



Factors Associated with Femoral Neck Shortening After Closed or Open Reduction and Screw Fixation

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Abstract

Purpose This study aimed to evaluate the incidence of femoral neck shortening (FNS) after the treatment of displaced and non-displaced femoral neck fractures with closed or open reduction internal fixation, and determine the independent factors associated with this condition.

Method The study included 81 patients who underwent internal fixation by closed or open reduction with multiple screws between 2013 and 2018 due to femoral neck fracture (FNF) and were followed up for at least 1 year. Patients were divided into two groups as with and without FNS. The patient, fracture, and surgical parameters compared between the two groups, and the factors affecting development of FNS were investigated.

Results Internal fixation was applied by closed reduction in 56 patients (69.1%) and open in 25 (30.9%). FNS was detected in 41 patients (50.6%), with the mean shortening 6.3 ± 6.4 mm. Fracture union achieved in 72 patients (89%). The mean time to fracture union was 4.3 ± 2.3 months.

No statistically significant relationship found between FNS and the parameters of gender, age, smoking, reduction type, number, type and orientation of screws, Singh index, and Garden fix index ($p > 0.05$).

However, there was significant difference between two groups regarding energy of the fracture, fragmentation, coronal angulation, Garden type, and fixation with medial buttress plate ($p < 0.05$).

Conclusion FNS is an expected condition in FNF fixed by screws. Patients with high-energy traumas and advanced Garden types are more likely to have FNS. The use of medial plate may be effective in preventing FNS.

Keywords Femoral neck fracture · Shortening · Malunion · Medial buttress plate

Introduction

The most important cause of hip fractures is low-energy trauma such as simple falls in the elderly population, whereas femoral neck fractures in the young population are mostly caused by high-energy trauma such as traffic accidents and falls from a high [1, 2]. Nowadays, closed or open reduction and internal fixation (cannulated screw \pm medial support plate, dynamic hip screw) are prioritized in young patients with femoral neck fractures, while treatment options may change at older ages depending on the patient's condition and bone quality, as well as the surgeon's experience [3–5].

Cannulated and dynamic hip screw fixations allow the fracture fragments to slide along the implant and compress the fracture line in the axial plane under load. However, these fixation methods can cause femoral neck shortening (FNS), resulting in malunion and changes in the moment

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arms of the hip abductors, eventually leading to functional limitation [6–8].

There are several studies in the literature investigating the incidence and amount of femoral neck shortening [9, 10]. Age, weight, and Pauwel's class were associated with femoral neck shortening [11]. In addition, the use of fully threaded screws and parallel configuration have been shown to reduce the risk of developing FNS [12, 13].

Although several studies have reported the incidence and association between femoral neck shortening and clinical outcomes [9–13], to our knowledge, independent risk factors associated with femoral neck shortening have not been investigated in the literature.

This study aimed to evaluate the incidence of FNS after treatment of displaced and non-displaced femoral neck fractures with closed or open internal reduction and to determine the independent factors associated with this condition.

Materials and Methods

Of 530 patients who underwent femoral neck fracture surgery between 2013 and 2019 by three experienced trauma surgeons, 81 who met inclusion and exclusion criteria were retrospectively evaluated. The study was approved by the institutional ethics committee.

Exclusion criteria were severe neurological disease that could interfere with the rehabilitation process (dementia, Parkinson's disease, etc.), mental retardation, pathological fractures (including osteoporotic fractures), history of previous hip surgery, incomplete clinical and radiological follow-up, ipsilateral femoral shaft fractures, and use of sliding screws and hip arthroplasty in treatment. Patients with a diagnosis of isolated intracapsular femoral neck fracture treated with an inverted triangular configuration and/or primary osteosynthesis with a medial support plate and who had follow-up data of at least 1 year were included in the study.

Clinical and radiologic follow-up of patients was performed at the second and sixth postoperative weeks, at the third, sixth, and twelfth months, and annually thereafter. Radiological evaluations were performed on anterior posterior (AP) of the pelvis and hip and lateral hip radiographs. Age, gender, trauma type (high/low energy), reduction type (open/closed), number of cannulated screws used, type of cannulated screw (distal/fully threaded), use of a medial support plate, and smoking status of patients were evaluated for their effect on FNS. Time to the bony union, failure of union, and development of avascular necrosis was examined, and patients with and without FNS were compared with respect to these parameters (Tables 1, 2).

