proximal femoral nail (PFN) or proximal femoral nail anti-rotation (PFNA), the PFBN replaces the parallel screw with a lateral support screw that intersects the fixation screw to form a three-dimensional intersection with the fixation screw in the proximal femur, making it a triangular cantilever beam stable structure that extends to the proximal femoral border and includes all macro and micro triangular structures of the proximal femur, significantly increasing the strength of the internal fixation. This significantly increases the strength of the internal fixation and provides an anti-rotational effect[7].

The new concept allows for optimal recovery of the proximal femoral pivot point position, provides strong fixation in the early postoperative period, and is effective in providing continuous and

Corresponding Author: Dong Chen, MD; e-mail: chendong1232023@163.com

stable fixation during postoperative healing and functional rehabilitation of the fracture. However, as this theory is relatively new, clinical data are scarce. Here, we retrospectively analyzed clinical data from our patients with fractures of the trochanter treated by PFBN and hip replacement (HR) surgery to find the treatment efficacy of PFBN for intertrochanteric fractures.

Patients and Methods

We retrospectively analyzed data from patients diagnosed with intertrochanteric fractures of the femur at Jinzhai County People's Hospital from October 2020 to September 2022. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki. All experimental protocols involved in the present study were approved by the Medical Ethics Committee of China-Japan Friendship Hospital (No. 2020-104-5). Informed consent was obtained from all individual participants.

These patients underwent either the PFBN or HR surgical approach (Figure 2) according to the physician's opinion and personal preference. We analyzed and compared the general data as well as the clinically relevant indicators of patients undergoing these two surgical procedures.

Inclusion Criteria

Patients were included in the study according to the following criteria: 1. Having a definite diagnosis of femoral intertrochanteric fracture; 2. Being not suitable for conservative treatment and having clear surgical indications; 3. Older than 18 years.

Exclusion Criteria

1. Patients with multiple fractures in other parts; 2. Patients with severe liver and kidney dysfunction and other medical diseases; 3. Having internal fixation implant material fracture and other reasons lead to surgery failure; 4. Incomplete or missing case data collection.

Grouping of Patients

All intertrochanteric fractures of the femur can be treated with PFBN, including patients with lateral wall fractures. Some patients are older, have a shorter life expectancy, and their families expect the patient to be out of bed in a shorter time; then HR is chosen. The choice of surgical procedure is based largely on the opinion of the patient and their family. In the end, we collected 26 cases of PFBN and 30 cases of hip replacement.

The General Procedure of PFBN

After stabilization of anesthesia, the patient was placed in a flat position with the right lower limb fixed in flexion, abduction, and external rotation, the left lower limb attached to the traction frame, and the left lower limb repositioned in internal retraction and internal rotation to restore the intertrochanteric fracture. The field was routinely disinfected, and a towel was placed. The skin and fascia were incised, and a guide pin was inserted through the opening at the apex of the greater trochanter. The tension screw (Tianjin ZhengTian Medical Instrument Co. Ltd., Tianjin, China) with a length of 0.5 cm was then placed below the cartilage of the femoral head; the pressure screw (Tianjin ZhengTian Medical Instrument Co. Ltd., Tianjin, China) was then placed close to the lower wall of the femoral neck and through the femoral neck into the femoral head. After attaching the distal locator, the 5.0 x 34 mm distal locking nail (Tianjin ZhengTian Medical Instrument Co. Ltd., Tianjin, China) was locked in under the static position, the connecting rod (Tianjin ZhengTian Medical Instrument Co. Ltd., Tianjin, China) was lowered, the tail cap (Tianjin ZhengTian Medical Instrument Co. Ltd., Tianjin, China) was screwed in, the fracture was well aligned on C-arm fluoroscopy [Ziehm Imaging GmbH/Ziehm Medical (Shanghai) Co. Ltd, Shanghai, China], and the internal fixation [Ziehm Imaging GmbH/Ziehm Medical (Shanghai) Co. Ltd, Shanghai, China] was well positioned.

