Is Helical Blade Nailing Superior to Locked Minimally Invasive Plating in Unstable Pertrochanteric Fractures?

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Abstract

Background Technical advancements have produced many challenges to intramedullary implants for unstable pertrochanteric fractures. Helical blade fixation of the femoral head has the theoretical advantages of higher rotational stability and cutout resistance and should have a lower rate of reoperation than a locked plating technique. **Questions/purposes** We asked whether (1) helical blade nailing reduces the rate of reoperation within 24 months compared with locked plating and (2) any of various preoperative, intraoperative, or postoperative factors predicted failure in these two groups.

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Methods We prospectively enrolled 108 patients with unstable pertrochanteric fractures in a surgeon-allocated study between November 2005 and November 2008: 54 with percutaneous compression plates (PCCP) and 54 with proximal femoral nail antirotation (PFNA). We evaluated patients regarding reoperation, mortality, and function. Seventy-four patients had a minimum followup of 24 months (mean, 26 months; range, 24–30 months).

Results We found no differences in the number of reoperations attributable to mechanical problems in the two groups: PCCP = six and PFNA = five. Despite a greater incidence of postoperative lateral wall fractures with helical blade nailing, only postoperative variation of the neck-shaft angle and tip-apex distance (33 mm versus 28 mm) predicted reoperation. Mortality and function were similar in the two groups.

Conclusions Our data suggest unstable pertrochanteric fractures may be fixed either with locked extramedullary small-diameter screw systems to avoid lateral wall fractures or with the new intramedullary systems to avoid potential mechanical complications of a broken lateral wall. Tip-apex distance and preservation of the preoperative femoral neck-shaft angle are the key technical factors for prevention of reoperation.

Level of Evidence Level III, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

The best treatment for unstable pertrochanteric femur fractures (AO/OTA 31-A2) is unclear and in the past, the treatment of these fractures was associated with a

mechanical complication rate of as much as 20% [23, 29, 33]. Several meta-analyses have not been able to confirm the clinical superiority of extramedullary or intramedullary implants [1, 14, 29]. Parker and Handoll [29], in a Cochrane Review, concluded additional studies are needed particularly for the more recently developed designs of intramedullary nails that have potentially fewer complications in comparison to those with previous nails. For example, helical blade fixation of the femoral head with an intramedullary device has theoretical advantages regarding rotational stability and cutout resistance and reportedly has reoperation rates ranging from 2.5% to 7% in unstable pertrochanteric femur fractures [19, 20, 24, 34, 38]. Locked minimally invasive plating has implant failure rates similar to those obtained with conventional sliding hip screw devices [13, 17], but potentially could reduce the complication rate by reducing the risk of medial shaft displacement and fracture collapse [31] and providing better lateral cortical support [18], which are important predictors of reoperation [10, 26]. These devices provide rotational stability via two small-diameter hip screws in locked barrels and are associated with reoperation rates between 2% and 8% [13, 17, 31], although fracture stability as a confounding factor was not considered in these studies. One study compared these locked extramedullary implants with a modern cephalocondylar nail (Gamma3TM, Stryker, Freiburg, Germany) with stable fractures (AO/OTA 31-A1, A2.1), and reported comparable rates of fracture collapse, mortality, and function [37].

We therefore determined in a preliminary study (1) whether patients who had helical blade nailing had lower reoperation rates than patients who had a locked plating technique for unstable pertrochanteric fractures and whether various factors predicted (2) reoperations for mechanical failures, (3) mortality (in-hospital, 2 years), and (4) outcome scores 24 months after surgery.

Patients and Methods

From November 2005 until November 2008 we treated 121 patients older than 60 years for unstable AO/OTA Type 31-A2 fractures [23]. The indication for the use of these two implants was an A2 pertrochanteric femur fracture. The rare contraindications for surgery were acute potentially life-threatening affections (eg, the combination of heart disease, bronchopneumonia, and an American Society of Anesthesiologists [ASA] Class 4 status [22]). All patients who met surgical indications and fulfilled our inclusion criteria (A2 fracture, older than 60 years) were assigned sequentially to one of the two therapy groups based on admission sequence (depending on work schedule of the six responsible consultants; surgeon-allocated study). We excluded from the

