An Original Study

# Treatment of Unstable Trochanteric Femur Fractures: Proximal Femur Nail Versus Proximal Femur Locking Compression Plate

Ashutosh Kumar Singh, MBBS, MS, Nidhi Narsaria, MBBS, MD, Arun G. R., MBBS, MS, and Vivek Srivastava, MBBS, MS

**Abstract**

Unstable trochanteric femur fractures are common fractures that are difficult to manage. We conducted a prospective study to compare functional outcomes and complications of 2 different implant designs, proximal femur nail (PFN) and proximal femur locking compression plate (PFLCP), used in internal fixation of unstable trochanteric femur fractures. On hospital admission, 48 patients with unstable trochanteric fractures were randomly assigned (using a sealed envelope method) to treatment with either PFN (24 patients) or PFLCP (24 patients). Perioperative data and complications were recorded. All cases were followed up for 2 years.

The groups did not differ significantly ($P > .05$) in operative time, reduction quality, complications, hospital length of stay, union rate, or time to union. Compared with the PFLCP group, the PFN group had shorter incisions and less blood loss. Regarding functional outcomes, there was no significant difference in mean Harris Hip Score ($P = .48$) or Palmer and Parker mobility score ($P = .58$). Both PFN and PFLCP are effective in internal fixation of unstable trochanteric femur fractures.

***Take-Home Points***

- Both PFN and PFLCP are effective treatments for unstable trochanteric femur fractures.
- PFN is superior to PFLCP only in terms of shorter incisions and shorter time to full weight-bearing.
- Both devices have good long-term functional outcomes.
- Complication rates in unstable trochanteric fractures treated with both implants are comparable.
- Larger randomized controlled multicenter studies are needed to further evaluate and compare both implants in displaced unstable trochanteric femur fractures.

Trochanteric fractures are among the most widely treated orthopedic injuries, occurring mainly as low-energy injuries in elderly patients and high-energy injuries in younger patients.[1,2] About half of these injuries are unstable.[3] According to the AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) system, trochanteric fractures can be classified stable (AO/OTA 31.A1-1 to 31.A2-1) or unstable (AO/OTA 31.A2-2 to 31.A3.3).[4,5] For surgical fixation of trochanteric femur fractures, various internal fixation devices have been used, either extramedullary (EM) or intramedullary (IM).[6] The dynamic hip screw (DHS) is the implant of choice in the treatment of stable trochanteric femur fractures (AO/OTA 31-A1), as it provides secure fixation and controlled impaction.[7] Mechanical and technical failures continue to occur in up to 6% to 18% of cases of unstable trochanteric fractures treated with DHS.[8] Excessive sliding of the lag screw within the plate barrel results in limb shortening and distal fragment medialization, which are the main causes of these failures.[9,10]

**Authors' Disclosure Statement:** The authors report no actual or potential conflict of interest in relation to this article.

Dissatisfaction with DHS use in unstable fractures led to the use of IM nails. The various IM devices available are condylocephalic (Ender) nails and cephalomedullary nails, such as gamma nails; IM hip screws; trochanteric antegrade nails; proximal femoral nails (PFNs); and trochanteric fixation nails.[11,12] Unstable trochanteric fractures treated with these IM fixation devices have had good results.[12-14] Because of their central location and shorter lever arm, IM nails decrease the tensile strain on the implant and thereby reduce the risk of implant failure and provide more efficient load transfer while maintaining the advantage of controlled fracture impaction, as in DHS.[15,16] According to some authors, IM nail insertion theoretically requires less operative time and less soft-tissue dissection, potentially resulting in decreased overall morbidity.[15,16] PFN is one of the most effective fixation methods used to treat unstable trochanteric femur fractures.[17] However, it is associated with various technical problems and failures, such as anterior femoral cortex penetration (caused by mismatch of nail curvature and intact femur), lag screw prominence in the lateral thigh, creation of a large hole in the greater trochanter (leading to abductors weakness), and potential for the Z-effect.[18,19] Studies have compared PFN with the Less Invasive Stabilization System-Distal Femur (LISS-DF) in the treatment of proximal femur fracture, and the clinical results are encouraging.[20,21] Recently, the proximal femoral locking compression plate (PFLCP) was introduced as a new implant that allows for angular-stable plating in the treatment of complex comminuted and osteoporotic intertrochanteric fractures.[22,23]

To our knowledge, our study is the first to compare functional outcomes and complications of unstable trochanteric fractures treated with PFN and those treated with PFLCP. We hypothesized that both PFN and PFLCP would provide good functional outcomes with acceptable and comparable complications in the treatment of unstable trochanteric fractures.

