International Journal of Gerontology 19 (2025) 27–32
https://doi.org/10.6890/IJGE.202501_19(1).0005

International Journal of Gerontology

journal homepage: http://www.sgecm.org.tw/ijge/

Original Article

Preliminary Results of Femoral Neck System in Treating Femoral Neck Fractures in Elderly Population

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ARTICLE INFO

Accepted 22 July 2024

Keywords:
femoral neck system,
femoral neck fractures,
implant failure,
periprosthetic fractures

SUMMARY

Background: The femoral neck system (FNS) has recently emerged as an innovative treatment option for femoral neck fractures and shown promising results. However, the studies of treatment outcome in elderly population are still insufficient. The purpose of this study is to evaluate outcome of elder patients with femoral neck fractures treated with FNS in Taiwanese population.
Materials and methods: We retrospective reviewed 61 patients who underwent treatment with FNS for femoral neck fractures at our institution, 8 patients were excluded. We divided remaining 53 patients into two groups according to age, with a cutoff at 60 years old. Radiography parameters, operative finding and postoperative complications were analyzed.
Results: Among these 53 cases, 5 patients in elderly group had severe complication resulting in failure and required revision surgery. There was no failure in young group. The overall failure rate of FNS was 9.4%, and it was 16.1% in elderly group. Preoperative posterior tilt had a significantly higher risk of implant failure ($p = 0.011$).
Conclusions: Excessive preoperative posterior tilt increased the risk of implant failure in elder population with non-displaced femoral neck fractures treated with FNS. In addition, peri-implant subtrochanteric fractures represented a significant complication that requires careful consideration when utilizing FNS.

1. Background

Hip fractures are a common injury. It is important to quickly diagnose and manage these injuries to prevent serious complications.[1] Low-energy falls are often the cause of femoral neck fractures in the elderly, while younger patients tend to sustain femoral neck fractures due to high-energy trauma such as falls from a substantial height or motor vehicle accidents.[2]

The aim of treatment is to relieve patient discomfort, restore hip function, and allow the return to mobility. This is achieved through the prompt attainment of anatomical reduction, stable internal fixation, or prosthetic placement.[3] In the case of elderly patients with displaced femoral fractures, the standard of care typically involves hemiarthroplasty.[4,5] The optimal treatment for nondisplaced femoral neck fractures in both elderly and younger adult patients was internal fixation. Various commonly employed implant systems for achieving internal fixation in femoral neck fractures encompass cannulated screws, dynamic hip screws (DHS), proximal femoral locking plates, and other contemporary plate systems.[6,7] In 2018, the novel femoral neck system (FNS; DePuy Synthes, Johnson & Johnson Medical Devices, New Brunswick, NJ, US) has been approved for the treatment of femoral neck fractures. The FNS design includes a screw-plate construct, which allows for stronger fixation, as well as a combination of blade and anti-rotation screw that improves axial and rotational stability.[8]

Recently, a few studies of FNS were published,[9–11] but there has no such study of this novel implant in elderly population. Our aim of this study was to evaluate the outcome of patients with femoral neck fractures treated with FNS in elderly population and examine the risk factors leading to unsuccessful osteosynthesis with the FNS.

2. Materials and methods

2.1. Study design

This retrospective study was approved by the Institutional Review Board of MacKay Memorial Hospital (approval number: 23 MMHIS395e). We collected patients from April 2022 to July 2023. Inclusion criteria for the study were patients with femoral neck fractures treated with FNS. Individuals who had poor reduction during surgery, additional cannulated screw usage and follow-up less than 1 year were excluded. A total of 61 patients were reviewed, one patient was excluded because of poor reduction during surgery, one patient was excluded because of loss of follow-up, and six patient was excluded due to cannulated screw usage. A total of remaining 53 patients were included in our statistical analysis. We divided all pa-

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tients into two groups based on whether they were above or below 60 years of age, which included 22 patients and 31 patients, respectively.