In the early postoperative radiological evaluation, screw orientation (parallel, convergent, or divergent), neck-shaft

angle, femoral offset (vertical or transverse), and Garden's Alignment Index [14] were recorded and evaluated for their influence on the FNS. In addition, the effects of fracture angulation (coronal/sagittal), fracture type (the Garden classification [15] and the Pauwels classification [16] and the Singh index [17] of the patients on FNS were investigated (Table 1).

Evaluation of FNS

Quantitative evaluation of femoral neck collapse was determined according to the method described by Zlowodzki et al. [4]. Postoperative radiographs of the first pelvis AP and the 12th-month pelvis AP were evaluated by a blinded and experienced musculoskeletal radiologist twice a month. Regarding interobserver reliability, two measurements were taken on different days and the difference between the measurements was examined. FNS was defined as 2 mm or more shortening to minimize measurement error. Images were calibrated based on the implant diameter used. Changes were measured in pixels and converted to true size (millimeters) (Figure). These data were then used to calculate femoral neck collapse in mm and input into the statistical analysis software.

Surgical Technique

Manual traction fluoroscopy images were obtained of all patients in the operating room before the surgical procedure. The cases that achieved adequate closed reduction after traction was placed on the traction table. The reduction was achieved under fluoroscopy on the traction table. Fixation was achieved with 3 Kirschner wires in an inverted triangle configuration. After drilling over the wires, osteosynthesis was achieved with 3 cannulated 6.5-mm screws. Compression was achieved with partially threaded screws according to the fracture configuration and displacement under traction. In cases where adequate compression was achieved with superiorly partially threaded screws in the inverted triangle configuration, a fully threaded inferior screw was preferred to prevent shortening. In some cases where screw stability was insufficient, additional cannulated screws were used.

The traction table was not used in cases where adequate closed reduction could not be achieved. In the supine position, the joint capsule was passed through the Smith–Petersen approach and an open reduction was performed. Fixation with cannulated screws was performed in the same manner as the closed technique. After 2018, in all cases in which we performed an open reduction, augmentation with a medial support plate was performed after fixation with cannulated screws.