The General Procedure of HR

After stabilization of anesthesia, the patient is placed in the lateral position, the pelvis and trunk are immobilized, and the left lower extremity is routinely disinfected. The skin, subcutaneous tissue, and deep fascia were incised in turn, and electrocoagulation was performed to stop the bleeding. The broad fascia and contour fascia tensor were incised from the bottom up, and the posterior edges of the gluteus medius and gluteus minimus muscles were bluntly separated and drawn forward. The femoral head and the base of the femoral neck were removed, and the round ligament was excised, the diameter of the femoral head was measured; the proximal medullary opening of the femur was chiseled with a cassette opening (Beijing AKEC Medical Co. Ltd., Beijing, China), the medullary cavity was enlarged with a medullary enlarger (Beijing AKEC Medical Co. Ltd., Beijing, China), the med-

Figure 1. Images of Proximal Femoral Bionic Nail (PFBN).

ullary cavity was then enlarged with a medullary shaping file (Beijing AKEC Medical Co. Ltd., Beijing, China) to flush the medullary cavity of the femur, a femoral prosthesis (Beijing AKEC Medical Co., Ltd., Beijing, China) was selected and slowly driven into the medullary cavity, the joint was repositioned, the hip was moved, and the joint was seen to be stable, loose, and tight. After moving the hip joint and seeing that the joint was stable and moderately tight, the greater trochanter was fixed with a tension band of Kirschner's pins (Beijing AKEC Medical Co., Ltd., Beijing, China), the incision was flushed, the hemostasis was complete, the external rotation muscle group was reconstructed, the incision was closed in layers, one drainage tube(Jiangyin Kangjie medical technology Co., Ltd, Jiangyin, China) was built into the incision and another hole was made to drain it, and a sterile dressing(Jiangsu Yongning Medical Instrument Co., Ltd., Yangzhou, China) was applied.

Follow-Up

Follow-up were carried out in the third, sixth and twelfth months after surgery, and every six months thereafter. Harris score was calculated at the third month after surgery.

Statistical Analysis

Data were analyzed by SPSS 23.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were presented as means ± standard deviations (SD) and ratios. The Shapiro-Wilk test was used to test the normality of the data distribution. Continuous variables were compared using the paired samples *t*-test. Categorical variables were presented as scores or quantities and analyzed by Chi-square test. $p<0.05$ was considered a significant difference between groups.

Results

We counted information on patients (n=56) who underwent PFBN as well as HR surgery in Jinzhai County People's Hospital between January 2019 and September 2022. The average age of the patients was 77.98±8.46 years. The length of stay in the hospital is 11.86±4.83 days. Harris at 3 months post-operation was 68.84±20.3. Ambulation time after the operation was 3.06±2.43 weeks. Other basic information is shown in Table I.

Of these patients, 26 (46.43%) underwent PFBN surgery, and 30 (53.57%) underwent HR. Of the patients, 23 (41.07%) were male, and 33 (58.93%) were female. 30 (53.57%) of the patients had hypertension, 10 (17.86%) had diabetes, and 18 (32.14%) had a history of cerebral infarction. According to the Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification, there were 8, 47, and 1 patients with A1, A2, and A3 types, respectively. The distribution of other clinical information about the patients is shown in Table II.

We compared multiple indicators for PFBN and HR patients. There was no difference in gender, age, underlying disease, AO typing, or the American Society of Anesthesiologists (ASA) classification between the two procedures. Post-operative death in 1 (3.85%) case in PFBN and 12 (40%) cases in HR, showed significant differences ($p<0.05$) (Table III).

We compared the clinical indicators of patients undergoing PFBN and HR surgery. The mean age of patients undergoing PFBN was 74.92 years compared to 80.63 years for patients undergoing HR; PFBN surgery patients were younger. The average length of stay for PFBN cases was 10.77 days, while for HR cases, it was significantly longer (12.8 days). The cost of HR cases was significantly higher compared to PFBN, and the average cost was 5,400 renminbi (RMB) higher. For ambulation time, 4.77 weeks for PFBN cases and