## Materials and Methods

The protocol for this prospective comparative study was approved by the Institutional Review Board at Mayo Institute of Medical Sciences. Informed consent was provided by all patients. A power analysis with power of 90% to detect a Harris Hip Score (HHS) difference of 10 as being significant at the 5% level, and with a 10% to 15% dropout rate, determined that a sample size of 50 patients was needed. Each group (PFN, PFLCP) required at least 25 participants. From April 2009 to June 2011, 74 patients with unilateral closed unstable trochanteric fractures were admitted to our hospital. Of these patients, 48 met our inclusion criteria and were included in the study. A sealed envelope method was used to randomly assign 24 of these patients to PFN treatment and the other 24 to PFLCP treatment. One patient died of causes unrelated to an implant during the study, and 2 were lost to follow-up (telephone numbers changed). The remaining 45 patients (23 PFN, 22 PFLCP) reached 2-year follow-up.

Inclusion criteria were unilateral, closed unstable trochanteric fractures, and age over 18 years. Exclusion criteria were bilateral fractures, polytrauma, pathologic fractures, open fractures (American Society of Anesthesiologists [ASA] grade 4 or 5),[24] and associated hip osteoarthritis (Kellgren-Lawrence grade 3 or 4).[25] We collected data on demographics, operative time, incision length, intraoper-

Table 1. **Demographic Profile of Study Patients**

| Characteristic | Group | |
|---|---|---|
| | PFN (n = 23) | PFLCP (n = 22) |
| Age, y | | |
| Mean | 58.3 | 60.5 |
| SD | 9.3 | 8.1 |
| Range | 19-82 | 20-84 |
| Sex | | |
| Male | 9 | 7 |
| Female | 14 | 15 |
| Fracture side | | |
| Right | 11 | 10 |
| Left | 12 | 12 |
| Preoperative walking ability | | |
| Independent | 17 | 18 |
| Assisted | 6 | 4 |
| Unable | 0 | 0 |
| Time from injury to surgery, d | | |
| Mean | 5.12 | 6.18 |
| SD | 2.24 | 2.42 |
| AO fracture type | | |
| 31.A2 | 14 | 12 |
| A2.1 | 7 | 6 |
| A2.2 | 4 | 4 |
| A2.3 | 3 | 2 |
| 31.A3 | 9 | 10 |
| A3.1 | 4 | 4 |
| A3.2 | 3 | 4 |
| A3.3 | 2 | 2 |

Abbreviations: AO, Arbeitsgemeinschaft für Osteosynthesefragen; PFLCP, proximal femur locking compression plate; PFN, proximal femur nail.

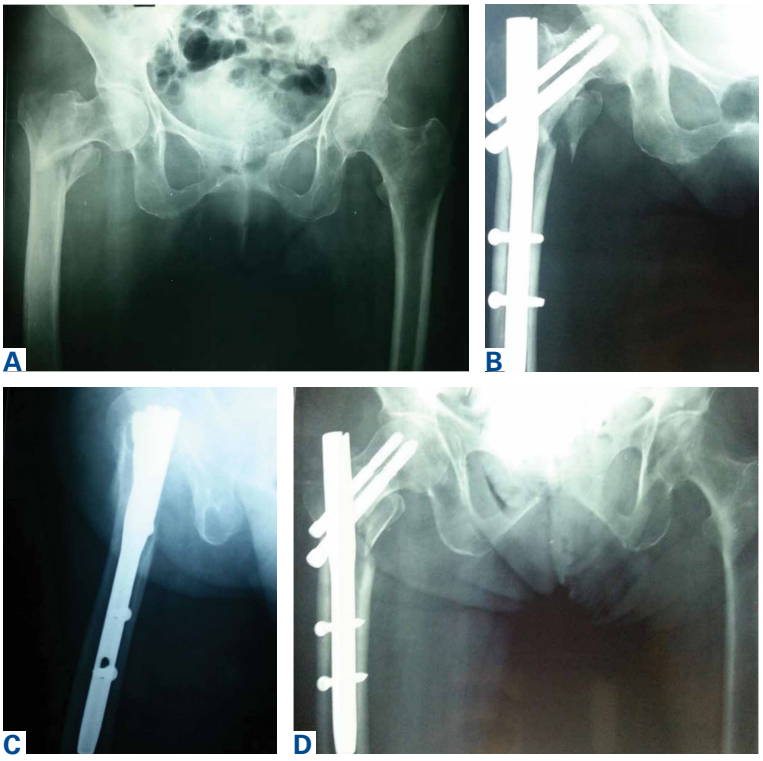


**Figure.** (A) Radiograph shows unstable intertrochanteric femur fracture of the right side in a 66-year-old man. (B) Immediate postoperative anteroposterior radiograph shows closed reduction and internal fixation with proximal femur nail. (C) Lateral radiograph shows fixation with proximal femur nail. (D) Six-month follow-up anteroposterior radiograph shows well-united fracture.