2.2. Surgical technique

The patient received either spinal or general anesthesia. We performed closed reduction under C-arm X-ray machine. An incision of about 5 cm was made under the greater trochanter. First, we inserted an anti-rotation for temporary fixation. Then, we inserted central guide wire using a 130° angled guide. We then inserted the proper implant over the central guide wire into pre-reamed hole and remove central guide wire. Finally, we drilled a hole for the locking screw and anti-rotation screw and inserted them (Figure 1). We didn't prescribed anticoagulant for venous thromboembolism prophylaxis. After surgery, the patient was instructed to passive exercise and protective weight bearing for three months and adjusted according to bone healing. The osteoporosis evaluation and followed-up X-ray were performed about two weeks after hospitalization.

2.3. Clinical outcome measurements

Fractures were classified according to the Garden and Pauwels classifications.[12,13] Fractures were considered stable if classified as Garden types 1 and 2 and unstable for types 3 or 4. Measurement of tip-apex distance (TAD) and Parker ratio in the anterior-posterior (AP) radiographs was obtained to represent the position of the FNS bolt in the femoral head. The posterior tilt angle was measured using Palm's method.[14] It was determined as the angle between the mid-column line (MCL) and the radial column line (RCL), which was drawn from the center of the caput circle to the intersection of the caput circle and the mid-column line (Figure 2). Valgus tilt was measured using AP radiographs with modified Palm's method of posterior tilt. It was the angle between mid-neck line and the femoral head line.[15] The operation time, American Society of Anesthesiologists (ASA) class, anesthesia type, intra operative blood loss, post-operative visual analog scale (VAS) score, length of hospital stay were recorded. Malreduction was defined as Garden alignment index below 155° or exceeding 180° on the AP or lateral radiograph. Sequelae such as failure, delay-union, non-union, avascular necrosis (AVN) were also analyzed.

2.4. Statistical analysis

Categorical variables were expressed as proportion, and chi-square test was used to compare two groups. If the theoretical frequency was < 1, Fisher's exact test was performed to compare binary variables. Continuous variables were reported as mean ± standard

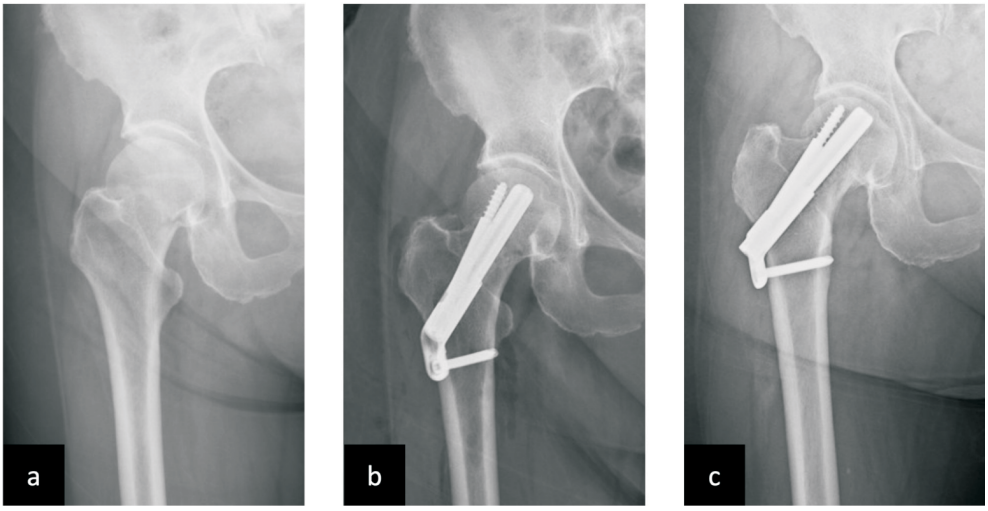

Figure 1. This was an 86-year-old female with Garden type I and Pauwels type II femoral neck fracture (Group 1) treated successfully by FNS and healed during three months. (a: preoperative, b: postoperative). The fracture site had union well one year post surgery (c).