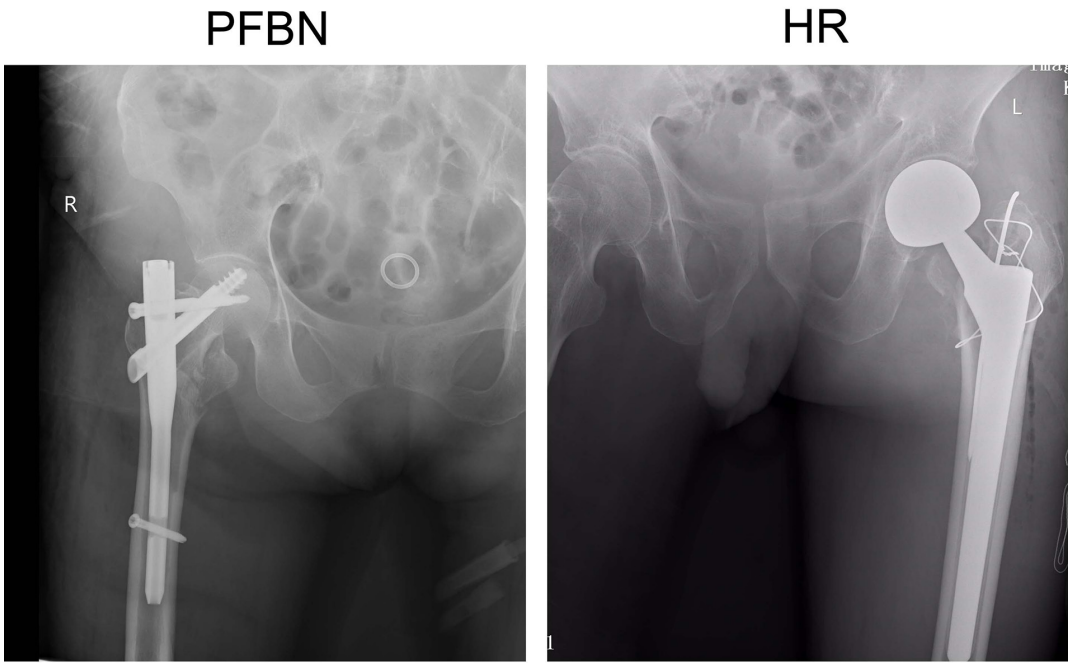

Figure 2. X-ray images of a patient taking PFBN or HR. PFBN, proximal femoral bionic nail; HR, hip replacement.

1.41 weeks for HR cases were registered, with a significant difference (Table IV).

We analyzed the overall survival of patients after surgery, as well as the survival of patients with PFBN and HR separately. We found that PFBN patients had a significantly higher survival rate than HR patients (p=0.037) (Figure 3).

Discussion

Timely multidisciplinary management and surgical intervention should be employed in the treatment of patients with intertrochanteric fractures. Patients should undergo surgery as soon as possible to limit the risk of secondary complications resulting from prolonged bed rest and to promote rapid functional recovery[8]. Since the 1950s, surgical treatment has been the standard of care for intertrochanteric fractures, and the concept and design of internal fixation have undergone several innovations. From simple screw fixation (e.g., sliding hip screws, compression hip screws, etc.), to eccentric extramedullary plate screw fixation systems, to central intramedullary fixation (e.g., Gamma nails, PFN, and PFNA)[9-11]. This innovation has led to a steady improvement in clinical outcomes and a gradual decrease in complications associated with internal fixation from 98% (sliding hip screws) to 5-12% (intramedullary fixation), but there has been no remarkable improvement in the last 30 years[12].

Table I. Basic information of patients (n=56).

Item	Mean±SD	Min.	Max.
Age (years)	77.98±8.46	47	93
Hospitalization time (days)	11.86±4.83	5	29
Total cost (yuan)	22,136.4±4,573.88	16,758.73	38,189.14
Length of surgery (min)	66.93±22.6	40	140
Pre-operative hemoglobin (g/L)	100.43±14	76	142
Post-operative hemoglobin (g/L)	90.98±11.77	72	115
Harris at 3 months post-operation	68.84±20.3	9	93
Ambulation time (weeks)	3.06±2.43	1	12