Table 1 Patient and surgical characteristics of patients

	All patients (<i>n</i> = 81) Mean ± SD/ <i>n</i> (%) / Median (range)	Shortening– (<i>n</i> = 40) Mean ± SD/ <i>n</i> (%) / Median (range)	Shortening + (<i>n</i> = 41) Mean ± SD/ <i>n</i> (%) / Median (range)	<i>p</i> value
Age (Years)	42.2 ± 17.8	42.4 ± 19.7	42.1 ± 15.6	0.925
Gender				0.496
Female	39 (48.1%)	20 (50%)	19 (46.3%)	
Male	42 (51.9%)	20 (50%)	22 (53.7%)	
Smoking				0.322
+	45 (55.6%)	20 (50%)	25 (60.9%)	
–	36 (44.4%)	20 (50%)	16 (39.1%)	
Reduction type (open/closed)				0.412
Open	28 (34.5%)	15 (37.5%)	13 (31.7%)	
Closed	53 (65.5%)	25 (62.5%)	28 (68.3%)	
Trauma mechanism				0.000
High energy	26 (32.1%)	7 (17.5%)	19 (46.3%)	
Low energy	55 (67.9%)	33 (82.5%)	22 (53.7%)	
Garden classification				0.003
Class 1	28 (34.5%)	21 (52.5%)	7 (17.1%)	
Class 2	10 (12.4%)	2 (5%)	8 (19.5%)	
Class 3	30 (37.1%)	12 (30%)	18 (43.9%)	
Class 4	13 (16.0%)	5 (12.5%)	8 (19.5%)	
Pauwels classification				0.111
Class 1	16 (19.8%)	11 (27.5%)	5 (12.2%)	
Class 2	31 (38.3%)	14 (35%)	17 (41.4%)	
Class 3	34 (41.9%)	15 (37.5%)	19 (46.4%)	
Screw number				0.204
3	76 (93.8%)	37 (92.5%)	39 (95.1%)	
4	5 (6.2%)	3 (7.5%)	2 (4.9%)	
Screw orientation				0.915
Convergent	12 (14.8%)	5 (12.5%)	7 (17.1%)	
Parallel	42 (51.8%)	22 (55%)	20 (48.7%)	
Divergent	27 (33.4%)	13 (32.5%)	14 (34.2%)	
Garden alignment index (°) AP	166.7 ± 13.6	166.0 ± 14.5	167.4 ± 12.7	0.639
Garden alignment index (°) Lateral	166.7 ± 10.1	167.4 ± 10.7	165.9 ± 9.5	0.501
Proximal screw thread				0.865
Full threaded	54 (66.7%)	26 (65%)	28 (68.3%)	
Partial threaded	27 (33.3%)	14 (35%)	13 (31.7%)	
Distal screw thread				0.744
Full threaded	49 (60.5%)	24 (60%)	25 (60.9%)	
Partial threaded	32 (39.5%)	16 (40%)	16 (30.1%)	
Singh index				0.320
3	5 (6.2%)	5 (12.5%)	0 (0%)	
4	33 (40.7%)	17 (42.5%)	16 (39.0%)	
5	23 (28.4%)	7 (17.5%)	16 (39.0%)	
6	20 (24.7%)	11 (27.5%)	9 (22%)	
Fracture line angulation (°) (AP)	31.3 ± 15.2	30.4 ± 9.1	31.9 ± 12.9	0.121
Fracture line angulation (°) (lateral)	19.3 ± 5.8	18.1 ± 3.7	20.5 ± 5.0	0.073
Femoral offset (mm) (transverse)	54.6 ± 9.5	54.6 ± 11.7	54.7 ± 6.7	0.975
Femoral offset (mm)(vertical)	66.1 ± 8.5	65.8 ± 8.1	66.3 ± 9.0	0.803
Femoral neck-shaft angle (°)	136.3 ± 8.8	137.0 ± 9.0	135.7 ± 8.6	0.514

Table 1 (continued)

	All patients (<i>n</i> = 81) Mean ± SD/ <i>n</i> (%) / Median (range)	Shortening− (<i>n</i> = 40) Mean ± SD/ <i>n</i> (%) / Median (range)	Shortening + (<i>n</i> = 41) Mean ± SD/ <i>n</i> (%) / Median (range)	<i>p</i> value
Fracture comminution				0.001
+	19 (23.4%)	5 (12.5%)	14 (34.1%)	
−	62 (76.6%)	35 (87.5%)	27 (65.9%)	
Medial plate				0.043
+	11 (13.6%)	8 (20%)	3 (7.3%)	
−	70 (86.4%)	32 (80%)	38 (92.7%)	

Table 2 Complications developed in patients with and without shortening

	All patients (<i>N</i> = 81)	Shortening− (<i>N</i> = 40)	Shortening + (<i>N</i> = 41)	<i>p</i> value
Avascular necrosis				0.084
+	13 (16.0%)	5 (12.5%)	8 (19.5%)	
−	68 (84.0%)	35 (87.5%)	33 (80.5%)	
Nonunion				0.905
+	9 (11.2%)	4 (10%)	5 (12.2%)	
−	72 (88.8%)	36 (90%)	36 (87.8%)	
Union time (months)	4.3 ± 2.3	4.0 ± 2.4	4.5 ± 1.6	0.362

Statistical Analysis

Descriptive data presented were the mean, standard deviation, lowest and highest values, and frequency. The distribution of the variables was assessed using the Kolmogorov–Smirnov test. The independent samples *t* test and Mann–Whitney *U* test were used for the analysis of the independent quantitative data, and the Chi square test was performed for the analysis of the independent qualitative data. Fischer’s exact test was used when the conditions for the chi-squared test were not met. The Benjamini–Hochberg procedure was performed to control the false discovery rate [18].

The intraclass correlation coefficient (ICC) with 95% confidence interval (CI) and Fleiss–Kappa coefficient (κ) were used to evaluate intraobserver reliability. We defined values below 0.5 as indicating poor reliability, values between 0.5 and 0.75 as moderate reliability, values between 0.75 and 0.9 as good reliability, and values above 0.90 as excellent reliability. Binary logistic regression analysis was performed when evaluating the independent risk factors for FNS. *p* values 0.05 were considered statistically significant. SPSS version 22 for Mac (SPSS Inc., Chicago, IL) was used for all statistical analyses.

