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Radiographic and functional results of osteosynthesis using the proximal femoral nail antirotation (PFNA) in the treatment of unstable intertrochanteric femoral fractures

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Objectives: We evaluated the radiographic and functional results of the proximal femoral nail antirotation (PFNA) system in patients with unstable intertrochanteric femoral fractures.

Methods: The study included 45 patients (25 women, 20 men; mean age 72 years; range 27 to 97 years) who underwent osteosynthesis using the PFNA for unstable intertrochanteric femoral fractures. The fractures were in the right hip in 25 patients, and in the left hip in 20 patients. The fractures were classified according to the AO system. One patient had an open fracture due to firearm injury (Gustilo-Anderson 3A). The patients underwent surgery within a mean of eight days (range 2 to 21 days) from injury. The mean hospital stay was 13.5 days (range 4 to 25 days). Closed reduction was achieved in all the patients. The results were assessed clinically and radiographically. The neck-shaft angle of the femur (collodiaphysial angle) and the tip-apex distance were measured. The position of the helical screw within the femoral head was determined using the method of Cleveland and Bosworth. Clinical evaluation was made using the Harris hip score. Perioperative and postoperative complications were recorded. The mean follow-up period was 17.3 months (range 6 to 23 months).

Results: The mean operation time was 37.8 min (range 22 to 118 min) and the mean blood loss was 225 ml (range 150 to 450 ml). During surgery, femoral shaft fracture occurred in three patients, and greater trochanter fracture occurred in nine patients. Union was obtained in all the patients. Reduction was poor in four patients (8.9%), acceptable in seven patients (15.6%), and good in 34 patients (75.6%). The mean collodiaphysial angle was 136.7° (range 125° to 148°). The tip-apex distance was <25 mm in 36 patients (80%), and ≥25 mm in nine patients (20%). The position of the helical screw in the femoral head was appropriate in 38 patients (84.4%). Postoperative complications included secondary varus (n=2, 4.4%), calcification at the tip of the greater trochanter (n=7, 15.5%), sensitivity over the fascia lata (n=7), medial thigh pain (n=11, 24.4%), and screw cut-out (n=1, 2.2%). Nine patients developed femoral shortness (mean 9.4 mm; range 8 to 13 mm). Screws showed lateral displacement in five patients (11.1%), which was less than 5 mm in four patients. Secondary surgery was required in four patients (8.9%). The mean Harris hip score was 77.8. Harris hip scores were very good in 11 patients (24.4%), good in 19 patients (42.2%), moderate in nine patients (20%), and poor in six patients (13.3%).

Conclusion: Due to advantages of high union rate, early postoperative mobilization, and short operation time, PFNA osteosynthesis is the method of choice for surgical treatment of unstable intertrochanteric femoral fractures.

Key words: Bone nails; femoral neck fractures/surgery; fracture fixation, intramedullary/instrumentation/methods; hip fractures/surgery.

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Intertrochanteric fractures have a high union rate owing to extracapsular and spongious structure. However, with conservative treatment, high mortality and morbidity rates have been reported especially in elderly patients due to long bed stay. These patients should be mobilized as soon as possible to prevent complications associated with immobilization. Therefore, a surgical technique allowing anatomic alignment and a stable fixation with early mobilization is accepted as the standard approach for intertrochanteric fractures.[1,2]

Most of the internal fixation methods used in stable intertrochanteric fractures allow early mobilization. However, despite many methods, there has been no gold-standard treatment for unstable fractures. Recently, intramedullary fixation devices have received particular attention with their biomechanical advantages and ease of application.

In this study, we aimed to assess the results of osteosynthesis using the proximal femoral nail-antirotation system (PFNA, Synthes, Switzerland), developed by the AO/ASIF group in 2004, in the treatment of unstable intertrochanteric femoral fractures.

Patients and methods

From June 2005 to April 2007, 49 patients underwent osteosynthesis using the PFNA nail for unstable intertrochanteric femoral fractures. Of these, 45 patients (25 women, 20 men; mean age 72 years; range 27 to 97 years) with an adequate follow-up time was included in the study. Four patients who died in the postoperative sixth month were not evaluated. The fractures were in the right hip in 25 patients, and in the left hip in 20 patients. Etiologies of fractures were as follows: firearm injury (n=1), fall from height (n=3), traffic accidents (n=7), and simple fall (n=34).