study five patients with pathologic fractures ($n = 2$), multiple injuries ($n = 2$), and with previous hip or femur operations of the affected limb ($n = 1$); we also excluded eight patients who had open repositioning of the fracture; only patients treated with minimally invasive methods were included in the study as the two implants are intended for a minimally invasive approach (Fig. 1). These initial exclusions left 108 patients. A total of 34 patients (nailing $n = 15$, plating $n = 19$) were lost to followup because of death in the hospital or after discharge. This left 74 patients with a minimum followup of 24 months (mean, 26 months; range, 24–30 months). No patients were recalled specifically for this study; all data were obtained from medical records and radiographs. Because of ill health, nine of the 74 patients were unable to return for followup (Fig. 1). For these patients, followup was completed at 2 years with a telephone consultation; radiographic review was not possible. We had prior approval from our local ethics committee.

Overall health and functionality before injury were determined by calculating the diverse comorbidities of the patients according to the ASA classification [22] and using established scoring systems (Merle d'Aubigné and Postel [6], and Harris hip score [HHS]) [12]. Additionally, semiquantitative determination of bone quality was performed via a preoperative radiograph of the uninjured side, as per the classification system described by Cooper et al. [5] (Table 1). Group size and sex distribution were similar (Table 1).

Fig. 1 The flow of participants through each stage of the trial is shown.

Table 1. Preoperative data

Patient and fracture characteristics	Total	PCCP	PFNA	95% CI
Number of patients	108	54	54	
Mean age (years, SD)	80 (13)	81 (12)	78 (13)	(−1.243; 8.317)
Sex (number of patients)				
Women	82 (76%)	41 (76%)	41 (76%)	(−0.221; 0.221)
Men	26 (24%)	13 (24%)	13 (24%)	
Side of fracture (number of patients)				
Left	55 (51%)	23 (43%)	32 (59%)	(−0.353; 0.019)
Right	53 (49%)	31 (57%)	22 (41%)	
Anesthesia risk (ASA, mean, SD)	2.8 (0.8)	2.8 (0.7)	2.7 (0.8)	(−0.124; 0.457)
Number of patients				
ASA 1	6 (6%)	2 (4%)	4 (7%)	
ASA 2	30 (28%)	15 (28%)	15 (28%)	
ASA 3	57 (53%)	27 (50%)	30 (56%)	
ASA 4	15 (14%)	10 (19%)	5 (9%)	
Hemoglobin preoperative (g/dL, mean, SD)	12.0 (2.0)	11.9 (1.8)	12.2 (2.2)	(−10.191; 4.978)
Function/scores preoperative				
Harris hip score (mean, SD)	88.4 (12.5)	86.1 (15.1)	90.6 (9.2)	(−11.594; 2.691)
Merle d'Aubigné & Postel (mean, SD)	16.4 (2.0)	16.0 (2.2)	16.8 (1.6)	(−1.870; 0.350)
Singh index (mean, SD)	3.1 (0.9)	3.1 (0.9)	3.2 (0.9)	(−0.478; 0.219)
Number of patients				
Singh 2	31 (29%)	17 (31%)	14 (26%)	
Singh 3	38 (35%)	19 (35%)	19 (35%)	
Singh 4	32 (30%)	15 (28%)	17 (31%)	
Singh 5	7 (6%)	3 (6%)	4 (7%)	
AO/OTA classification				(−0.038; 0.369)
Number of patients				
31-A2.1	41 (38%)	24 (44%)	17 (31%)	
31-A2.2	50 (46%)	21 (39%)	29 (54%)	
31-A2.3	17 (16%)	9 (17%)	8 (15%)	
Mean treatment delay in hours (SD)	23.0 (25.2)	27.4 (31.3)	18.3 (15.2)	(−0.643; 18.800)
Neck-shaft angle (degrees, mean, SD)*	131 (8)	132 (9)	129 (7)	(−1.016; 6.453)

PCCP = percutaneous compression plates; PFNA = proximal femoral nail antirotation; ASA = American Society of Anesthesiologists score; * preoperative, uninjured hip.

Three surgeons (HJE, BS, ML) were proficient in the locked plating technique and three (FT, MN, AS) were proficient with helical blade nailing. Both implants had been used by the surgeons for more than 3 years, so they would have been beyond the learning curve and they had a comparable experience level for each implant. There was no blinding of the selected treatment to either the patients or surgeons. Patients in the first group ($n = 54$) were treated with locked extramedullary implants (PCCP; Orthofix, McKinney, TX, USA) and those in the second group ($n = 54$) were treated with the intramedullary load carrier (PFNA; Synthes, Umkirch, Germany). The neck-shaft angle of the PCCP measured 135° (fixed cephalic screw angulation), whereas that of the PFNA measured 130° (10 or 11 mm diameter nail, 170 mm, locked statically) in all cases.