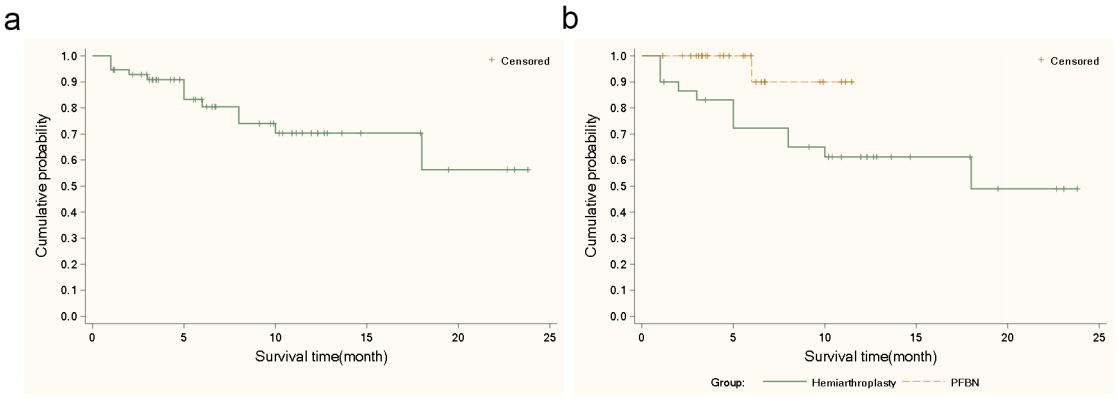

Figure 3. **a**, Overall patient survival curve after surgery. **b**, Survival curves for patients with two surgical approaches.

Table II. Percentage of patients in each variable.

Variables		n	%
Procedure	PFBN	26	46.43
	HR	30	53.57
Sex	Male	23	41.07
	Female	33	58.93
Age (years)	<80	29	51.79
	≥80	27	48.21
Hypertension	No	26	46.43
	Yes	30	53.57
Diabetes mellitus	No	46	82.14
	Yes	10	17.86
History of cerebral infarction	No	38	67.86
	Yes	18	32.14
Fracture at other sites	No	48	85.71
	Yes	8	14.29
Other underlying medical conditions	No	39	69.64
	Yes	17	30.36
History of smoking	No	50	89.29
	Yes	6	10.71
History of alcohol consumption	No	50	89.29
	Yes	6	10.71
AO typing	A1	8	14.29
	A2	47	83.92
	A3	1	1.79
EVANS staging	Type 1-3	39	69.64
	Type 4-5	17	30.36
ASA classification	I	12	21.43
	II	35	62.5
	III	9	16.07
Left or right side	Right	22	39.29
	left	34	60.71
Post-operative transfusion	No	36	64.29
	Yes	20	35.71
Post-operative death	No	43	76.79
	Yes	13	23.21

PFBN, proximal femoral bionic nail. HR, hip replacement. AO, Arbeitsgemeinschaft für Osteosynthesefragen. ASA, American Society of Anesthesiologists.

Intertrochanteric fractures continue to disturb surgeons worldwide due to the wide range of options for surgical approaches and fixation materials for patients of different ages. The dynamic

hip screw is a widely used extramedullary plate, but it has the disadvantage of having a high rate of failure and misalignment[13]. PFNA has become a widely used material today, which improves on the traditional supporting screw of the PFN with a helical blade nail, thus promoting a biomechanical structure resistant to rotation and increasing post-operative stability[14,15]. However, PFNA still suffers from reverse displacement and a high incidence of secondary lateral wall fractures[16,17]. In addition, problems with screw withdrawal, fracture, and dissection still exist[18]. The newly designed PFBN by Ding et al[19] exhibited lower maximum stresses and smaller displacements than PFNA for the same load by finite element analysis. In addition, in another study by Wang et al[20], authors found that PFBN has better mechanical and biomechanical properties in the treatment of intertrochanteric fractures in the elderly than PFNA and InterTan (Tianjin ZhengTian Medical Instrument Co., Ltd., Tianjin, China) through finite element analysis. In a clinical study[21] of 12 patients treated with PFBN for intertrochanteric fractures, it was shown that PFBN is an efficient internal fixation device with both stability and safety. Nevertheless, no comparison of data with other surgical procedures was made in this study.

In our study, we compared clinical data on the treatment of intertrochanteric fractures of the femur with the PFBN and HR. The mean age of patients in the PFBN group was lower than that of patients in the HR group, which is likely to be related to the willingness to choose the surgical approach. We have addressed that patients who select HR have an expectation of a shorter ambulation time. Compared to HR, patients in the PFBN group had shorter hospital stays and spent significantly less. However, at ambulation time, the PFBN group took significantly longer than the HR group. The survival rate of patients in the PFBN group was significantly higher than that of the HR group after surgery. Zang et al[22] also found that the PFNA can provide better fixation for intertrochanteric fractures, accelerating hip joint recovery. These findings suggest a potential advantage of PFBN in the treatment

Table III. Univariate analysis of PFBN and HR variance factors.