Table 1
AO classification of the fractures

Fracture type		n	%
A2	1	7	15.6
	2	12	26.7
	3	11	24.4
A3	1	3	6.7
	2	3	6.7
	3	9	20.0

Preoperatively, the fractures were classified according to the AO classification (Table 1). One patient had an open fracture due to firearm injury (Gustilo-Anderson type 3A).

The patients underwent osteosynthesis using the PFNA nail within a mean of eight days (range 2 to 21 days) from injury. The mean hospital stay was 13.5 days (range 4 to 25 days). The reasons of delayed surgery included late presentation to the hospital, availability problems, or time needed to resolve the internal problems.

We used spinal anesthesia in 17 patients (37.8%), and general anesthesia in 28 patients (62.2%). All operations were performed using the traction table and fluoroscopy and after achievement of closed reduction. All patients received prophylactic antibiotic therapy and prophylaxis for thromboembolism.

Based on the intraoperative stability and radiographic findings, 23 patients (51.1%) were allowed partial weight-bearing with two crutches, and 18 patients (40%) were allowed full weight-bearing after the operation. Weight-bearing was not allowed for six weeks in four patients, due to an intraoperative femoral diaphyseal fracture in three (6.7%), and to poor reduction in one (2.2%).

After the visits at 6 and 12 postoperative weeks, control visits were scheduled every three months in the first year, and every six months in the second year, at which time clinical and radiographic examinations were made . Clinical evaluation was made using the Harris hip scoring system which considers pain,

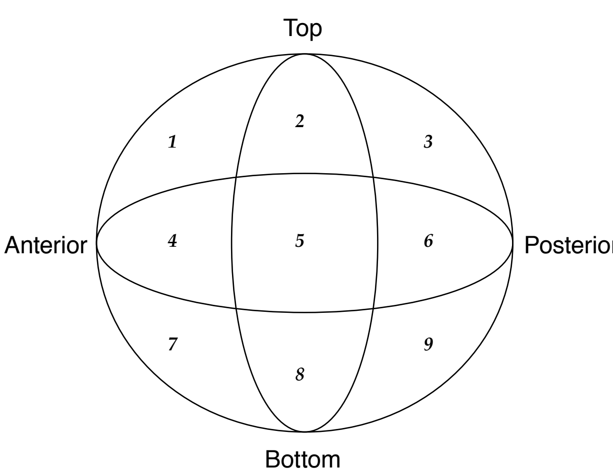

Fig. 1. Position of the helical screw within the femoral head; the femoral head is divided into nine zones and enumerated.

Table 2

Postoperative evaluation of reduction[6]

I	Alignment	Anteroposterior plane: Normal collodiaphysial angle or slight valgus Lateral plane: Angulation less than 20° degrees
II	Displacement of main fragments	More than 80% overlapping in both planes Shortening less than 5 mm
Result		
	Good	Meets both criteria
	Acceptable	Meets only one criterion
	Poor	Does not meet both criteria

walking capacity and physical examination findings.[3] Radiographic evaluations included union, calcification in the greater trochanter, cortical thickening at the distal locking site, cut-out of the helical screw in the femoral head, lateral migration of the helical screw (telescoping), and shortening of the femoral neck length. The neck-shaft angle of the femur (collodiaphysial angle) and the tip-apex distance (distance from the tip of the implant to the apex of the femoral head) were calculated.[4] The position of the helical screw within the femoral head was determined using the method of Cleveland and Bosworth (Fig. 1).[5] In this method, the femoral head is divided into nine zones on anteroposterior and lateral radiographs and the tip of the implant is located. Postoperative evaluation of reduction was made using the Baumgaertner's criteria modified by Fogagnolo et al (Table 2).[6] The mean follow-up period was 17.3 months (range 6 to 23 months).

Results

At the end of the follow-up period, of 49 patients who underwent osteosynthesis with the PFNA nail, six were dead, one died in the first postoperative month, three in six months, and two in the first year. Mortality rate within the first year was 12.2%. Four patients who died within the first six-months were not included in the study.

Evaluation of the quality of reduction on postoperative radiographs showed that four patients (8.9%) had poor, seven patients (15.6%) had acceptable, and 34 patients (75.6%) had good reduction.

The mean blood loss was 225 ml (range 150 to 450 ml). One patient required intraoperative transfusion and five patients required postoperative transfusion of only one unit of blood. The mean operation time was 37.8 min (range 22 to 118 min). In early cases, the duration of operations was longer than the mean operation time; after the first 20 cases, however, the operation time decreased to 30 minutes or below.