ative blood loss (measured by gravimetric method), hospital length of stay (LOS), and time to full weight-bearing. Mean (SD) age was 58.3 (9.3) years for the PFN group (range, 19-82 years) and 60.5 (8.1) years for the PFLCP group (range, 20-84 years). The groups were similar in terms of sex proportion ($P = .42$), fracture side ($P = .82$), fracture type ($P = .15$), time from injury to surgery ($P = .24$), and Palmer and Parker mobility (PPM) score ($P = .26$). The Singh index was used to evaluate osteoporosis grading; there was no significant difference between groups ($P = .48$). The AO/OTA system was used to classify fractures. Only AO type 31.A2 and 31.A3 fractures (unstable trochanteric fractures) were included in the study (**Table 1**).

Before surgery, each patient's standard plain radiographs (1 anteroposterior [AP], 1 lateral) were evaluated. Patients underwent surgery as soon as their general medical condition allowed. Surgery was performed through a lateral approach with the patient supine and in traction on a fracture table. PFN patients received 2 femoral neck screws (DePuy Synthes) (**Figures A-D**), and PFLCP patients received PFLCP (DePuy Synthes) in a fashion similar to that described in AO internal fixation manuals. Intraoperative reduction was assessed and graded good, acceptable (5°-10° varus/valgus and/or anteversion/retroversion), or poor (>10° varus/valgus and/or anteversion/retroversion).[26]

A standard postoperative protocol was followed. Knee and ankle exercises were started on postoperative day 1. Non-weight-bearing walking with bilateral axillary crutches was started after surgery, usually on postoperative day 3 to 5, as tolerated. Follow-up was monthly the first 3 months, then every 3 months until 2 years. At each follow-up, patients were assessed clinicoradiologically; functional outcome scores and complications were assessed and reported; and AP and lateral radiographs were examined for implant position and signs of fracture union. Progressive weight-bearing was started after 6 weeks, initially with 25% of the patient's weight. Walking with gradually increasing weight-bearing was allowed, provided that reduced and stabilized fracture position remained unchanged, and there were clinicoradiological signs of bone healing (no pain, swelling, or tenderness at fracture site clinically; invisible fracture lines on radiographs). Walking ability was assessed with a PPM score (maximum, 9 points), which covered 3 items, ability to walk indoors (1 item) and ability to walk outdoors (2 items).[27] Overall patient outcomes were summarized using the HHS system (excellent, 90-100 points; good, 80-89 points; fair, 70-79 points; poor, <70 points).[28] Evaluated complications included superficial wound infection (positive bacterial culture from above fascia), deep wound infection (positive bacterial culture from below deep fascia), nonunion, fixation failure (lag-screw penetration in joint, back-out or cut-out of femoral head, breakage of implant, nonunion of fracture, secondary loss of reduction), and complications unrelated to implant (deep vein thrombosis, bed sore, chest infection).

Absolute values of differences were used for statistical analysis. For categorical outcome variables (eg, reoperation reason and type), Pearson $\chi^2$ test was used; for continuous variables (eg, pain, HHS), Student $t$ test was used. Statistical significance was set at $P = .05$ (2-sided).

## Results

Intraoperative blood loss ($P = .02$) and incision length ($P = .008$) were significantly less in the PFN group than in the PFLCP group. No significant difference was found between the groups in terms of operative time ($P = .08$), reduction quality ($P = .82$),

radiologic exposure time ($P = .18$), LOS ($P = .32$), union rate ($P = .42$), and time to union ($P = .68$). Time to full weight-bearing was significantly ($P = .048$) lower in the PFN group (mean, 4.0 months; SD, 2.2 months; range, 2.8-9.2 months) than in the PFLCP group (mean, 5.3 months; SD, 2.6 months; range, 3.4-12.2 months). Of the 23 PFN patients, 22 achieved union uneventfully; all 22 PFLCP patients achieved union ($P = .42$) (**Table 2**).

Two PFN patients and 3 PFLCP patients developed a superficial infection ($P = .36$); all 5 infections were controlled with oral antibiotics. There was 1 nonunion in the PFN group but none in the PFLCP group ($P = .28$). The nonunion patient, who also had a broken implant without any history of fresh trauma, was treated with implant removal and bipolar hemiarthroplasty. Two implant-related complications (1 implant breakage, 1 Z-effect) occurred in the PFN group but none in the PFLCP group ($P = .10$). Revision surgery was performed in 2 PFN patients (1 bipolar hemiarthroplasty, 1 removal of protruding screw) but not in any PFLCP patients ($P = .10$). The groups' incidence of fracture-unrelated postoperative complications (eg, chest infection, bed sore, urinary tract infection, deep vein thrombosis) was comparable and not significantly different ($P = .19$) (**Table 3**).