Before surgery, all patients received an antibiotic for prophylaxis. All patients underwent surgery at the earliest opportunity (between 2 and 24 hours after fracture). Closed reduction and internal fixation were performed with the patient in the supine position on a fracture table using an image intensifier. Implantation of the PCCP was accomplished using a standardized, minimally invasive technique [9]. For minimally invasive insertion of this device, two 2-cm, to 2.5-cm-long incisions with minimal dissection of soft tissue are required on the lateral aspect of the proximal femur. However, correct insertion of the PCCP device is technically demanding. After maintenance of posterior reduction and correct alignment of the aiming guide, the barrels must be completely and stably screwed into the plate [15, 16]. Furthermore, the two telescoping screws

must be inserted with care to ensure adequate, long-term fracture reduction [28]. In contrast to screw systems, however, the helical blade of the PFNA is not screwed in, but hammered in, unlocked (Fig. 2). Only after the desired end position is achieved is the neck blade locked via an internal screw locking system, thus blocking any rotational movement of the blade [34].

Full weightbearing was allowed immediately after surgery. Whenever possible the patients were mobilized to the edge of the bed with the support of physiotherapists on the first day after surgery. On the second day they were mobilized using a walking frame twice a day for 30 minutes. Anticoagulation with low-molecular-weight heparin

(enoxaparin-natrium, 40 mg subcutaneous a day) was used until the sixth postoperative week.

Clinical followup was performed 3, 6, 12, and 24 months after surgery. Emphasis was placed on the pain experienced daily and the functionality and mobility of the hip region. At the 24-month visit, we obtained Merle d'Aubigné and Postel scores [6] and HHS [12]. Reoperation and mortality data were available for all 108 patients. Indications for revision surgery attributable to mechanical failure included screw cutout/cut-through, implant failure, femur fracture, and nonunion. These complications were assessed by radiographic screening and the physical examination based on pain or limited functionality

Fig. 2A–D The radiographs show an unstable intertrochanteric femur fracture (A) before surgery and (B) after surgery with PCCP. These radiographs show another unstable intertrochanteric femur fracture (C) before surgery and (D) after surgery with PFNA.

(Grade IIIB [7]). Lower grades of mechanical complications (slight screw migration, sintering, femoral shortening, trochanteric bursitis) were separated and the indication for revision was determined by the consultant or chief (MN, BS, HCP) according to prior patient agreement.

Radiographs were obtained preoperatively and on the first postoperative day for all patients, and at each clinic visit for all available patients. Three of us (MK, MN, BS) evaluated all radiographs. The combined magnification-adjusted tip-apex distance measured on AP and lateral radiographs was analyzed according to the method of Baumgaertner et al. [3]. The status of the lateral wall was assessed before and after surgery to identify an intraoperative or postoperative fracture [10, 26]. All radiographs and the uninjured hip were analyzed for neck-shaft angle, medialization of the shaft, femoral shortening, and femoral neck shortening according the method of Olsson et al. [25]. Fracture healing was assessed radiographically and was stated by documented healing of three of four cortices in the two radiographic planes. Using AP and lateral radiographs of the involved proximal femur region, fracture reduction and position of the implant were assessed. For these purposes, a rating of good (configuration of the opposite side, displacement between the fragments not exceeding 2 mm in any position), acceptable (5° to 10° varus/valgus and/or anteversion/retroversion), or poor ($> 10^{\circ}$ varus/valgus and/or anteversion/retroversion) was used [4]. To determine the screw position in the femur head, the two-dimensional projections were divided into nine zones [36]. An ideal screw position was defined as central positioning of the neck screw on the lateral radiograph and a central or inferior position (PFNA) or inferior position of the lower screw (PCCP) on the AP radiograph.

