Comparison of early clinical results for the femoral neck system and cannulated screws in the treatment of unstable femoral neck fractures

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Research article

Keywords: Femoral neck fracture, Internal fixation, Femoral neck system, Cannulated screw

DOI: https://doi.org/10.21203/rs.3.rs-129837/v2

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Abstract

Objective: To compare early clinical effects of the femoral neck system (FNS) and three cannulated screws for the treatment of patients with unstable femoral neck fractures.

Methods: A retrospective analysis with pair matching of 81 patients who received FNS or cannulated screw internal fixation for Pauwels type-3 femoral neck fracture in our hospital from January 2019 to December 2019 was conducted. Patients who received FNS were the test group, and those who received cannulated screws comprised the control group. Matching requirements were as follows: same sex, similar age and similar body mass index (BMI). A total of 30 pairs were successfully matched, and the average age was 53.84 years. The operation time, intraoperative blood loss, hospital stay, hospitalization cost, postoperative visual analogue scale (VAS) score, time to walking without crutches, Harris score, femoral head necrosis rate and complication rate were compared between the groups.

Results: Postoperative re-examination of radiographs showed satisfactory reduction in all patients, and all patients were followed up for 10-22 months. Those in the FNS group had lower postoperative VAS scores, earlier times to walking without crutches, higher Harris scores at the last follow-up and lower complication rates ($P<0.05$). However, intraoperative blood loss and hospitalization costs were greater in the FNS group ($P<0.05$). No statistically significant difference in operation time, hospital stay or femoral head necrosis rate was observed between the two groups ($P>0.05$).

Conclusion: For patients with unstable femoral neck fractures, FNS has better clinical efficacy than cannulated screws, though it is also more expensive. The excellent biomechanical performance and clinical efficacy of FNS make it a new choice for the treatment of unstable femoral neck fractures.

Introduction

Femoral neck fractures are often caused by high-energy trauma in young adults. For patients with femoral neck fracture who are younger than 65 years old, internal fixation with femoral head preservation is considered to be the first choice[1]. Compared with hip arthroplasty, internal fixation has advantages of less trauma, short operation time, less bleeding and low cost, and it is consistent with the concept of hip preservation. Nevertheless, current opinion remains inconsistent with regard to the selection of internal fixation approaches to achieve better outcomes of fracture end stability, bone union, decreasing incidences of femoral head necrosis and complications[2]. To date, the use of 7.5-mm cannulated screws (Triad) is the most commonly approach for internal fixation. By compressing the fracture end, fixation with three cannulated screws contributes to anatomical reduction, rigid internal fixation and union of femoral neck fractures[3]. However, some problems in the fixation of partially unstable femoral neck fractures with three cannulated screws remain[4, 5].

An ideal minimally invasive implant guarantees stability of the internal fixation without shortening of the femoral neck or tilt or rotation of the femoral head. For dynamically fixing fractured femoral necks, a novel femoral neck system (FNS) was developed by the Lower Extremity Expert Group, the Association for...
the Study of Internal Fixation and DePuy Synthes Products (Figure 1). FNS is able to provide angular stability with minimally invasive procedures. An implant with a small side plate can be fixed to the femoral shaft, which reduces the footprint of the implant and at the same time fixes the femoral head by locking the screw in the bolt. By combining minimally invasive insertion technology with the stability of the DHS (dynamic hip screw), FNS retains the function of the femoral head as much as possible. Notably, FNS highlights the biological characteristics of fracture healing via compression at the fracture end.

Overall, there is scant literature about clinical application of the newly developed FNS. Hence, this study aims to retrospectively analyse the therapeutic efficacy of FNS and cannulated screw fixation for the treatment of unstable femoral neck fracture in younger patients, hoping to provide some evidence-based references for clinical treatment.

Materials And Methods

Inclusion and exclusion criteria.