There was no significant difference between the groups in terms of functional outcome (HHS) at final follow-up ($P = .48$). Based on HHS grading, 6 PFN patients had excellent results, 12 good, 4 fair, and 1 poor; in the PFLCP group, 5 patients had excellent results, 13 good, and 4 fair. There was no significant difference ($P = .58$) between the groups' PPM scores (**Table 4**).

Table 2. **Comparison of Perioperative Measures and Outcomes of Both Groups**

| Measure/Outcome | Group | | *P* |
|---|---|---|---|
| | PFN (n = 23) | PFLCP (n = 22) | |
| Operative time, min | | | .08 |
| Mean | 56.6 | 68.1 | |
| SD | 12.8 | 14.8 | |
| Range | 42-82 | 50-102 | |
| Incision length, cm | | | .008 |
| Mean | 4.5 | 10.2 | |
| SD | 1.0 | 1.5 | |
| Range | 3-5.5 | 8.5-12 | |
| Radiologic exposure, min | | | .18 |
| Mean | 2 | 3 | |
| SD | 0.8 | 1.3 | |
| Range | 1-3 | 1.4-3.6 | |
| Hospital length of stay, d | | | .32 |
| Mean | 11.2 | 12.8 | |
| SD | 3.2 | 4.4 | |
| Range | 5-15 | 6-16 | |
| Blood loss, mL | | | .02 |
| Mean | 176 | 298 | |
| SD | 90 | 116 | |
| Range | 100-320 | 170-440 | |
| Union rate | | | .42 |
| n | 22 | 22 | |
| % | 95.83 | 100 | |
| Time to union, mo | | | .68 |
| Mean | 4.1 | 4.8 | |
| SD | 1.3 | 1.5 | |
| Range | 3-7 | 3.4-7.6 | |
| Reduction quality | | | .82 |
| Good | 17 | 15 | |
| Acceptable | 6 | 7 | |
| Poor | 0 | 0 | |

Abbreviations: PFLCP, proximal femur locking compression plate; PFN, proximal femur nail.

## Discussion

The goal in managing proximal femoral fractures is to achieve near anatomical reduction with stable fracture fixation. Over the years, EM and IM devices have been used to treat trochanteric fractures; each has its merits and demerits.[29,30] However, unstable trochanteric fractures treated with EM devices (eg, DHS, dynamic condylar screw) have high complication rates (6%-18%).[8,31] Excessive sliding of the lag screw within the plate barrel may result in limb shortening and distal fragment medialization. EM devices cannot adequately prevent secondary limb shortening after weight-bearing, owing to medialization of the distal fragment.[32,33] Varus collapse and implant failure (eg, cut-out of the femoral head screw) are also common.[29] These complications led to the development of IM hip screw devices, such as PFN, which has several potential advantages, including a shorter lever arm (decreases tensile strain on implant) and efficient load transfer capacity. PFN has been found to have increased fracture stability, with no difference in operative time or intraoperative complication rates, but some studies have reported implant failure and other complications (3%-17%) in PFN-treated unstable trochanteric fractures.[29,34,35]

We conducted the present study to compare PFN and PFLCP, new treatment options for unstable and highly comminuted trochanteric fractures. The characteristics of the patients in this study are very different from those in most hip fracture studies. Our PFN and PFLCP groups' mean ages were lower relative to other studies.[14,15,36] In addition, time from injury to surgery was longer for both our groups than for groups in other studies, though

Table 3. **Comparison of Complications of Both Groups**

| Complication | Group PFN (n = 23) | Group PFLCP (n = 22) | *P* |
|---|---|---|---|
| Infection | | | .36 |
| Superficial | 2 (8.69%) | 3 (13.6%) | |
| Deep | 0 | 0 | |
| Local-site pain | 2 (8.69%) | 1 (4.54%) | .24 |
| Nonunion | 1 (4.34%) | 0 | .28 |
| Implant-related | 2 (8.69%) | 0 | .10 |
| Breakage | 1 | 0 | |
| Cut-out | 0 | 0 | |
| Z-effect | 1 | 0 | |
| Unrelated to fracture (eg, bed sore, chest infection, deep vein thrombosis) | 1 (4.34%) | 2 (9.09%) | .19 |
| Revision surgery | 2 (8.69%) | 0 | .10 |
| Shortening (>2 cm) | 2 (8.69%) | 1 (4.54%) | .24 |

Abbreviations: PFLCP, proximal femur locking compression plate; PFN, proximal femur nail.