The mean collodiaphysial angle measured on postoperative radiographs was 136.7° (range 125° to 148°). On final radiographs, secondary varus was detected in two patients (4.4%). In one patient with cut-out of the helical screw in the femoral head, the collodiaphysial angle decreased from 125° to 118°. In the other patient, the helical screw showed 15-mm lateral migration and the collodiaphysial angle decreased from 134° to 130°. The Harris hip score was poor in these two patients. Secondary varus development was not observed in the remaining patients.

The tip-apex distance was <25 mm in 36 patients (80%), and ≥25 mm in nine patients (20%). In the latter, screw cut-out in the femoral head was seen in only one patient. According to the zones described by Cleveland and Bosworth,[5] the screw was placed

Table 3

Distribution of complications

Complication	n	%
Intraoperative		
Fracture of the greater trochanter	9	20.0
Distal extension of the proximal fracture	2	4.4
Femoral shaft fracture distal to the nail	1	2.2
Early postoperative		
Pressure ulcers	2	4.4
Superficial wound with serous discharge	1	2.2
Late postoperative		
Deep soft tissue infection	1	2.2
Cut-out	1	2.2
Calcification at the tip of the greater trochanter	7	15.5
Femoral shortness	9	20.0
Sensitivity over the fascia lata	7	15.5
Pain at the medial aspect of the femur	11	24.4
Lateral migration of the helical screw (telescope effect)	5	11.1
Secondary varus development	2	4.4

Table 4
The relationship between the fracture type and Harris hip score

			Harris hip score							
			Very good		Good		Moderate		Poor	
Fracture type	n	%	n	%	n	%	n	%	n	%
A2	30	66.7	8	26.7	13	43.3	5	16.7	4	13.3
A3	15	33.3	3	40.0	6	20.0	4	26.7	2	13.3

in zone 2 in this patient. Thirty-eight screws (84.4%) were placed in an ideal and secure zone.

Complications were grouped in three periods: intraoperative, early postoperative, and late postoperative (Table 3). Femoral shaft fracture occurred in three patients during insertion of the nail into the medulla, which was localized at the distal tip of the nail in one patient, and extended distally along the proximal fracture line in two patients. The results were moderate in two patients, and good in one patient. During surgery, fracture of the greater trochanter occurred in nine patients. These fractures showed successful union during the follow-up.

In the early postoperative period, two patients experienced sacral pressure sores that healed without debridement. One patient developed a superficial wound problem with serous discharge that healed on the fourth day.

In the late postoperative period, seven patients (15.5%) showed calcification at the tip of the greater trochanter. There was tenderness over the fascia lata in seven patients (15.5%). Eleven patients (24.4%) in whom the nail extended to the distal femoral cortex had pain at the medial aspect of the femur. Nine patients developed femoral shortness (mean 9.4 mm; range 8 to 13 mm); this condition was thought to be secondary to impaction and varus development in the cervicotrochanteric region of the femur and did not cause any complaints. Screws showed lateral displacement in five patients (11.1%). Displacement was less than 5 mm in four patients. In one patient, the helical screw was displaced 15 mm to the lateral.

Secondary surgery was required in four patients (8.9%). In three patients, the blades were removed after union to relieve tenderness over the fascia lata due to long helical blade. One of these patients also had late deep soft tissue infection. In one patient, fracture of the greater trochanter extended to the femoral shaft and the reduction was found to be poor. Four days after the initial operation, open reduction was performed and the fracture was fixed using a cerclage wire and repeated instrumentation. At the end of the third month, sufficient union was achieved in these patients.

In clinical evaluations, the mean Harris hip score was 77.8. Harris hip scores were very good in 11 patients (24.4%), good in 19 patients (42.2%), moderate in nine patients (20%), and poor in six patients (13.3%). Very good and good results accounted for 66.7%. Changes in the hip score in relation to the type of fractures and the quality of reduction are shown in Table 4 and Table 5.

In seven patients with sensitivity over the fascia lata, the results were rated as moderate in two and poor in five. In 11 patients with femoral pain, the results were very good or good in five, moderate in two, and poor in four patients. In nine patients whose tip-apex distance was ≥25 mm, the results were poor in two, moderate in two, and good or very good in five. Two patients who developed secondary varus had a poor outcome. In seven patients with calcification at the tip of the greater trochanter, the results were good or very good in four, moderate in one, and poor in two. The findings of patients with a poor Harris hip score are given in Table 6.