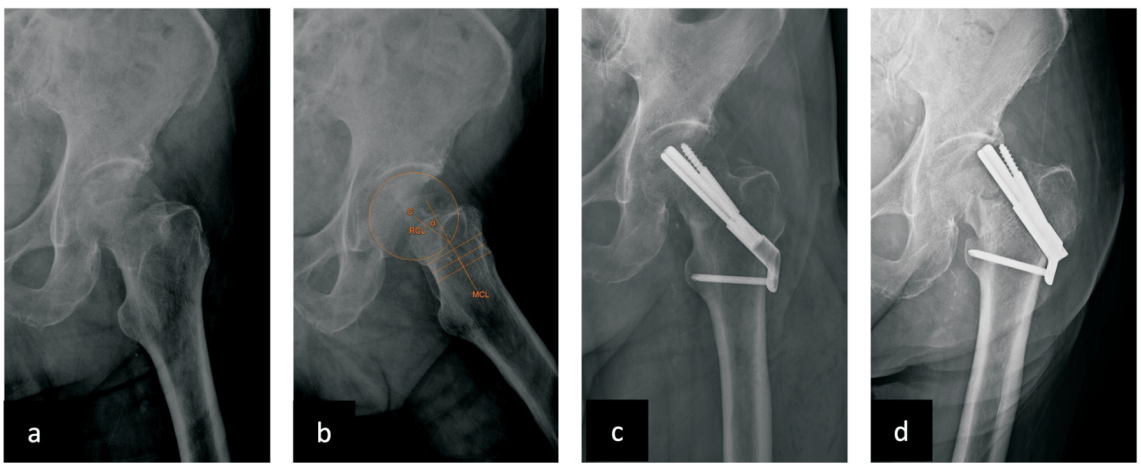

Figure 2. This was a 73-year-old man with Garden type II and Pauwels type II femoral neck fracture (a). The posterior tilt is the angle (α) between the MCL and RCL (b). FNS was placed successfully (c). Implant cut-out from femoral head occurred five months after the surgery (d).

deviation (SD) and were analyzed by Mann-Whitney U test. Differences with $p < 0.05$ were considered statistically significant. Logistic regression analyses were performed to identify risk factors for implant failure after FNS fixation. The logistic regression data were presented with odds ratio (ORs) and 95% confidence intervals (CIs). All statistical analysis was performed with SPSS version 22.0 (IBM Corporation, Armonk, NY, USA).

3. Results

A total of 53 patients were included in the study and divided into two age-based groups, consisting of 22 and 31 patients respectively. Preoperative baseline characteristics and postoperative complication of the patients are summarized in Table 1. No significant statistical differences were noted in sex, injury time to surgery, posterior tilt, valgus tilt, anesthesia type, duration of surgery, blood loss, Parker ratio, TAD, and bone density. Patients who was older than 60 years old had higher ASA class ($p = 0.017$) and longer length of hospital stay ($p = 0.023$).

Regarding postoperative complications, all fractures healed within 6 months and there was no implant failure in the young group after at least one year follow-up (average of 15.3 months). Five patients in elderly group experienced implant failure: two with peri-implant subtrochanteric fractures (6.5%, Figure 3) and three with implant cut-outs. The overall implant failure rate was 9.4% and it was 16.1% in elderly group.

All implant failure occurred in elderly group, so we performed subgroup analysis. Logistic regression analysis and comparisons of characteristics between the patients with and without implant failure in elderly group were presented (Table 2). The preoperative posterior tilt angle was $15.14 \pm 4.02^\circ$ in the failure group and $4.92 \pm 4.39^\circ$ in the group without failure, which was statistically significant compared with the two groups (OR, 1.51; 95% CI, 1.10–2.07; $p = 0.011$). The valgus tilt angle was not a risk factor for implant failure, although it appeared to be positively associated with implant failure ($p = 0.062$). There was no statistical significance in age, sex, injury time to surgery, Garden classification, Pauwels classification, bone density, ASA class, anesthesia type, TAD and Parker ratio.

4. Discussion

Femoral neck fractures in elder patients are challenging injuries to treat because of the low bone mineral density and the multiple comorbidities typically found in this patient population. For elder patients with non-displaced femoral neck fractures, fracture reduction and internal fixation are still the most widely accepted treatments. The novel implant FNS was developed for the dynamic fixa-

Table 1
Demographic characteristics of two group.