Table 4. **Comparison of Functional Outcome Scores of Both Groups at Final Follow-Up**

| Outcome Score | Group PFN (n = 23) | Group PFLCP (n = 22) | *P* |
|---|---|---|---|
| **Harris Hip Score** | | | |
| AO fracture type 31.A2 | | | |
| Mean | 83.8 | 81.9 | |
| SD | 8.2 | 7.6 | |
| Range | 80-94 | 76-92 | |
| AO fracture type 31.A3 | | | |
| Mean | 80.0 | 79.1 | |
| SD | 10.6 | 11.6 | |
| Range | 68-92 | 72-92 | |
| Overall | | | .48 |
| Mean | 82.8 | 81.0 | |
| SD | 10.5 | 18.8 | |
| Range | 68-94 | 72-92 | |
| **Palmer and Parker mobility score** | | | |
| Preoperative | | | .26 |
| Mean | 7.4 | 6.9 | |
| SD | 2.11 | 2.54 | |
| 2-year follow-up after surgery | | | .58 |
| Mean | 6.3 | 6.0 | |
| SD | 2.1 | 1.92 | |

Abbreviations: AO, Arbeitsgemeinschaft für Osteosynthesefragen; PFLCP, proximal femur locking compression plate; PFN, proximal femur nail.

some studies[36] have reported comparable times. Moreover, our groups showed no statistically significant differences in operative time, radiologic exposure time, LOS, union rate, or time to union. Our PFN patients had significantly shorter incisions and less time to full weight-bearing.

Wang and colleagues[37] compared the clinical outcomes of DHS, IM fixation (IMF), and PFLCP in the treatment of trochanteric fractures in elderly patients. Incision length and operative time were shorter for the IMF group than for DHS and PFLCP, but there were no significant differences between DHS and PFLCP. Intraoperative blood loss, rehabilitation, and time to healing were less for the IMF and PFLCP groups than for DHS, but there were no significant differences between IMF and PFLCP. Functional recovery was better for the IMF and PFLCP groups than for DHS, and there were significant differences among the 3 groups. There were fewer complications in the PFLCP group than in IMF and DHS.

Yao and colleagues[38] compared reverse LISS and PFN treatment of intertrochanteric fractures and reported no significant differences in operative time, intraoperative blood loss, or functional outcome. Regarding complications, the PFN group had none, and the LISS group had 3 (1 nonunion with locking screw breakage, 2 varus unions).

Haq and colleagues[39] compared PFN and contralateral reverse distal femoral locking compression plate (reverse DFLCP) in the management of unstable intertrochanteric fractures with compromised lateral wall and reported better intraoperative variables, better functional outcomes, and lower failure rates in the PFN group than in the reverse DFLCP group.

Zha and colleagues[22] followed up 110 patients with intertrochanteric and subtrochanteric fractures treated with PFLCP fixation and reported a 100% union rate at 1-year follow-up. Mean operative time was 35.5 minutes, and mean bleeding amount was 150 mL, which included operative blood loss and wound drainage. Mean radiologic exposure time was 5 minutes, and mean incision length was 9 cm. There was 1 case of implant breakage.

Strohm and colleagues[40] reported good results in children with trochanteric fractures treated with conventional locking compression plate.

Brett and colleagues[41] compared blade plate and PFLCP with and without a kickstand screw in a composite femur subtrochanteric fracture gap model. In their biomechanical study, the PFLCP with a kickstand screw provided higher axial but less torsional stiffness than the blade plate. The authors concluded that, though the devices are biomechanically equivalent, PFLCP may allow percutaneous insertion that avoids the potential

morbidity associated with the blade plate's extensile approach.

Our PFN group's mean (SD) time to healing was 4.2 (1.3) months. In other studies, mean healing time for IMF-treated unstable trochanteric fractures was 3 to 4 months. Some authors have reported even longer healing times, up to 17 months,[42] for PFN-treated trochanteric fractures. Many of the studies indicated that gradual weight-bearing was allowed around 6 weeks, when callus formation was adequate.[43] Our treatment protocol differed in that its protected weight-bearing period was prolonged, and controlled weight-bearing was delayed until around 6 weeks, when callus formation was adequate.

The better PFLCP outcomes in our study, relative to most other studies, can be attributed to the relatively younger age of our PFN and PFLCP groups. In a study of 19 patients with trochanteric fractures treated with open reduction and internal fixation using PFLCP, Wirtz and colleagues[44] reported 4 cases of secondary varus collapse, 2 cut-outs of the proximal fragment, and 1 implant failure caused by a broken proximal screw. Eight patients experienced persistent trochanteric pain, and 3 underwent hardware removal.

Streubel and colleagues[45] retrospectively analyzed 29 patients with 30 OTA 31.A3 fractures treated with PFLCP and reported 11 failures (37%) at 20-month follow-up. The most frequent failure mode (5 cases) was varus collapse with screw cut-out. Presence of a kickstand screw and medial cortical reduction were not significantly different between cases that failed and those that did not.