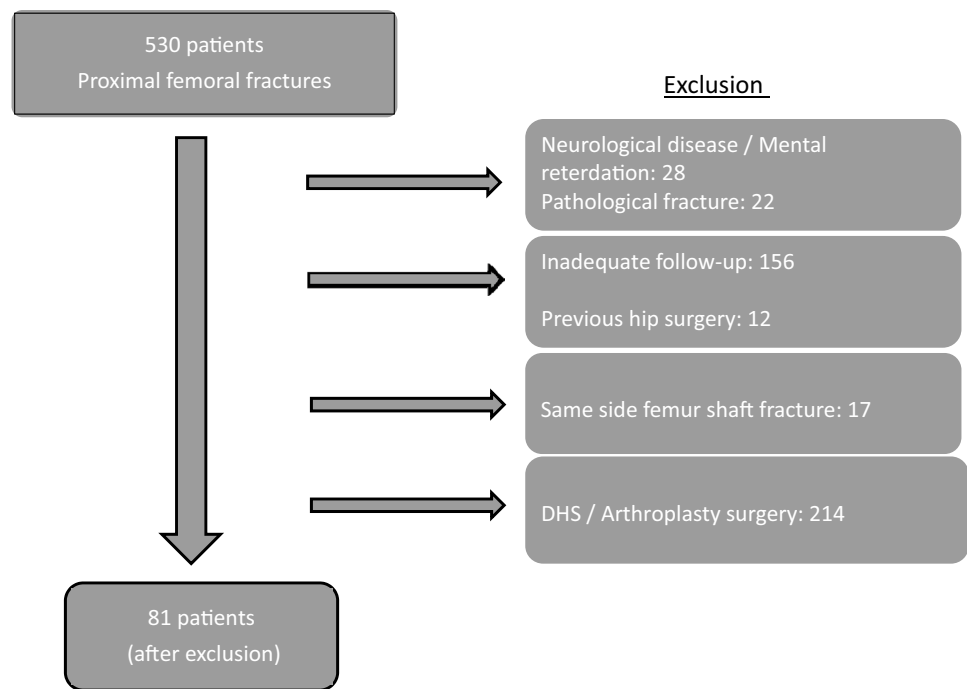
Results

Of the 530 patients who underwent open or closed reduction surgery with internal fixation diagnosed with proximal femoral fractures between January 2013 and January 2018, 81 who met the inclusion and exclusion criteria were included in the study (Figs. 1, 2).

At postoperative month 12, the mean length of the FNS was 6.3 ± 6.4 (range: 2–19) mm, and an FNS of 2 mm or more was noted in 41 patients (50.6%). The mean time to bone union after surgery was 4.3 ± 2.3 months. The median time to onset of FNS was 30 days (range: 0 to 45 days). At the end of the first year, 72 (89%) of patients had a successful bone union. During follow-up, three (3.7%) patients developed avascular necrosis, and 14 (17.2%) cases had a failure of bone union. Patient and surgical characteristics were summarized in Table 1.

There was good intraobserver reliability (ICC > 0.81, $p < 0.001$ and $k > 0.85$, $p < 0.001$) with respect to the parameters evaluated.

No statistically significant relationship was found between FNS and the parameters of gender, age, smoking, trauma type (high/low energy), Pauwels fracture classification, fragmentation, reduction type, number, type and orientation

Fig. 1 Exclusion criteria of the sample

of screws used in fixation, Singh index, neck-shaft angle, femoral offset (vertical/transverse), and Garden fix index ($p > 0.05$). FNS also did not have a significant relationship with the presence of avascular necrosis and bone nonunion during the follow-up period (Table 1). However, there was significant difference between two groups regarding energy of the fracture, fragmentation, Garden type, coronal angulation, and fixation with medial buttress plate ($p < 0.05$) (Table 1).

It was found that high-energy trauma (OR: 3.490), Garden-type 3 and 4 fracture (OR: 1.495), and fixation with a medial support plate (OR: – 3.634) were independently associated with the development of femoral neck shortening (Table 3).