Table 5
The relationship between the reduction quality and Harris hip score

	Harris hip score		
Reduction	Very good/good	Moderate	Poor
Good	26	5	3
Acceptable	4	2	1
Unacceptable	–	2	2

Table 6
Findings of patients with a poor Harris hip score

Findings	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Fascia lata pain	+	+	+	–	+	–
Fracture type	A2.3	A2.2	A2.1	A3.1	A2.3	A3.2
Reduction	Good	Good	Good	Bad	Bad	Fair
Tip-apex distance (mm)	<25	<25	<25	>25	<25	>25
Zone	5	5	5	2	5	3
Secondary varus (°)	–	–	–	–	4	–
Femoral pain	+	–	+	–	+	+
Femoral shortness (mm)	–	–	–	15	–	-
Femoral neck shortness (mm)	–	3	–	8	3	4
Telescope effect (mm)	–	–	–	–	15	–
Calcification of the trochanter	+	–	+	–	–	–
Cut-out	–	–	–	+	–	–

Discussion

Advances in the treatment of chronic diseases and improvements in living standards have resulted in a considerable increase in life expectancy of individuals. However, as the quality of bone decreases with age, the prevalence of hip fractures and particularly intertrochanteric fractures increases. These patients usually have additional systemic diseases and require prolonged hospital stay after fracture occurrence, making them susceptible to many complications that adversely affect prognosis and increase mortality, such as deep vein thrombosis, pulmonary embolism, pneumonia, uremia, urinary tract infections, and pressure ulcers. For this reason, there is general consensus in the literature that the primary goal of treatment should be to obtain a stable fixation of the fracture that will allow early mobilization.[1,2,6,7] Treatment methods include osteosynthesis using dynamic hip nails and intramedullary fixation devices and, in selection cases, arthroplasty.[8]

When the hip joint is loaded, forces are transferred from the femoral head to the femoral shaft particularly via the posteromedial cortex. Stable fractures are those in which the posteromedial cortex remains intact and the calcar femorale is not affected. Stably reduced fractures are Comminuted fractures in which posteromedial continuity is maintained following reduction are also stable fractures. Unstable fractures are comminuted fractures in which the continuity of the posteromedial cortex is disrupted or cannot be re-established by reduction. This also applies to intertrochanteric fractures with subtrochanteric extension. Reverse obliquity fractures, even though the posteromedial cortex is intact, are accepted as unstable due to vectorial relationship of the forces applied on the fracture, because these forces displace the femoral shaft medial to the proximal fragment. Unstable fractures have a tendency to outward rotation and varus angulation when the hip is under load, leading to limb shortening and insufficiency of the abductor mechanism.[9,10]

Sliding and compression dynamic hip screws are accepted as the gold standard in the surgical treatment of stable intertrochanteric fractures.[11-13] The advantages making dynamic hip screws the first choice in stable fractures do not offer similar success rates in unstable fractures. In unstable fractures, excessive sliding of the implant due to telescoping dynamic hip screw and medialization of the femoral shaft more than one-third of the diameter of the femur result in fixation failure.[14,15] Steinberg et al.[16] reported that sliding of the implant exceeding 15 mm was associated with fixation failure. Wolfgang et al.[17] reported mechanical complication rates as 9% for stable fractures and 19% for unstable fractures in intertrochanteric fractures treated with sliding screw plates. The most frequent cause of fixation failure is cut-out of the neck screw in the femoral head.[18] Simpson et al.[19] listed the causes of fixation failure in intertrochanteric fractures in the following order: cut-out of the screw from the femoral head, pull-out of the plate from the lateral cortex together with the screws, and plate break. In our study, cut-out of the helical blade through the femoral head was observed in only one patient. Although the overall complication rate in our patients was high, all the fractures were unstable and the majority of complications were not so severe to affect the final results and occurred during the learning curve.

The buttress effect of the lateral cortex prevents excessive sliding of the dynamic hip screw due to telescope effect. Gotfried[20] reported that the fractures of 24 subjects which were preoperatively classified as type 31.A2 turned to type 32.A3 fractures postoperatively due to lateral cortex fracture. On radiographic examinations, he noticed that the head-neck fragment was displaced into the varus position, the femoral shaft was medialized, and the screw showed significant lateral sliding in all patients. He attributed fracture of the lateral cortex to weakening of the bone during the use of a lateral cortex drill of 16 mm diameter for the placement of the sliding screw.[20] In our study, fracture of the greater trochanter with lateral extension occurred in nine patients during surgery. These fractures were thought to develop from incorrect determination of the insertion site of the nail disrupting the fracture line and insufficient drilling. We observed that this complication could be avoided by careful determination of the insertion site and sufficient drilling. Preservation of the stability of osteosynthesis in these patients without additional fixation shows biomechanical advantages of intramedullary osteosynthesis.