Variables		PFBN	HR	Quantity (χ^2)	*p*-value
Gender	Male	12 (46.15)	11 (36.67)	0.518	0.472
	Female	14 (53.85)	19 (63.33)		
Age (years)	<80	17 (65.38)	12 (40.00)	3.595	0.058
	≥80	9 (34.62)	18 (60.00)		
Hypertension	No	9 (34.62)	17 (56.67)	2.723	0.099
	Yes	17 (65.38)	13 (43.33)		
Diabetes	No	19 (73.08)	27 (90.00)	-	0.162
	Yes	7 (26.92)	3 (10.00)		
History of cerebral infarction	No	16 (61.54)	22 (73.33)	0.888	0.346
	Yes	10 (38.46)	8 (26.67)		
Fracture at other sites	No	23 (88.46)	25 (83.33)	-	0.712
	Yes	3 (11.54)	5 (16.67)		
History of smoking	No	25 (96.15)	25 (83.33)	-	0.2
	Yes	1 (3.85)	5 (16.67)		
AO typing	A1	5 (19.23)	3 (10.00)	-	0.451
	A2	21 (80.77)	26 (86.67)		
	A3	0 (0.00)	1 (3.33)		
EVANS staging	Type 1-3	19 (73.08)	20 (66.67)	0.271	0.603
	Type 4-5	7 (26.92)	10 (33.33)		
ASA classification	II	8 (30.77)	4 (13.33)	-	0.146
	III	16 (61.54)	19 (63.33)		
	IV	2 (7.69)	7 (23.33)		
Left or right side	Right	10 (38.46)	12 (40.00)	0.014	0.906
	Left	16 (61.54)	18 (60.00)		
Post-operative blood transfusion	No	18 (69.23)	18 (60.00)	0.517	0.472
	Yes	8 (30.77)	12 (40.00)		
Post-operative death	No	25 (96.15)	18 (60.00)	10.214	0.001
	Yes	1 (3.85)	12 (40.00)		

PFBN, proximal femoral bionic nail. HR, hip replacement. AO, Arbeitsgemeinschaft für Osteosynthesefragen. ASA, American Society of Anesthesiologists.

Table IV. Differences in clinical indicators between PFBN and HR groups.

Variables	Group	Mean±SD	Median (Quartile spacing)	Quantity (T or Z)	*p*-value
Age (years)	PFBN	74.92 ± 9.31	76.00 (71.00, 81.00)		
	HR	80.63 ± 6.73	81.00 (75.00, 86.00)	-2.32	0.020
	Difference	-5.71	95% CI (-10.14,-1.28)		
Hospitalization time (days)	PFBN	10.77 ± 5.05	9.50 (7.00, 12.00)		
	HR	12.80 ± 4.51	12.00 (10.00, 16.00)	-2.088	0.037
	Difference	-2.03	95% CI (-4.59, 0.53)		
Total cost	PFBN	19243.22 ± 3539.83	18,199.72 (17,541.46, 19,613.11)		
	HR	24643.83 ± 3855.64	24,197.74 (22,661.00, 26,555.97)	-5.389	0
	Difference	-5400.62	95% CI (-7,395.11, -3,406.12)		
Length of surgery	PFBN	64.65 ± 21.37	60.00 (53.00, 75.00)		
	HR	68.90 ± 23.80	60.00 (54.00, 75.00)	-0.661	0.509
Difference	-4.25	95% CI (-16.44, 7.95)			
Pre-operative hemoglobin	PFBN	101.69 ± 13.80	97.50 (92.00, 112.00)		
	HR	99.33 ± 14.32	100.00 (90.00, 105.00)	0.658	0.511
	Difference	2.36	95% CI (-5.21, 9.92)		
Post-operative hemoglobin	PFBN	93.83 ± 13.73	92.00 (81.00, 107.00)		
	HR	88.80 ± 9.71	88.50 (82.00, 95.00)	1.203	0.229
	Difference	5.03	95% CI (-1.79, 11.84)		
Difference between pre- and post-operative hemoglobin	PFBN	9.52 ± 8.94	9.00 (6.00, 14.00)		
	HR	10.53 ± 12.24	11.50 (1.00, 16.00)	-0.334	0.74
	Difference	-1.01	95% CI (-7.10, 5.08)		
Harris at 3 months post-operation	PFBN	74.81 ± 11.20	79.00 (69.00, 83.00)		
	HR	62.64 ± 25.48	72.00 (60.00, 76.00)	-1.586	0.113
	Difference	12.17	95% CI (0.87, 23.46)		
Ambulation time (weeks)	PFBN	4.77 ± 1.27	4.50 (4.00, 6.00)		
	HR	1.41 ± 2.12	1.00 (1.00, 1.00)	6.011	0
	Difference	3.36	95% CI (2.40, 4.33)		