During postoperative follow-up, 13 patients (16.1%) developed osteonecrosis and 9 patients (11.2%) developed femoral neck nonunion (Table 2). They underwent total hip arthroplasty.

Discussion

FNS is a common problem after treatment of femoral neck fractures. In the recovery phase, fixation materials such as cannulated screws and dynamic hip screws allow a certain amount of compression due to their nature, which stimulates healing but also causes shortening at the ends of the fracture.

FNS and its impact on patient quality of life is an area of interest in orthopedic traumatology. Zlowodzki et al. [9] reported that FNS greater than 5 mm has a negative

impact on patients' quality of life. In another study, it was observed that the shortening rate reached 66% in advanced age [4]. In a case series of non-elderly 65 patients, Stockton et al. reported that the length of FNS was more than 5 mm in 54% of cases and more than 1 cm in 32% of patients after fixation with sliding hip or cannulated screws. Considering the high rate of FNS, the authors recommended that treatment methods and implant selection should be carefully reviewed [10]. Slobogean et al. investigated the effect of FNS over 1 cm on functional scores. After a 1-year follow-up of femoral neck fractures in patients younger than 55 years, the authors reported that the length of FNS was greater than 1 cm in 13% of cases. Harris hip scores were lower in these patients compared to the remaining cases [19]. These are important findings to show that FNS negatively affects functional scores. The main objective of the current study was to determine the risk factors for the development of FNS in femoral neck fractures.

This study examined 17 parameters that may influence FNS (Table 1). 50.6% of patients who underwent internal fixation with multiple cannulated screws had FNS of 2 mm or more. Postoperative FNS was observed mainly in cases with increased coronal angulation, fragmented fractures, advanced Garden-type fractures (3 and 4), and also in cases with high-energy trauma. In addition to fixation with cannulated screws, the use of a medial support plate was shown to significantly reduce the development of FNS.

In the literature, the effects of biological factors such as age, gender, osteoporosis, and smoking on the development

Fig. 2 Measurement of femoral neck shortening by superimposing early postoperative and postoperative 12-month radiographs