Continuous data were summarized by means and corresponding SD, and categorical data by frequencies and

percentages. Differences in reoperation rate, mortality data, and qualitative radiographic measures (ideal implant position, fracture reduction, lateral wall fracture) between PCCP and PFNA were described by 95% CI. Differences in outcome scores and quantitative radiographic measures (tip-apex distance, shaft displacement, neck-shaft angle, femoral shortening, and femoral neck shortening) were described by 95% CI for continuous data. We used logistic regression models to assess the relation between age, gender, AO/OTA classification, ASA score, Singh index, tip-apex distance, fracture reduction, implant position, neck-shaft angle, variation of neck-shaft angle, or lateral wall fracture, and the need for reoperation within 24 months. To reduce bias in odds ratio estimation we used Firth's penalized maximum likelihood approach [8]. Exploratory factors were assessed as relevant to be mutually included in our final multivariate model if the p value was less than 0.2 in the univariate analysis. We computed the odds ratios, corresponding 95% penalized likelihood CI, and p values resulting from penalized likelihood ratio tests. All tests were two-tailed and assessed at the 5% significance level. Because of the exploratory nature of the secondary hypotheses, no adjustment was made to account for multiple testing. All analyses were performed with SAS® statistical analysis software, V9.2 (SAS Institute Inc, Cary, NC, USA).

Results

We found no differences in the number of reoperations attributable to mechanical problems between PCCP and PFNA. After implantation of the PCCP, six (11%) reoperations (all early postoperative) were necessary owing to mechanical complications (Table 2). The primary cause for such revisions after PCCP implantation was barrel loosening

Table 2. Postoperative data

Hospitalization variables and reoperations	PCCP	PFNA	95% CI
Units transfused 24 hours (mean, SD)	1.1 (1.4)	1.7 (1.8)	(−1.215; 0.029)
Patients transfused 24 hours (number of patients)	24 (44%)	31 (57%)	(−0.3; 0.057)
Hospitalization time (days, mean, SD)	16 (7)	18 (8)	(−5.27; 0.774)
In-hospital death (number of patients)	2 (4%)	4 (7%)	(−0.279; 0.400)
Reoperation rate (number of patients)	6 (11%)	5 (9%)	(−0.26; 0.36)]
Cutout	2 (4%)	3 (6%)	(−0.545; 0.335)
Barrel loosening	3 (6%)	0 (0%)	
Incorrect screw placement	1 (2%)	1 (2%)	
Femoral shaft fracture	0 (0%)	1 (2%)	
Removal/change/correction of implant (number of patients)	5	4	
Hip prosthesis (number of patients)	1	0	
Cerclage	0	1	

PCCP = percutaneous compression plates; PFNA = proximal femoral nail antirotation.

($n = 3$; 6%) (Fig. 3) [15, 16]. In two of the three patients, the PCCP implant was preserved and in one patient the implant was changed to a dynamic hip screw. Additional complications included an incorrectly placed screw (migration under weightbearing, before cutout) in one patient (revision with PFNA 3 weeks after surgery), and cutout in two patients, (4%). In one of the two patients, we revised the PCCP, and in the second patient a hip endoprosthesis was used. Early postoperative complications were observed in five patients (9%) in the PFNA group. The cutout phenomenon was

observed in three patients (6%). In all cases a Gamma3TM nail (Stryker) was used. Additional reoperations after PFNA were attributable to one incorrectly placed screw in which the hip pin migrated into the acetabulum 6 weeks after the operation (revision of the screw) and one femoral shaft fracture (fixation with cerclage wires).

The postoperative tip-apex distance ($p = 0.003$; odds ratio, 1.16; 95% CI, 1.05–1.34) and postoperative variation of the neck-shaft angle ($p = 0.035$; odds ratio, 1.13; 95% CI, 1.01–1.32) were the main independent risk factors for a

Fig. 3A–B The (A) AP and (B) lateral view radiographs show barrel loosening in a patient in the PCCP group. Both barrels are loose (white arrows), with loss of locked fixation stability.

Table 3. Analysis for prediction of reoperation within 24 months postoperatively

Patient/fracture characteristics	Univariate analysis Odds ratio/95% CI/p value	Multivariate analysis Odds ratio/95% CI/p value
Female gender	8.52/1.04, 1108.19/0.044	3.97/0.30, 625.79/0.342
Postoperative tip-apex distance (mm)	1.08/1.00, 1.16/0.051	1.16/1.05, 1.34/0.003
Ideal screw position in femoral head	3.45/0.99, 14.69/0.051	5.29/0.85, 61.63/0.077
Neck-shaft angle postoperative	0.94/0.87, 1.01/0.097	0.91/0.77, 1.05/0.203
Variation neck-shaft angle preoperative versus postoperative	1.06/0.97, 1.16/0.197	1.13/1.01, 1.32/0.035
Good postoperative fracture reduction	1.48/0.70, 2.84/0.278	
Age (years)	1.02/0.97, 1.10/0.442	
ASA score	1.33/0.60, 3.21/0.492	
Lateral wall fracture postoperative	0.56/0.06, 2.62/0.499	
AO/OTA classification	1.34/0.56, 3.18/0.501	
Osteoporosis (Singh index)	1.20/0.61, 2.33/0.597	

ASA = American Society of Anesthesiologists.