Variable	< 60 y (N = 22)	> 60 y (N = 31)	p
Age (years)	50.64 ± 8.43	75.55 ± 8.36	**0.000**
Sex			0.245
Female	12 (54.5%)	21 (67.7%)	
Male	10 (45.5%)	10 (32.3%)	
Injury time to surgery (hours)	26.32 ± 62.42	39.68 ± 72.58	0.094
Garden classification			**0.000**
I	7 (31.8%)	18 (58.1%)	
II	3 (13.6%)	13 (41.9%)	
III	6 (27.3%)	0 (0.0%)	
IV	6 (27.3%)	0 (0.0%)	
Pauwels classification			0.051
I	1 (4.5%)	5 (16.1%)	
II	16 (72.7%)	25 (80.6%)	
III	5 (22.7%)	1 (3.2%)	
Posterior tilt (°)	6.1 ± 3.75	6.62 ± 5.76	0.818
Valgus tilt (°)	9.88 ± 7.35	9.33 ± 8.22	0.643
ASA class			**0.017**
1	2 (9.1%)	2 (6.5%)	
2	17 (77.3%)	13 (41.9%)	
3	3 (13.6%)	16 (51.6%)	
Anesthesia			
Spinal			
General			
Duration of surgery (mins)	103.91 ± 39.69	100.61 ± 41.69	0.307
Blood loss (ml)	82.73 ± 63.56	90.97 ± 86.15	0.675
Parker ratio AP	48.59 ± 6.69	46.84 ± 5.44	0.192
Parker ratio lateral	48.32 ± 6.51	48.26 ± 6.21	0.935
TAD AP (mm)	82.05 ± 29.05	70.71 ± 29.68	0.100
TAD lateral (mm)	88.41 ± 29.37	81.65 ± 28.72	0.316
TAD total (mm)	170.45 ± 56.23	152.35 ± 57.02	0.156
Bone density (T score)	-2.36 ± 1.07	-2.64 ± 1.54	0.262
Length of hospital stay (days)	3.5 ± 1.6	4.45 ± 1.75	**0.023**
Malreduction	1 (4.5%)	5 (16.1%)	0.195
AVN	1 (4.5%)	1 (3.2%)	0.663
Peri-implant fracture	0 (0.0%)	2 (6.5%)	0.337
Implant failure	0 (0.0%)	5 (16.1%)	0.059
Reoperation	0 (0.0%)	4 (12.9%)	0.107

AP: antero-posterior, ASA: American Society of Anesthesiologists, AVN: avascular necrosis, TAD: tip-apex distance.

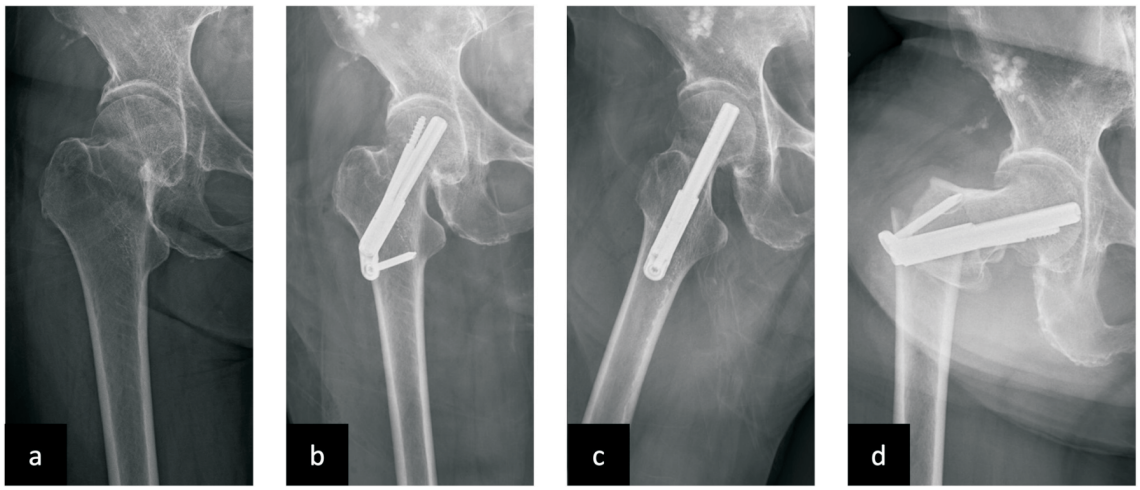

Figure 3. This was a 66-year-old female with femoral neck fracture treated by FNS (a: pre-op, b: post-op AP view, c: post-op lateral view). Peri-implant subtrochanteric fracture was noted (d).