PFBN, proximal femoral bionic nail. HR, hip replacement.

of intertrochanteric fractures. However, it is important to note that PFBN should not be considered a universal method for treating trochanteric fractures. Factors such as age, timing, comorbidities, bone quality, femoral head vascularization, fracture displacement, intrinsic instability, and comminution need to be taken into account to mitigate possible complications[23]. Furthermore, the use of bone cement with an anti-rotation intramedullary nail is considered to significantly shorten the time to weight-bearing after reconstruction[24]. It is crucial to consider these factors to minimize potential complications associated with the use of PFBN.

Limitations

However, we cannot hastily conclude that PFBN has a higher survival rate than HR, as there are significant differences in age between the two groups of patients that may have an impact on the outcome. This is where our study was inadequate. This is because the difference in age may have affected survival as well as length of stay in hospital. In addition, the follow-up period of our study was insufficient, resulting in a lack of indicators to evaluate post-operative function, which does not allow for a more complete accounting of changes in post-operative function.

Conclusions

As a new treatment for intertrochanteric fractures, PFBN is less costly, has a shorter postoperative hospital stay, and has a better survival rate compared to HR.

Conflicts of Interest
The authors declare no conflict of interest.

Ethics Approval
We retrospectively analyzed data from patients diagnosed with intertrochanteric fractures of the femur at Jinzhai County People's Hospital from October 2020 to September 2022. The study protocol conforms to the ethical guidelines of the Declaration of Helsinki. All experimental protocols involved in the present study were approved by the Medical Ethics Committee of China-Japan Friendship Hospital (No. 2020-104-5).

Informed Consent
Informed consent was obtained from all individual participants.

Availability of Data and Materials
The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Funding
The authors have no sources of funding to declare for this manuscript.

Authors' Contributions
ZS, DC, and YS contributed to the conceptualization, data curation, methodology, and writing of the original draft. BH contributed to the methodology and software. YC contributed to writing, review & editing, and data curation. All authors read and approved the final manuscript.