Table 4. Intraoperative data

Operative variables and radiographic measures	PCCP	PFNA	95% CI
Operative time (minutes, mean, SD)	61 (27)	76 (25)	(−25.438; −4.505)
Fluoroscopy time (seconds, mean, SD)	129 (96)	182 (154)	(−107.5; 1.293)
Ideal implant position (number of patients)	29 (54%)	31 (57%)	(−0.227; 0.152)
Good fracture reduction (number of patients)	46 (85%)	44 (82%)	(−0.185; 0.318)
Tip-apex distance (mm, mean, SD)	28 (8)	28 (9)	(−3.03; 3.672)
Medial shaft displacement (mm, mean, SD)	3 (6)	4 (7)	(−8.644; 12.793)
Neck-shaft angle (degrees, mean, SD)	128 (8)	122 (9)	(2.916; 11.942)
Varisation neck-shaft angle (degrees, mean, SD)	−4 (9)	−8 (9)	(−0.582; 7.750)
Lateral wall fracture (number of patients)	4 (7%)	16 (30%)	(−0.57; −0.166)

PCCP = percutaneous compression plates; PFNA = proximal femoral nail antirotation.

Table 5. Mortality and radiographic and functional outcomes at 24-months followup

Variables	PCCP	PFNA	95% CI
Died (number of patients)	19 (35%)	15 (28%)	(−0.032; 0.357)
Radiographic measures			
Tip-apex distance (mm, mean, SD)	30 (10)	29 (8)	(−4.261; 5.229)
Medial shaft displacement (mm, mean, SD)	−1 (8)	−2 (6)	(−12.516; 21.011)
Neck-shaft angle (degrees, mean, SD)	125 (8)	118 (5)	(2.964; 11.942)
Varisation neck-shaft angle			
Preoperative versus followup (degrees, mean, SD)	−9 (9)	−14 (8)	(−1.237; 11.285)
Postoperative versus followup (degrees, mean, SD)	−3 (6)	−5 (5)	(−1.491; 5.528)
Femoral neck shortening (mm, mean, SD)	5 (6)	5 (5)	(−2.806; 2.758)
Femoral shortening (mm, mean, SD)	2 (8)	3 (6)	(−4.587; 2.646)
Function/scores			
Harris hip score (mean, SD)	65.2 (18.9)	69.3 (19.4)	(−15.046; 6.961)
Merle d'Aubigne & Postel score (mean, SD)	12.4 (2.4)	13.2 (3.0)	(−2.276; 0.836)
Function/scores preoperative versus followup			
Difference in Harris hip score (mean, SD)	20.9 (17.8)	21.3 (17.7)	(−10.615; 9.796)
Difference in d'Aubigne & Postel score (mean, SD)	3.6 (2.4)	3.6 (2.9)	(−1.549; 1.469)

PCCP = percutaneous compression plates; PFNA = proximal femoral nail antirotation.

reoperation (Table 3). Patients with mechanical complications had a higher tip-apex distance than patients without reoperations (33 mm [SD, 13 mm] versus 28 mm [SD, 8 mm]). We observed a difference between the two groups in terms of the intraoperative neck-shaft angle (Table 4), that persisted at followup. However, there was no difference between the groups in terms of the postoperative varisation (preoperative versus postoperative; preoperative versus followup) of the neck-shaft angle, in comparison to the preoperative uninjured hip (Table 5).

A fractured lateral femoral wall had no influence on the reoperation rate in the univariate logistic regression model (Table 3). Postoperatively, there were more fractures of the lateral femoral wall seen in patients in the PFNA group ($n = 16$; 30%) than in patients in the PCCP group ($n = 4$; 7%) (Table 4). These fractures had occurred during the

surgical procedure as the lateral femoral wall had been intact preoperatively and fractures had been classified as A2.