Table 2
Logistic regression of variables associated with failure case in elderly group.

Variable	> 60 y no failure (N = 26)	Failure (N = 5)	Odds ratio (95% CI)	p
Age (years)	75.81 ± 8.55	74.2 ± 8.04	0.98 (0.87–1.10)	0.690
Sex				
Female	18 (69.2%)	3 (60.0%)	Reference	-
Male	8 (30.8%)	2 (40.0%)	1.50 (0.21–10.79)	0.687
Injury time to surgery (hours)	43.81 ± 78.51	18.2 ± 17.12	0.99 (0.95–1.03)	0.551
Garden classification				
I	17 (65.4%)	1 (20.0%)	Reference	-
II	9 (34.6%)	4 (80.0%)	7.56 (0.73–78.9)	0.090
Pauwels classification				
I	4 (15.4%)	1 (20.0%)	Reference	-
II	21 (80.8%)	4 (80.0%)	0.762 (0.07–8.73)	0.827
III	1 (3.8%)	0 (0.0%)	-	> 0.999
Posterior tilt (°)	4.92 ± 4.39	15.14 ± 4.02	1.51 (1.10–2.07)	**0.011**
Valgus tilt (°)	7.54 ± 5.82	18.62 ± 12.9	1.15 (0.98–1.32)	0.062
ASA class				
1	2 (7.7%)	0 (0.0%)	Reference	-
2	12 (46.2%)	1 (20.0%)	-	> 0.999
3	12 (46.2%)	4 (80.0%)	-	> 0.999
Anesthesia				
Spinal	17 (65.4%)	4 (80.0%)	Reference	-
General	9 (34.6%)	1 (20.0%)	0.47 (0.05–4.88)	0.529
Duration of surgery (mins)	100.73 ± 43.62	100 ± 33.8	1.00 (0.98–1.02)	0.971
Blood loss (ml)	77.69 ± 43.48	160 ± 191.7	1.01 (1.00–1.02)	0.154
Parker ratio AP	46.73 ± 5.71	47.4 ± 4.22	1.02 (0.85–1.23)	0.798
Parker ratio lateral	48 ± 6.53	49.6 ± 4.45	1.04 (0.90–1.21)	0.594
TAD AP (mm)	69.62 ± 29.93	76.4 ± 30.92	1.01 (0.98–1.04)	0.636
TAD lateral (mm)	80.69 ± 28.36	86.6 ± 33.51	1.01 (0.98–1.04)	0.670
TAD total (mm)	150.31 ± 56.72	163 ± 64.1	1.00 (0.99–1.02)	0.645
Bone density (T score)	-2.68 ± 1.69	-2.48 ± 0.95	1.09 (0.58–2.03)	0.792
Length of hospital stay, days	4.19 ± 1.55	5.8 ± 2.28	1.64 (0.95–2.86)	0.079
Malreduction	4 (15.4%)	1 (20.0%)	1.38 (0.12–15.72)	0.798

AP: antero-posterior, ASA: American Society of Anesthesiologists, TAD: tip-apex distance.

tion of femoral neck fractures and provide superior biomechanical characteristics.[8] According to the literature, FNS have lower rates of overall complications, non-union, femoral neck shortening, implant failure or reoperation comparing with cannulated screw or DHS.[9,16–18] Our study showed the overall implant failure rate was 0%, and 16.1% in young group and elderly group, respectively. We confirmed that FNS effectively reduces the implant failure and revision in the young group. However, the incidence of implant failure appeared higher in the elderly group although it was not statistically significant. Some studies have found that in the elderly population with non-displaced femoral neck fractures, the failure rate of using FNS ranges from 9.8% to 16.7%, and it does not show significant superiority over cannulated screws.[19,20]

We encountered five cases of failure attributed to distinct reasons. Several studies discovered main risk factors for implant failure were the amount of initial displacement, preoperative posterior tilt, insufficient reduction, implant protrusion, increasing surgical delay, female sex, alcohol excess and systemic comorbidities.[21,22]