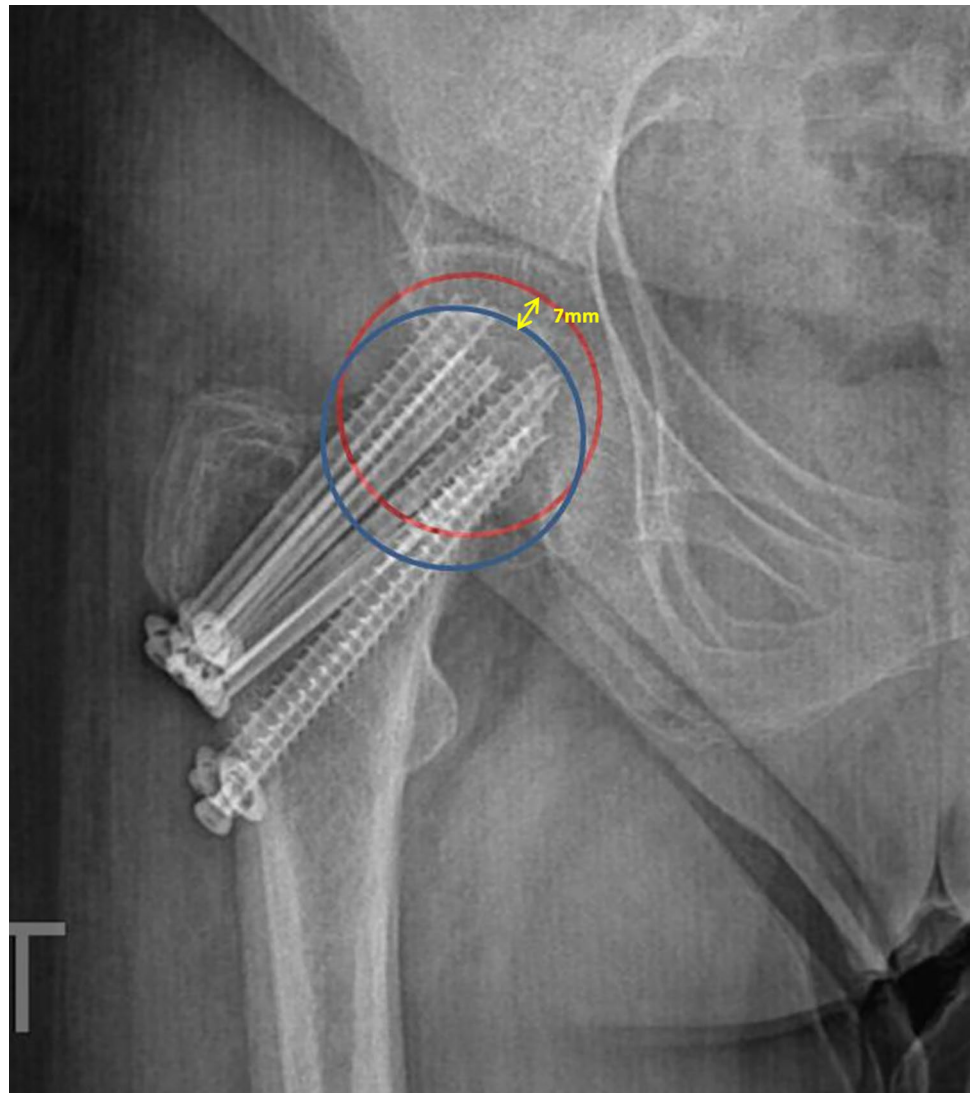


Table 3 Independent risk factors associated with femoral neck shortening

	Odds ratio (95% CI)	<i>p</i> value
High energy	3.490 (1.867–7.319)	0.046
Garden type (3 and 4)	1.495 (0.865–3.442)	0.012
Medial plate	–3.634 (–1.998 to –6.047)	0.032

of FNS after treatment of femoral neck fractures have been investigated [5, 9, 11, 13, 19].

Zielinski et al. reported that FNS increased significantly with increasing age and weight [11]. Sung et al. also showed that age and bone density play a significant role in the development of FNS [13]. Boraiah et al. investigated the relationship between FNS and various parameters, such as gender, age, and osteoporosis status. However, they found no significant difference between FNS and any of these variables

[5]. The influence of biological factors on fracture union is undisputed; however, as can be shown, different findings regarding the relationship between FNS production and biological factors are reported in the literature.

In our study, age, osteoporosis (Singh index), gender, and smoking habits were found to be similar in the patient groups with and without FNS.

Femoral neck fractures can occur in low-energy traumas such as falls from standing height or indirect sports injuries, as well as in high-energy traumas such traffic accidents, fall from height, or crush injuries. In a 2013 epidemiological study by Ani et al. examining data from 185 FNF patients under 70 years of age, it was reported that the severity of trauma showed an inverse correlation with age [20]. It can be predicted that the severity of trauma both increases the initial displacement of the fracture in femoral neck fractures and produces a negative effect on the biology of the fracture with fragmentation at the fracture line.

Fragmentation and displacement at the fracture line are accepted as risk factors that impair blood flow and cannot be controlled by the surgeon, affecting postoperative outcomes [21].

Pauwels' classification is defined according to the angle of the fracture line to the horizontal plane in femoral neck fractures. According to this classification, the higher the level, the higher the vertical loads on the fracture in the postoperative period [16]. Garden classification is based on the displacement of the fracture. As expected in high-energy fractures, fracture displacement and fragmentation will be greater in the fracture line. This is directly related to the quality of fracture reduction, the need for open reduction, and whether stable fixation is achieved after reduction [15].

Felton et al., in their recent study, in which they retrospectively examined 350 patients, showed that poor reduction quality and advanced Garden classification were associated with FNS [22]. Zielinski et al. also pointed out the importance of fracture displacement in their multicenter randomized trial published in 2013, showing that the rate of FNS development is higher in Garden 3 and 4 type fractures [11]. Similarly, there are many articles in the literature stating that fracture fragmentation, initial displacement amount, and Garden classification are effective in FNS development [10, 11, 19, 22].