Glassner and Tejwani[46] retrospectively studied 10 patients with trochanteric fractures treated with open reduction and internal fixation with PFLCP. Failure modes were implant fracture (4 cases) and fixation loss (3 cases) resulting from varus collapse and implant cutout.

One of our PFN patients had a lower neck screw back out by 9-month follow-up. As the fracture had consolidated well, the patient underwent screw removal. Another PFN patient had a broken implant and fracture nonunion at 1-year follow-up. Various complications have been reported in the literature,[13,14,47,48] but none occurred in our study. There were no implant-related complications in our PFLCP group, possibly because of the mechanical advantage of 3-dimensional and angular-stable fixation with PFLCP in unstable trochanteric fractures.

Gadegone and Salphale[49] analyzed 100 cases of PFN-treated trochanteric fractures and reported femoral head cut-through (4.8%), intraoperative femoral shaft fracture (0.8%), implant breakage (0.8%), wound-healing impairment (9.7%), and false placement of osteosynthesis materials (0.8%). The 19% reoperation rate in their study mainly involved cephalic screw removal for lateral protrusion at the proximal thigh. Our PFN reoperation rate was 8.7%; none of our PFLCP patients required revision surgery.

Tyllianakis and colleagues[50] analyzed 45 cases of PFN-treated unstable trochanteric fractures and concluded technical or mechanical complications were related more to fracture type, surgical technique, and time to weight-bearing than to the implant itself. Our postoperative wound complication rate was similar to that of other studies.[14,47,51] Regarding functional outcomes, our groups' HHSs were good and comparable at final follow-up, as were their PPM scores.

This study was limited in that it was a small prospective comparative single-center study with a small number of patients. Larger randomized controlled multicenter studies are needed to evaluate and compare both implants in displaced unstable trochanteric femur fractures.

This study found that both PFN and PFLCP were effective treatments for unstable trochanteric femur fractures. PFN is superior to PFLCP only in terms of shorter incisions and shorter time to full weight-bearing. Both devices can be used in unstable trochanteric fractures, and both have good functional outcomes and acceptable complication rates.

Dr. Singh is Assistant Professor, Department of Orthopedics, Mayo Institute of Medical Sciences, Barabanki, India. Dr. G. R. is Assistant Professor, Department of Orthopedics, Shree Mokambika Institute of Medical Sciences, Kanyakumari, India. Dr. Srivastava and Dr. Narsaria are Residents, Mayo Institute of Medical Sciences, Barabanki, India.

Address correspondence to: Ashutosh Kumar Singh, 2/38, Vinamra Khand, Gomti Nagar, Lucknow, Uttar Pradesh, India (tel, 919-616-315-971; email, ashu.ortho@gmail.com).

*Am J Orthop*. 2017;46(2):E116-E123. 

## References

1. Cummings SR, Rubin SM, Black D. The future of hip fractures in the United States. Numbers, costs, and potential effects of postmenopausal estrogen. *Clin Orthop Relat Res*. 1990;(252):163-166.
2. Kyle RF, Cabanela ME, Russell TA, et al. Fractures of the proximal part of the femur. *Instr Course Lect*. 1995;44:227-253.