Failure of dynamic hip screws in unstable fractures may be as high as 56% in special conditions such as reverse obliquity fractures.[21] As the course of the sliding screw runs parallel to the fracture line in reverse obliquity fractures, the dynamic hip screw acts like a fixed-angle plate, increasing the risk for cut-out.[12,22] In addition, the femoral shaft is displaced medially by the pull of the adductor muscles.[21,23] In our study, nine patients had (20%) reverse obliquity fractures. Clinical results of these patients were similar to those of the remaining patients. This suggests that intramedullary fixation can be safely used in reverse obliquity fractures.

Femoral shaft fracture is a complication associated with the use of intramedullary hip nails, and is more frequent with the use of the Gamma nail.[24] Banan et al.[11] reported two cases (2/46), Fogagnolo et al.[6] reported one case (1/47) of femoral diaphyseal fractures that occurred distal to the nail. In our study, undisplaced femoral shaft fractures occurred in three cases, one was localized to the distal tip of the nail, two were seen as distal extension of the proximal fracture line. In none of these patients, the fracture line extended to the distal locking screw of the nail. We observed that this condition did not affect the clinical results; however, it would be convenient to avoid this complication especially in short-statured patients.

Extension of the nail to the distal femoral cortex was not associated with fracture occurrence, but presented as pain at the medial aspect of the femur. This condition was encountered in 11 patients. To avoid this complication, use of PFNA nails of smaller dimensions may be appropriate. For this, the PFNA XS (extra small) nail has been designed based on racial physical characteristics.[25]

The PFNA system was developed by the AO/ASIF in 2004. The main difference from other nails is that it consists of a single proximal neck screw designed as a helical blade. The use of a single screw prevents the Z-effect phenomenon. The wide surface area and special design of the helical blade enables insertion by impaction even in osteoporotic bones. The amount of bone removed during insertion is less compared with standard screws. A single helical blade provides the same rotational stability obtained by two screws.[26,27] As the helical blade is inserted by the drill and tap method, rotational forces are avoided during insertion of the screw into the proximal fragment. We did not observe the Z-effect phenomenon in our patients. Secondary varus development was seen in only two patients and the initial reduction was preserved in the remaining patients. We think that the helical blade contributes to a stable fixation provided by intramedullary nails. It has been demonstrated that, compared with screws, intramedullary nail fixation with a helical blade provides a stronger fixation and rotational control of the femoral head and prevents varus collapse.[28,29]

Insertion of the hip screw in a wrong position or inappropriate selection of screw length may result in cut-out of the screw in the femoral head.[25,30] The incidence of cut-out may be as high as 10%.[6,31] Following PFNA applications, the cut-out rate was reported as 3.6% by Mereddy et al.,[28] and 2% by Takigami et al.[25] In our study, this complication was seen in only one patient (2.2%). The tip-apex distance was greater than 25 mm and the screw was placed in zone 2 in this patient.

When a new implant is used, the rate of complications is higher in early groups of patients during the learning curve.[32] In our study, the duration of operation was longer than the mean operation time and the incidence of complications was higher in early cases. Nonetheless, the majority of complications did not have an adverse effect on the stability of fixation and functional results. The main reason of poor results obtained in the treatment of intertrochanteric fractures using osteosynthesis seems to be reduction losses occurring in the postoperative period.[33-38] In our study, poor functional results were mainly associated with the sensitivity over the fascia lata. Secondary surgery was required in only four patients, three of whom developed fascia lata irritation due to long screw selection. The other patient underwent open reduction and nail revision due to postoperative extension of the greater trochanter fracture to the femoral shaft and poor intraoperative reduction. Even under loading, the helical blade maintained the reduction that was achieved during surgery till the union of the fracture. Every new implant requires a learning period for correct application. When the learning period is over, we think that correct application of intramedullary nails is easier than extramedullary implants in the treatment of unstable intertrochanteric fractures and that intramedullary implants offer more advantages in case of potential complications such as lateral cortex fracture during surgery. Most of the complications associated with intramedullary implants can be tolerated within the system.

The results of our study show that this new implant offers biomechanical advantages of intramedullary nails with significant contribution of the helical screw to a strong fixation and can be safely used in the treatment of unstable intertrochanteric fractures.

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