In our study, no statistically significant effect of Pauwels classification on FNS development was found. The reason is that the development of FNS in postoperative follow-up cannot be explained by isolated vertical loading, and a more dynamic loading structure could have an influence on the development of FNS. But advanced Garden types (3 and 4), which may be associated with fracture line fragmentation and high-energy trauma, show a significant effect on FNS development.

In the healing of femoral neck fractures, as in all fractures, anatomical reduction and stable fixation are essential. In femoral neck fracture surgery, the quality of the reduction should be carefully assessed before fixation. For fractures with poor reduction quality or for which reduction cannot be evaluated well, open reduction should not be avoided [21]. The benefit of open reduction can be shown by the direct performance of optimal reduction, which cannot be performed indirectly by closed methods, the possibility of evacuation of fracture hematoma causing an increase in intracapsular pressure, and the possibility of medial plating providing additional stability in the fixation of fractures [23, 24]. The use of open reduction, intraoperative compression, longitudinally secure implants, and stable calcar pilot reduction was suggested by Boraiah et al. to prevent FNS that could develop during the union [5].

In our study, no significant effect of open or closed reduction was observed on the development of FNS. However, the effect of medial plate application, which we have started to

apply relatively less in open reduction, in preventing the development of FNS was found to be statistically significant.

As with many fractures, the most important success factor in the treatment of femoral neck fractures is anatomic reduction and achievement of stable fixation. Although many implants can be used for FNF fixation, DHS and cannulated screw fixation are prominent in the literature [21]. Stockton et al., in their retrospective study of 65 patients published in 2015, examined patients with femoral neck fractures fixed with multiple cannulated screws and DHS + cannulated screws and reported that there was an average of 2.2 mm more shortening in the DHS + cannulated screw group [10].

The literature has demonstrated the biomechanical superiority of cannulated screws inserted in the partially threaded inverted triangular configuration near the endosteal cortex [25]. The inverted triangular configuration was also found to be superior to the triangular configuration in preventing subtrochanteric fractures [26]. Placement of the fourth screw was reported to increase stability in cases with posterior cortical fragmentation [27].

Partially threaded screws are used for controlled fracture impaction, whereas fully threaded screws are used to protect the reduction provided. Weil et al. showed that the use of fully threaded screws with parallel configuration prevents the development of FNS [12]. Also, Sung et al. reported that advanced age and the use of non-parallel cannulated screws are risk factors for the postoperative development of FNS [13].

After primary fixation of femoral neck fractures, further fixation, such as an infero-medial support plate, may be used [23]. In their meta-analysis study published in 2020, Su et al. reported that plate fixation applied from the medial side of the femoral neck in addition to cannulated screw fixation shortens the time to union, reduces complications such as nonunion, avascular necrosis, FNF, and implant failure, and provides better postoperative functional outcomes [28].

In our study, no patient underwent DHS. Most of our patients were fixed in an inverted triangular configuration with three screws, preferring the distal fully threaded screw to avoid varus, especially in the fracture line. In a limited number, medial buttress plates were applied in addition to screw fixation. In most of our cases, the screws were inserted in parallel. In our study, no significant relationship was found between the number of screws, their configuration, and partial or full thread on the development of FNS. A statistically significant association was found with the use of medial plates. Despite the limited number of patients, the effect of the medial plate suggests that it both aids reduction of the calcar and provides additional fixation of the fracture.

As a result, it was observed that postoperative FNS occurred at a significantly higher rate in femoral neck fractures have comminution on the fracture line caused by high-energy traumas, those with increased coronal angulation and

fragmentation, and those classified as advanced Garden (3 and 4) types.

It was found that the use of a medial buttress plate in addition to cannulated screws during fixation significantly reduced the development of FNS.

However, no significant difference was found between the FNS and non-FNS cases in terms of time to bone union, failure of bone union, and development of avascular necrosis.

There are several limitations that should be noted. First, the evaluation was retrospective. Second, the follow-up period was limited to 1 year. The radiological effects of shortening in a longer follow-up period might be different.

Finally, the effect of FNS on clinical and functional outcomes was not evaluated.

Conclusion

FNS is an expected condition in FNF fixed by screws. Patients with high-energy trauma and advanced Garden types are more likely to have FNS. The use of a medial plate may be effective in preventing FNS.

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Declarations

Conflict of interest The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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