3. Koval KJ, Aharonoff GB, Rokito AS, Lyon T, Zuckerman JD. Patients with femoral neck and intertrochanteric fractures. Are they the same? *Clin Orthop Relat Res*. 1996;(330):166-172.
4. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma*. 2007;21(10 suppl):S1-S133.
5. Lindskog D, Baumgaertner MR. Unstable intertrochanteric hip fractures in the elderly. *J Am Acad Orthop Surg*. 2004;12(3):179-190.
6. Kokoroghiannis C, Aktselis I, Deligeorgis A, Fragkomichalos E, Papadimas D, Pappadas I. Evolving concepts of stability and intramedullary fixation of intertrochanteric fractures—a review. *Injury*. 2012;43(6):686-693.
7. Larsson S, Friberg S, Hansson LI. Trochanteric fractures. Influence of reduction and implant position on impaction and complications. *Clin Orthop Relat Res*. 1990;(259):130-139.
8. Simpson AH, Varty K, Dodd CA. Sliding hip screws: modes of failure. *Injury*. 1989;20(4):227-231.
9. Rha JD, Kim YH, Yoon SI, Park TS, Lee MH. Factors affecting sliding of the lag screw in intertrochanteric fractures. *Int Orthop*. 1993;17(5):320-324.
10. Baixauli F, Vicent V, Baixauli E, et al. A reinforced rigid fixation device for unstable intertrochanteric fractures. *Clin Orthop Relat Res*. 1999;(361):205-215.
11. Harrington P, Nihal A, Singhania AK, Howell FR. Intramedullary hip screw versus sliding hip screw for unstable intertrochanteric femoral fractures in the elderly. *Injury*. 2002;33(1):23-28.
12. Parker MJ, Handoll HH. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. *Cochrane Database Syst Rev*. 2010;(9):CD000093.
13. Pajarinen J, Lindahl J, Michelsson O, Savolainen V, Hirvensalo E. Pertrochanteric femoral fractures treated with a dynamic hip screw or a proximal femoral nail. A randomised study comparing postoperative rehabilitation. *J Bone Joint Surg Br*. 2005;87(1):76-81.
14. Papasimos S, Koutsojannis CM, Panagopoulos A, Megas P, Lambiris E. A randomised comparison of AMBI, TGN and PFN for treatment of unstable trochanteric fractures. *Arch Orthop Trauma Surg*. 2005;125(7):462-468.
15. Saudan M, Lübbeke A, Sadowski C, Riand N, Stern R, Hoffmeyer P. Pertrochanteric fractures: is there an advantage to an intramedullary nail? A randomized, prospective study of 206 patients comparing the dynamic hip screw and proximal femoral nail. *J Orthop Trauma*. 2002;16(6):386-393.
16. Schipper IB, Steyerberg EW, Castelein RM, et al. Treatment of unstable trochanteric fractures. Randomised comparison of the gamma nail and the proximal femoral nail. *J Bone Joint Surg Br*. 2004;86(1):86-94.
17. Gardenbroek TJ, Segers MJ, Simmermacher RK, Hammacher ER. The proximal femur nail antirotation: an identifiable improvement in the treatment of unstable pertrochanteric fractures? *J Trauma*. 2011;71(1):169-174.
18. Egol KA, Chang EY, Cvitkovic J, Kummer FJ, Koval KJ. Mismatch of current intramedullary nails with the anterior bow of the femur. *J Orthop Trauma*. 2004;18(7):410-415.
19. Werner-Tutschku W, Lajtai G, Schmiedhuber G, Lang T, Pirkl C, Orthner E. Intra- and perioperative complications in the stabilization of per- and subtrochanteric femoral fractures by means of PFN [in German]. *Unfallchirurg*. 2002;105(10):881-885.
20. Ma CH, Tu YK, Yu SW, Yen CY, Yeh JH, Wu CH. Reverse LISS plates for unstable proximal femoral fractures. *Injury*. 2010;41(8):827-833.
21. Pryce Lewis JR, Ashcroft GP. Reverse LISS plating for proximal segmental femoral fractures in the polytrauma patient: a case report. *Injury*. 2007;38(2):235-239.
22. Zha GC, Chen ZL, Qi XB, Sun JY. Treatment of pertrochanteric fractures with a proximal femur locking compression plate. *Injury*. 2011;42(11):1294-1299.
23. Oh CW, Kim JJ, Byun YS, et al. Minimally invasive plate osteosynthesis of subtrochanteric femur fractures with a locking plate: a prospective series of 20 fractures. *Arch Orthop Trauma Surg*. 2009;129(12):1659-1665.
24. American Society of Anesthesiologists new classification of physical status. *Anesthesiology*. 1963;24:111-114.
25. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis*. 1957;16(4):494-502.
26. Vidyadhara S, Rao SK. One and two femoral neck screws with intramedullary nails for unstable trochanteric fractures of femur in the elderly—randomised clinical trial. *Injury*. 2007;38(7):806-814.
27. Parker MJ, Palmer CR. A new mobility score for predicting mortality after hip fracture. *J Bone Joint Surg Br*. 1993;75(5):797-798.
28. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am*. 1969;51(4):737-755.
29. Sadowski C, Lübbeke A, Saudan M, Riand N, Stern R, Hoffmeyer P. Treatment of reverse oblique and transverse intertrochanteric fractures with use of an intramedullary nail or a 95 degrees screw-plate: a prospective, randomized study. *J Bone Joint Surg Am*. 2002;84(3):372-381.
30. Suckel AA, Dietz K, Wuelker N, Helwig P. Evaluation of complications of three different types of proximal extra-articular femur fractures: differences in complications, age, sex and surviving rates. *Int Orthop*. 2007;31(5):689-695.
31. Nuber S, Schönweiss T, Rüter A. Stabilisation of unstable trochanteric femoral fractures. Dynamic hip screw (DHS) with trochanteric stabilisation plate vs. proximal femur nail (PFN) [in German]. *Unfallchirurg*. 2003;106(1):39-47.
32. Klinger HM, Baums MH, Eckert M, Neugebauer R. A comparative study of unstable per- and intertrochanteric femoral fractures treated with dynamic hip screw (DHS) and trochanteric butt-press plate vs. proximal femoral nail (PFN) [in German]. *Zentralbl Chir*. 2005;130(4):301-306.
33. Bridle SH, Patel AD, Bircher M, Calvert PT. Fixation of intertrochanteric fractures of the femur. A randomised prospective comparison of the gamma nail and the dynamic hip screw. *J Bone Joint Surg Br*. 1991;73(2):330-334.
34. Utrilla AL, Reig JS, Muñoz FM, Tufanisco CB. Trochanteric gamma nail and compression hip screw for trochanteric fractures: a randomized, prospective, comparative study in 210 elderly patients with a new design of the gamma nail. *J Orthop Trauma*. 2005;19(4):229-233.
35. Lenich A, Mayr E, Rüter A, Möckl CH, Füchtmeier B. First results with the trochanter fixation nail (TFN): a report on 120 cases. *Arch Orthop Trauma Surg*. 2006;126(10):706-712.
36. Tao R, Lu Y, Xu H, Zhou ZY, Wang YH, Liu F. Internal fixation of intertrochanteric hip fractures: a clinical comparison of two implant designs. *ScientificWorldJournal*. 2013;2013:834825.
37. Wang Y, Yang YY, Yu ZH, Li CQ, Wu YS, Zheng XX. Comparative study of intertrochanteric fractures treated with proximal femur locking compress plate in aged [in Chinese]. *Zhongguo Gu Shang*. 2011;24(5):370-373.
38. Yao C, Zhang CQ, Jin DX, Chen YF. Early results of reverse less invasive stabilization system plating in treating elderly intertrochanteric fractures: a prospective study compared to proximal femoral nail. *Chin Med J (Engl)*. 2011;124(14):2150-2157.
39. Haq RU, Manhas V, Pankaj A, Srivastava A, Dhammi IK, Jain AK. Proximal femoral nails compared with reverse distal femoral locking plates in intertrochanteric fractures with a compromised lateral wall; a randomised controlled trial. *Int Orthop*. 2014;38(7):1443-1449.
40. Strohm PC, Schmal H, Kuminack K, Reising K, Südkamp NP. Intertrochanteric femoral fractures in children [in German]. *Unfallchirurg*. 2006;109(5):425-430.
41. Brett CD, Lee MA, Khalafi AK, Hazelwood SJ. A comparison