There were no differences between the two groups regarding in-hospital mortality (Table 2). Two patients (4%) died after PCCP and four (7%) died after PFNA. The 2-year mortality was 35% for patients who had PCCP ($n = 19$) and 28% for patients who had PFNA ($n = 15$) (Table 5).

We found no differences for the Merle d'Aubigné and Postel score or HHS at the 24-month followup (Table 5).

Discussion

Currently, there exists no consensus regarding optimal therapy of unstable extracapsular hip fractures, with a

reported mechanical complication rate of as much as 20% [23, 29, 33]. However, the authors of the Cochrane meta-analysis recommended further comparative studies with new-generation nails and sliding extramedullary devices, especially for unstable fracture subgroups [29]. One of the more promising innovations uses nails with a blade instead of a screw for the head and neck fragment, with promising results in the first clinical studies [19, 20, 24, 34, 38]. Locked minimally invasive plating also potentially could reduce the complication rate [9, 10, 13, 17, 28, 31, 37] (Table 6). Such techniques are becoming more popular in modern orthopaedic trauma as they at least theoretically, seem to be associated with less postoperative pain, lower risk for postoperative morbidity, and rapid rehabilitation [4]. A clinical comparison of locked minimally invasive plating with a modern cephalocondylar nail has been attempted only with stable pertrochanteric fractures with both options offering comparable results [37]. In our study we therefore examined whether (1) patients who had helical blade nailing (PFNA) had lower reoperation rates than patients who had a locked plating technique (PCCP) for unstable pertrochanteric fractures, and whether various factors predicted (2) reoperations attributable to mechanical failures. We report mortality (in-hospital, 2 years) and outcome scores 24 months after surgery.

Readers should be aware of limitations to our study. First, the group assignment was not a randomized process, but rather patients were assigned sequentially to one of two sets of three consultants (surgeon-allocated study). We believe this is a reasonable approach given differing familiarities with the surgical methods [32]. Second, patients and healthcare providers were not blinded to the treatment method owing to restraints of the clinical setting and preference of surgeons. However, the baseline data were well balanced between these two treatment groups. Third, the number of patients was limited owing to the stringent inclusion and exclusion criteria and the relatively short time during which the study was conducted. Because of the absence of prior data we did not perform a sample size power analysis. We considered this a preliminary study to generate definitive hypotheses. However, we prospectively included registration of detailed preoperative and intraoperative data including osteoporosis, exact fracture type, reduction, and implant position with a magnification-corrected tip-apex distance and the fact that the primary outcome was available for all patients. Fourth, the middle between the two screws was used to measure the tip-apex distance of the PCCP assuming a different migration resistance of single- and double-lag screw implants. Using this approach we verified the centric position of this

Table 6. Comparison of literature and current study

Study	Implants	Reoperation*	Mortality#	Function/quality of life#	Fractures	Followup
Barton et al. [2]	Gamma3 TM , sliding hip screw	3%, 2%	32% 22%	Mobility/residency/ EuroQoL - no difference	A2	12 months
Varela-Egocheaga et al. [37]	PCCP, Gamma3 TM	0%, 7.5%	10% 2.5%	Walking ability - no difference	A1 > A2	12 months
Peyser et al. [31]	PCCP, sliding hip screw	4%, 7.5%	10% 24.5%	VAS pain/weightbearing no difference	A1 > A2	12 months
Kosygan et al. [17]	PCCP, sliding hip screw	2%, 4%	13.5% 16%	–	A1, A2	6 months
Janzing et al. [13]	PCCP, sliding hip screw	8%, 3%	21% 19%	Mobility/residency - no difference	A1, A2	12 months
Simmermacher et al. [34]	PFNA	4%	18.5%	Parker mobility score 56% pretrauma	A2 > A3	12 months
Liu et al. [20]	PFNA	1%	–	Harris hip score 84 points, 74% pretrauma	A1-A3	21 months
Merreddy et al. [24]	PFNA	4%	8%	Mobility/range of movement 80% pretrauma	A2, A3	3 months
Yaozeng et al. [38]	PFNA, Gamma3 TM	2%, 0%	7% 2%	Parker mobility score - no difference	A1-A3	18 months
Lenich et al. [19]	PFN, PFNA	14%, 6%	3%	Mobility/social status 34% pretrauma	A1-A3	3 months
Current study	PCCP, PFNA	11%, 9%	35% 28%	Merle d'Aubigné & Postel/ Harris hip score - no difference	A2	24 months