Many studies and meta-analysis have reported an association between preoperative posterior tilt and implant failure, non-union, and osteonecrosis.[23–25] Zhu et al. investigated posterior tilt angle was the highest prognostic value to predict reoperation after internal fixation in elderly populations.[26] The wide range of reoperation rates reported in the literature (10% to 56%) might be due to differences of sample size and measurements. Although most studies indicated that 20° is the threshold of clinical significance with cannulated screw or DHS,[22,24,27] Shin et al. found that posterior tilt greater than 9° already shows a significant difference.[28] They believe that elderly patients with osteoporosis may be the reason for the smaller cut-off value. Further, to the best of our knowledge, no previous study has investigated the posterior tilt threshold with patients treated by FNS. The increased failure rate observed in patients with a more pronounced tilt may be attributed to two main reasons. Firstly, a greater posterior tilt is associated with increased posterior comminution of the femoral neck which threatened the stability of implant.[29] Additionally, vascular disruption affecting the retinacular arteries and venous drainage of the femoral neck and head, resulting in AVN or non-union.[30] On the basis of the high rate of failure for those with the preoperative posterior tilt, every patient with a femoral neck fracture should have a lateral radiographs or computer tomography to evaluate the posterior tilt. Primary hip arthroplasty should be considered to treat these patients to avoid complications such as AVN, non-union or implant failure.

Among our failure cases, two of five suffered from peri-implant subtrochanteric fractures. Peri-implant subtrochanteric fractures are a rare complication of cannulated screws and DHS when the placement of the most distal screw distal to the level of the lesser trochanter. The incidence of subtrochanteric fractures following cannulated screw fixation reported in the literature was approximately 0.78 to 5.7%.[31,32] Crump et al. found that the placement of distal screw in this region is associated with a reduction in the force required to cause failure.[32] Oakey et al. hypothesized that the placement of screws at the proximal lateral femoral cortex functions as a stress riser.[33] The design of locking screws in the plate not only enhances construct rigidity but also causes stress concentration. This effect arises from alterations in the elastic modulus due to the rigid implants utilized to achieve compression through the femoral neck. The implant traverses the endosteal corridor of the femoral neck,

potentially disrupting the mechanical load transfer from the femoral head to the lateral cortex of the femur.[34] The combination of axial loading and abductor muscle distraction results in the creation of a weak point within the subtrochanteric region, thereby contributing to a peri-implant fractures.[35] A finite element analysis has revealed that the peak Von Mises stress experienced by the locking plate and screw in FNS near the lesser trochanter is sufficient to induce a stress fracture.[36] Recent case series have documented an elevated risk of peri-implant subtrochanteric fractures in patients with non-displaced fractures treated with FNS fixation.[37] Moreover, the stress riser effect can also result from the presence of multiple drill holes in the femoral cortex and compromised bone quality.[38]

Our preliminary study has several limitations. First, it was an observational and retrospective study design. Secondly, clinical and radiological outcomes were documented with a small patient cohort. Most of variables do not exhibit statistically significant differences. Third, FNS was released only in 2018, and it has been gradually used in our institute since 2022. Hence, the follow-up period for our study was restricted. A long-term follow-up and more patient involvement would be useful in detecting delayed complications such as AVN and peri-implant fracture and giving more theoretical insights of this newly-designed implant. Fourth, we did not include patients treated with cannulated screw and DHS, so further study to compare the results of different implant is necessary.

5. Conclusion

Using FNS for fixation of femoral neck fractures was a new implant and showed the fine result in younger populations. However, excessive preoperative posterior tilt had a considerably increased risk of implant failure in elder population with non-displaced femoral neck fractures. In addition, peri-implant subtrochanteric fractures represented a significant complication that requires careful consideration when utilizing FNS. Future high quality, large volume, long term prospective randomized studies are necessary to corroborate these finding.

Conflicts of interest

The funders had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Author contributions

Wen-Po Chiang: Writing original draft; Yan-Shiang Lian: Writing original draft; Chung-Ting Liu: Editing original draft; Min-Yao Chuang: Revised the draft; Ting-Kuo Chang: Conceived and supervised the study, revised the draft. All authors have read and agreed to the final version of the manuscript.

Funding

This research did not receive any external funding.

Acknowledgments

Nil.

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