of percutaneous versus traditional open plate fixation in a subtrochanteric fracture gap model. In: Proceedings of the Annual Meeting of the Orthopaedic Trauma Association (OTA); October 5-7, 2006; Phoenix, AZ. Basic science poster 71 (abstract).
42. Park SY, Yang KH, Yoo JH, Yoon HK, Park HW. The treatment of reverse obliquity intertrochanteric fractures with the intramedullary hip nail. *J Trauma*. 2008;65(4):852-857.
43. Habernek H, Wallner T, Aschauer E, Schmid L. Comparison of Ender nails, dynamic hip screws, and gamma nails in the treatment of peritrochanteric femoral fractures. *Orthopedics*. 2000;23(2):121-127.
44. Wirtz C, Abbassi F, Evangelopoulos DS, Kohl S, Siebenrock KA, Krüger A. High failure rate of trochanteric fracture osteosynthesis with proximal femoral locking compression plate. *Injury*. 2013;44(6):751-756.
45. Streubel PN, Moustoukas MJ, Obremskey WT. Mechanical failure after locking plate fixation of unstable intertrochanteric femur fractures. *J Orthop Trauma*. 2013;27(1):22-28.
46. Glassner PJ, Tejwani NC. Failure of proximal femoral locking compression plate: a case series. *J Orthop Trauma*. 2011;25(2):76-83.
47. Ekström W, Karlsson-Thur C, Larsson S, Ragnarsson B, Alberts KA. Functional outcome in treatment of unstable trochanteric and subtrochanteric fractures with the proximal femoral nail and the Medoff sliding plate. *J Orthop Trauma*. 2007;21(1):18-25.
48. Boldin C, Seibert FJ, Fankhauser F, Peicha G, Grechenig W, Szyszkowitz R. The proximal femoral nail (PFN)—a minimal invasive treatment of unstable proximal femoral fractures: a prospective study of 55 patients with a follow-up of 15 months. *Acta Orthop Scand*. 2003;74(1):53-58.
49. Gadegone WM, Salphale YS. Proximal femoral nail—an analysis of 100 cases of proximal femoral fractures with an average follow up of 1 year. *Int Orthop*. 2007;31(3):403-408.
50. Tyllianakis M, Panagopoulos A, Papadopoulos A, Papasimos S, Mousafiris K. Treatment of extracapsular hip fractures with the proximal femoral nail (PFN): long term results in 45 patients. *Acta Orthop Belg*. 2004;70(5):444-454.
51. Morihara T, Arai Y, Tokugawa S, Fujita S, Chatani K, Kubo T. Proximal femoral nail for treatment of trochanteric femoral fractures. *J Orthop Surg (Hong Kong)*. 2007;15(3):273-277.