* Rate attributable to mechanical failure; #at followup; PCCP = percutaneous compression plate; PFNA = proximal femoral nail antirotation; PFN = proximal femoral nail.

double-lag screw implant introduced by Gotfried [9] and generated comparability to a standard single-lag screw system. Nevertheless, the individual tip-apex distance values of every screw were stated (Table 4). Fifth, there was a different operation time for the implants, with 15 minutes more for intramedullary nailing. This might be attributable to the sequential assignment of patients given different surgeons in the two study arms. Furthermore, the slightly higher number of A2.2 fractures in the PFNA group (eight more than in PCCP group) may play a role in this context. However, in the multivariate regression analysis, this was not a factor. Sixth, the process indicating a surgical revision followed a team-based approach. That is why we cannot provide statistical measures such as interobserver variability for the three responsible surgeons evaluating the postoperative radiographs. Seventh, we could obtain radiographs for only 65 of the 108 patients at followup owing to death or illness. The loss of patients in this geriatric community is a common problem and diminished the power of the results regarding the radiographic and functional outcomes. However, the remaining patients underwent radiographic analysis for lateral trochanteric wall fracture, fracture collapse, medial displacement, and limb and femoral neck shortening, clinical followup 24 months after surgery, and use of detailed scoring systems. Eighth, patient-reported outcomes and detailed health-related quality of life assessments would have strengthened the study. On the strength of experience, completion of the comprehensive quality of life questionnaires, such as the SF-36, often was a problem for our geriatric patients. To provide a temporary and stress-free followup procedure we excluded the standardized analysis of health-related quality of life from our study protocol.

Our findings reinforce the results of Barton et al. [2] and Jones et al. [14], showing no difference in the reoperation rates (11% for the PCCP, 9% for the PFNA) after treatment of unstable pertrochanteric fractures with an intramedullary or an extramedullary device. We had the same complication rates between implants using the new helical blade nailing and the locked minimally invasive plating technique. After PCCP implantation, cutout occurred in two patients (4%). Other studies have reported lower reoperation rates after PCCP implantation (Table 6), although without taking fracture instability into consideration [13, 17, 31, 37]. Only patients with unstable A2 fractures were included in the current study using this locked minimally invasive plate system, resulting in a higher complication rate. Regarding the PCCP, the barrels must be completely and stably screwed into the plate using the aiming guide. If this does not occur, the barrel might gradually loosen from the plate, the locking option disappears, and the implant fails [15, 16]. No direct observation of the plate is possible, and with a fixed cephalic screw angulation of 135°, there is

the potential for surgical error [28]. We observed barrel loosening in three patients in the PCCP group (Fig. 3). However, complication rates after use of the newer modified nails (blades, optimized anatomic design) appear to be lower in comparison to those of older nail generations [19, 34]. In the study by Simmermacher et al., the main complications were cutout (1%) and ipsilateral femur fracture (2%) [34]. Cutout of the lag screw still appears to be a relevant (range, 3–7%) problem for new-generation intramedullary therapy [19]. We have seen one femur fracture after the use of the PFNA and a cutout rate of 6%. The reoperation rate of the PFNA seems to vary between 1% and 6% (Table 6), whereas only two studies stringently focused on unstable fractures [24, 34].

We found postoperative variation of the neck-shaft angle in addition to the tip-apex distance were the predictors for reoperation. The value of fracture reduction in restoring the neck-shaft angle, as observed on the AP radiograph, was shown, with an increased cutout rate for fractures fixed in varus position [30]. Fracture reduction and implant positioning are directly related, with correct reduction being the prerequisite to correct implant placement. Eccentric placement of an implant increases the risk of cutout [3]. Despite a higher postoperative neck-shaft angle after the PCCP (also slight preoperative difference, and possibly there was greater valgisation in reduction owing to the fixed cephalic screw angulation of 135°, in contrast to 130° in PFNA), its variation in comparison to the uninjured hip was no different than that for the PFNA. This is in contrast to the results of Madsen and Naess [21], who observed a decrease in the neck-shaft angle during fracture healing more frequently in patients treated with the gamma nail than those treated with the dynamic hip screw. In contrast to the findings of Palm et al. [26] and Gotfried [10], we found a lateral wall fracture did not predict reoperation. For patients with a necessary reoperation, only one had an intraoperative or postoperative lateral wall fracture after proximal femoral nailing. For fracture fixation using the PCCP, the lateral wall of the femur is thought to be better preserved, which adds stability when compared with the sliding hip screw [10]. We found a 30% incidence of lateral femoral wall fractures in patients treated with the PFNA as compared with 7% in the patients treated with PCCP for A2 fractures. These results contrast the findings of Palm et al. [26] who, in a retrospective study, reported a 27% rate of lateral wall fractures in patients after sliding hip screw and 6% in patients after intramedullary nailing for stable and unstable fractures, leading to a lower reoperation rate for the nailing group. However, PCCP had a decreased incidence of perioperative lateral wall fractures compared with the sliding hip screw, with a greater difference in unstable fractures [9, 18]. This was attributed to the small diameter of the holes at the