Inclusion criteria: (i) cases of fresh unilateral femoral neck fracture; (ii) younger than 65 years; (iii) Pauwels type-3 femoral neck fracture; (iv) no fractures at other sites; (v) complete follow-up data.

Exclusion criteria: (i) excessive drinking, long-term history of hormone drugs or femoral head necrosis; (ii) other severe diseases; (iii) pathological fractures; and (iv) severe cognitive dysfunction.

Baseline characteristics.

A retrospective analysis was performed from January 2018 to December 2019 using 81 eligible femoral neck fracture patients undergoing FNS or cannulated screw fixation in the Department of Orthopedics, The Affiliated Suzhou Hospital of Nanjing Medical University, Suzhou Municipal Hospital. Among them, 30 patients were treated with FNS and 51 patients with three traditional cannulated screws. The patients treated with FNS were selected as the experimental group; those treated with cannulated screws were selected as the control group. A pair-matched clinical research study was performed with the following requirements: sex, age ± 3 years old, BMI (body mass index) ± 2 kg/m². A total of 30 pairs were successfully matched at a 1:1 ratio, including 12 males and 18 females. The average age of the patients in the FNS group was 54.53±6.71 years, with a BMI of 23.24±2.12 kg/m². In the cannulated screw group, the average age of the patients was 53.14±7.19 years, and the BMI was 22.73±2.13 kg/m². No significant differences in preoperative baseline characteristics were identified.

Perioperative management.

Femoral neck fracture surgery was conducted within 48 h of admission by the same group of surgeons. Patients received spinal anaesthesia and were fixed in a supine position. The operated limb was placed on the traction frame in an abducted, internally rotated position. Postoperative reduction was observed by C-arm localization.
For patients who received FNS, a longitudinal incision was cut on the lateral hip to expose the proximal femur. A Kirschner wire was inserted into the femoral head alongside the lateral femur to temporarily fix the femoral neck fracture with satisfactory reduction. Under the guidance of a localizer at 130°, a Kirschner pin was inserted in the femoral neck, which was placed in the centre of both the femoral neck and the femoral head in the anteroposterior view. FNS (DePuy Synthes Products, USA) was inserted after reaming and sounding. A locking screw was placed in the distal hole and rotated in the femoral neck, after which the temporarily fixed Kirschner pin was removed.

For patients who received cannulated screw fixation, three parallel guide needles were inserted into the femoral head along the longitudinal axis of the femoral neck in the shape of an inverted triangle[6]. The needles were placed in the centre of the femoral neck and the femoral head, as well as 1 cm below the articular surface. A 1-cm incision was cut at the tip of the parallel guide needles. After exposing the lateral cortical bone, a hole was drifted until the fracture end. An appropriate cannulated screw was rotated under the guidance of the parallel guide needle, which was localized by X-ray. The parallel guide needles were finally removed.

Postoperative multimodal analgesia and anti-coagulation using rivaroxaban were performed. The patients were encouraged to begin exercise within 24 h of the surgery. By the 2nd postoperative week, the patients started to ground exercise with the help of crutches, though weight-bearing on the affected limb was forbidden. Partial weight-bearing exercise was encouraged at the 6th week, recovering to normal exercise based on the patient’s condition, followed by walking without crutches. The patients were followed up at 1, 3, 6, 9 and 12 months after the operation. Typical cases that received FNS and cannulated screw fixation are depicted in Figure 2 and Figure 3, respectively.

**Testing indices.**

The quality of fracture reduction was assessed based on the quantitative indicators proposed by Haidukewych et al., as follows: (i) excellent reduction - displacement after reduction < 2 mm and deformity angle at any plane < 5°; (ii) fair reduction - displacement after reduction ranging from 6-10 mm and deformity angle at any plane ranging from 11-20°; and (iii) poor reduction - displacement after reduction > 10 mm and deformity angle at any plane > 20°[7]. Operation time, intraoperative blood loss, 1st day postoperative VAS (visual analogue scale) score, hospital stay, hospitalization cost, time to walking without crutches, Harris score, complication rate and femoral head necrosis rate were recorded. Complications included bone nonunion, loss of reduction, and loosening of internal fixation.