References

1) Kannus P, Parkkari J, Sievänen H, Heinonen A, Vuori I, Järvinen MJB. Epidemiology of hip fractures. Bone 1996; 18: S57-S63.
2) Cooper C, Campion G, Melton LJ 3rd. Osteoporosis international. Hip fractures in the elderly: a world-wide projection. Osteoporos Int 1992; 2: 285-289.
3) Michael Lewiecki E, Wright N, Curtis J, Siris E, Gagel R, Saag K, Singer A, Steven P, Adler RJOI. Hip fracture trends in the United States, 2002 to 2015. Osteoporos Int 2018; 29: 717-722.
4) Melton LJ 3rd, Wahner HW, Richelson LS, O'fallon WM, Riggs BL. Osteoporosis and the risk of hip fracture. Am J Epidemiol 1986; 124: 254-261.
5) Xu R, Ru J, Ji F, Liu J, Ji Y, Wu Z, Shi D. Comparison of efficacy, complications and TGFβ2 expression between DHS and PFNA in elderly patients with osteoporotic femoral intertrochanteric fracture. Exp Ther Med 2018; 16: 394-399.
6) White TD, Black MT, Folkens PA. Human osteology. Academic Press; 2011.
7) Yanbin Z, Wei C, Dandan Y, ZhangQi, Hongzhi L, Zhanle Z, Yingze Z. Proximal Femur N Triangle Theory and the Design Concept of Proximal Femur Bionic Nail (in Chinese). Chin J Geriatr Orthop Rehabil (Electronic Edition) 2021; 7: 257-259.
8) Basile G. Remarks on the management of proximal femoral fractures in times of COVID-19 pandemic. Clin Ter 2022; 173: 398-399.
9) Lim SJ, So SY, Yoon YC, Cho WT, Oh JK. A forward-striking technique for reducing fracture gaps during intramedullary nailing: A technical note with clinical results. Injury 2015; 46: 2507-2511.
10) Horner NS, Samuelsson K, Solyom J, Bjørgul K, Ayeni OR, Östman B. Implant-related complications and mortality after use of short or long gamma nail for intertrochanteric and subtrochanteric fractures: a prospective study with minimum 13-year follow-up. JB JS Open Access 2017; 2: e0026.
11) von Rüden C, Hungerer S, Augat P, Trapp O, Bühren V, Hierholzer C. Breakage of cephalomedullary nailing in operative treatment of trochanteric and subtrochanteric femoral fractures. Arch Orthop Trauma Surg 2015; 135: 179-185.
12) Mavrogenis AF, Panagopoulos GN, Megaloikonomos PD, Igoumenou VG, Galanopoulos I, Vottis CT, Karabinas P, Koulouvaris P, Kontogeorgakos VA, Vlamis J. Complications after hip nailing for fractures. Orthopedics 2016; 39: e108-e116.
13) Vaquero J, Munoz J, Prat S, Ramirez C, Aguado H, Moreno E, Perez M. Proximal Femoral Nail Antirotation versus Gamma3 nail for intramedullary nailing of unstable trochanteric fractures. A randomised comparative study. Injury 2012; 43: S47-S54.
14) Seyhan M, Turkmen I, Unay K, Ozkut AT. Do PFNA devices and Intertan nails both have the same effects in the treatment of trochanteric fractures? A prospective clinical study. J Orthop Sci 2015; 20: 1053-1061.
15) Cai L, Wang T, Di L, Hu W, Wang J. Comparison of intramedullary and extramedullary fixation of stable intertrochanteric fractures in the elderly: a prospective randomised controlled trial exploring hidden perioperative blood loss. BMC Musculoskelet Disord 2016; 17: 1-7.
16) Gotfried Y. Integrity of the lateral femoral wall in intertrochanteric hip fractures: an important predictor of a reoperation. JBJS 2007; 89: 2552-2553.
17) Ramakrishnan M, Prasad S, Parkinson R, Kaye J. Management of subtrochanteric femoral fractures and metastases using long proximal femoral nail. Injury 2004; 35: 184-190.
18) Al-Yassari G, Langstaff R, Jones J, Al-Lami M. The AO/ASIF proximal femoral nail (PFN) for the

treatment of unstable trochanteric femoral fracture. Injury 2002; 33: 395-399.

19) Ding K, Zhu Y, Li Y, Wang H, Cheng X, Yang W, Zhang Y, Chen W, Zhang Q. Triangular support intramedullary nail: A new internal fixation innovation for treating intertrochanteric fracture and its finite element analysis. Injury 2022; 53: 1796-1804.

20) Wang Y, Chen W, Zhang L, Xiong C, Zhang X, Yu K, Ju J, Chen X, Zhang D, Zhang Y. Finite element analysis of proximal femur bionic nail (PFBN) compared with proximal femoral nail antirotation and InterTan in treatment of intertrochanteric fractures. Orthop Surg 2022; 14: 2245-2255.

21) Zhao H, Deng X, Liu W, Chen W, Wang L, Zhang Y, Wang Z, Wang Y, Lian X, Hou Z. Proximal femoral bionic nail (PFBN)—an innovative surgical method for unstable femoral intertrochanteric fractures. Int Orthop 2023: 1-11.

22) Zang W, Liu P, Han X. A comparative study of proximal femoral locking compress plate, proximal femoral nail antirotation and dynamic hip screw in intertrochanteric fractures. Eur Rev Med Pharmacol Sci 2018; 22: 119-123.

23) Randelli F, Viganò M, Liccardi A, Mazzoleni MG, Basile G, Menon A, Cosmelli N. Femoral neck fractures: Key points to consider for fixation or replacement a narrative review of recent literature. Injury 2023; 54: S70-S77.

24) Ni XH, Zhu XY, Zhang ZY, Zhang L, Ren LB, Wu JS, Wang LJ, Zhao QM, Zhang F. Clinical effect of cement-enhanced APFN in the treatment of elderly osteoporotic intertrochanteric fractures. Eur Rev Med Pharmacol Sci 2022; 26: 3872-3877.