drilling site with percutaneous compression plating [9, 10]. A pertrochanteric fracture deteriorates to a subtrochanteric fracture-equivalent and these complications, occurring during or after surgery, result in a long period of disability [9, 10].

A recent meta-analysis reported a decreased trend (not statistically significant) in overall mortality using the locked minimal invasive plating system owing to its minimally invasive property [28]. Our preliminary data do not support this trend comparing two forms of minimally invasive fixation, taking the Level III study design into account. Several studies have reported no influence of the implant on morbidity and mortality, but the rates range from 2% to 32% (Table 6). The different followup times (range, 3–21 months) in the previous series are likely one explanation for the discrepancy. Our mortality data at followup seem to be high, but our observation period was the longest (24 months). Furthermore, stringent inclusion criteria play a prominent role in this context. All unstable fractures in the intertrochanteric region occurring in patients older than 60 years were included in our series, whereas criteria, including detailed in-hospital data, often were missing or unspecified in previous studies [19, 20, 24, 37, 38].

We found no published study of the PCCP using detailed outcome scores for function and quality of life (Table 6). Additionally, we found no study reporting final outcomes of lateral wall fractures which result in a long period of disability [9, 10]. Despite a different incidence of lateral wall fractures, we found no functional differences between locked extramedullary and intramedullary fixation at the 24-month followup. As we observed no different medial shaft displacement and no difference regarding limb or neck shortening between the two implants, it is likely that the intramedullary nail stops telescoping displacement of these consecutive comminuted fracture types (A3 fracture-equivalent after lateral wall fracture) by directly blocking lateralization of the head-neck fragment [11, 27]. Preventing varus collapse and medial shaft displacement, it leads to prevention of cutout and negative functional consequences (such as hip abductor insufficiency) of lateral wall fractures after intramedullary treatment. Using a multitude of outcome scales and scores, which often were unspecified, no previous study showed any difference in function or quality of life comparing extramedullary and intramedullary implants (Table 6). Our data for unstable pertrochanteric fractures, use of the most modern extramedullary and intramedullary implants currently available, and 2 years of followup support these findings showing comparable function attributable to pain level, walking ability, and range of hip mobility. Possibly consideration of patient subgroups with higher risks for poor outcome could bring existing differences to light. Using a modified VAS,

quality of life with marked osteoporosis was greater after PCCP compared with that of the sliding hip screw [15]. The helical blade increases the contact surface area between the purchase-holding device and the femoral head cancellous bone, and compresses the limited amount of bone which possibly leads to higher stability in osteoporosis [34, 35]. This may be a topic for future randomized clinical studies.

For unstable pertrochanteric femur fractures (AO/OTA 31-A2), we identified no differences in the reoperation rates between locked minimally invasive extramedullary implants (PCCP) and intramedullary systems of helical blades (PFNA). Postoperative variation of the neck-shaft angle and tip-apex distance predicted reoperation. Patients with reoperations attributable to mechanical complications had a higher tip-apex distance than patients without reoperations (33 mm versus 28 mm), regardless of the implant type. Despite a higher incidence of lateral wall fracture with intramedullary nailing, we found no difference in the reoperation rate and in functional outcome at the 24-month followup, using the HHS and Merle d'Aubigné and Postel score, between extramedullary and intramedullary fixation. Based on our findings we believe unstable A2 fractures should be fixed either with locked small-diameter screw systems like the PCCP to avoid lateral wall fractures or with intramedullary helical blade systems to avoid potential negative consequences of lateral trochanteric wall fractures.

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