**Statistical analysis.**

SPSS 25.0 was used for statistical analysis. Data are expressed as ±s. Age, BMI, operation time, intraoperative blood loss, length of stay, hospital stay, hospitalization cost, 1st day postoperative VAS score, time to walking without crutches, and Harris score were compared using Student’s t test. Sex, postoperative reduction, femoral head necrosis rate and complication rate were compared by the c² test or Fisher’s exact test. \( P<0.05 \) was considered statistically significant.
Results

All patients achieved satisfactory postoperative reduction. In the FNS group and the cannulated screw group, 24 and 25 patients achieved an excellent reduction, and 6 and 5 achieved a fair reduction, respectively, with no significant difference ($P=0.739$).

All patients were followed up for 10-22 months. Intraoperative blood loss was greater in the FNS group (99.73±4.69) than in the cannulated screw group (30.27±9.04) ($P<0.001$). In addition, patients in the FNS group (46976±2270¥) spent more on hospitalization costs than did those in the cannulated screw group (15626±1732¥) ($P<0.001$). No significant differences in operation time or hospital stay were detected between the FNS group and the cannulated screw group ($P>0.05$, Table 1).

Table 1. Operation time, intraoperative blood loss, hospital stay, and hospitalization cost between the FNS group and cannulated screw group (±s)

| Group           | Operation time (minutes) | Intraoperative blood loss (ml) | Hospital stay (day) | Hospitalization cost (RMB/¥) |
|-----------------|--------------------------|-------------------------------|---------------------|-----------------------------|
| FNS             | 42.83±4.69               | 99.73±52.73                   | 5.07±1.31           | 46978±2270                  |
| cannulated screw| 40.90±5.22               | 30.27±9.04                    | 5.33±1.52           | 15626±1732                  |

$t$ 1.595 4.747 1.547 54.825

$P$ value 0.122 □ 0.001 0.133 □ 0.001

Notably, VAS scores were lower in the FNS group (3.13±1.07 scores) than in the cannulated screw group (3.77±1.04 scores) ($P=0.018$). Patients in the FNS group (5.23±1.33 months) recovered to walking without crutches earlier than did those in the cannulated screw group (6.03±1.45 months) ($P<0.001$). In addition, a statistically higher postoperative Harris score was detected in the FNS group (86.16±7.26) than in the cannulated screw group (82.37±7.52) ($P=0.039$, Table 2).

Table 2. Postoperative VAS score, time to walking without crutches and Harris score between the FNS and cannulated screw groups (±s)

| Group           | Postoperative VAS score | Time to walking without crutches (months) | Harris score |
|-----------------|-------------------------|------------------------------------------|--------------|
| FNS             | 3.13±1.07               | 5.23±1.33                                | 86.16±7.26   |
| cannulated screw| 3.77±1.04               | 6.03±1.45                                | 82.37±7.52   |

$T$ 2.520 5.174 2.164

$P$ value 0.018 □ 0.001 0.039
Overall, a higher incidence of complications was observed in the cannulated screw group than in the FNS group ($P=0.042$). In fact, complications occurred in only two of the thirty patients in the FNS group. One patient with delayed union was conservatively treated with drugs to promote fracture healing, and the fracture was healed by 7 months after the operation. One patient was treated by total hip arthroplasty after removing the internal fixation because the fracture reduction was lost after another fall. During the follow-up period, there was no case of osteonecrosis of the femoral head.

A total of nine patients developed postoperative complications. One patient with delayed union was conservatively treated with drugs to promote fracture healing, and the fracture was healed by 8 months after the operation. Two patients with delayed union were not treated conservatively and underwent total hip arthroplasty after internal fixation removal. Two patients also lost reduction, but the fractures healed; they were followed up for further observation. The fractures of three patients with internal fixation loosening healed, and the internal fixations were removed. During the follow-up period, one patient experienced osteonecrosis of the femoral head and underwent total hip arthroplasty.

**Discussion**

Our study recruited femoral neck fracture patients of a younger age (<65 years) who were treated with FNS or cannulated screw fixation and followed up for 10~22 months. We found that for Pauwels type-3 unstable femoral neck fracture, FNS has significant advantages with regard to early clinical efficacy and complication rate compared with the traditional three cannulated screws and does not increase surgical trauma. The disadvantage is that the cost is relatively high.

This study found no significant difference in operation time or length of stay between patients treated with FNS and cannulated screw fixation. The average intraoperative blood loss in the FNS group was 99.73 ml. Although the difference was statistically significant, the amount of blood loss was still small and had no effect on postoperative rehabilitation or the clinical effect. The fast operation time and lack of trauma suggest that FNS treatment is a simple procedure and a good choice. FNS effectively reduces soft tissue exposure and usually only requires a lateral incision of approximately 4-5 cm; in addition, only partially cutting open the lateral vastus muscle is needed, with no damage to the gluteus medius.

Based on a fast-track programme, all patients underwent surgery within 48 h of admission. Postoperative multimodal analgesia and anticoagulation were routinely administered. Moreover, the patients were encouraged to exercise their hip joint early, aiming to prevent postoperative thrombosis. As a result, no evidence of deep vein thrombosis or pulmonary embolism was found in this study. Some studies have reported that poor reduction following femoral neck fracture is a risk factor for complications and femoral head necrosis[8]. In our study, all patients achieved a satisfactory reduction by the 1st day postoperatively, and there was no significant difference between the two groups.

The Pauwels angle reflects the interaction between compressive stress and shear force during the healing process of femoral neck fractures, and it has been widely used in clinical practice. As the Pauwels angle
increases, the shear force acting on the fracture end gradually becomes the main force, leading to an increase in the complication rate[9]. At present, Pauwels type-1 is considered to be a stable fracture, Pauwels type-3 is an unstable fracture, and Pauwels type-2 is somewhere in between. Liporace F et al. reported that the fixed capacity of cannulated screw fixation is weaker than that of other internal fixation in the treatment of vertical femoral neck fractures; it may lead to shortening of the femoral neck and hip function damage, especially in osteoporosis patients[10]. Other evidence has shown that cannulated screw fixation is particularly suitable for the treatment of Garden + and Pauwels + femoral neck fractures[5, 11, 12]. According to our clinical experience, the effect of cannulated screws for the treatment of stable femoral neck fractures is essentially satisfactory, though there are some problems for unstable femoral neck fractures. Due to the high cost of FNS, we utilized FNS and cannulated screws in a comparative study for unstable femoral neck fractures (Pauwels type-3). We believe that a single cannulated screw lacks angular stability, exhibiting poor capacity against shear stress. In addition, as a single screw is prone to longitudinally cut distal fractures, the incidence of complications in the treatment of Pauwels type-3 femoral neck fractures is high.

Moreover, FNS resulted in better biomechanical properties than conventional internal fixation using three cannulated screws for the treatment of Pauwels type-3 femoral neck fracture. The biomechanical advantages of FNS have been previously reported. Karl et al. compared the axial compression load and cycle times for shortening the femoral neck by 15 mm in biomechanical testing with a 0.1-N increase per cycle[13]. These authors pointed out that FNS presents better overall structural stability than internal fixation using three cannulated screws. FNS involves not only angular stability but also rotational stability. Schopper et al. further demonstrated that FNS leads to higher stability and better resistance to varus and deformation in femoral neck fractures than Hansson Pins[14]. Xu et al. used FNS to treat 16 patients with femoral neck fracture, including 7 cases of Garden type-3 and 6 cases of Garden type-4. The results were satisfactory at the last follow-up, and none of the patients experienced complications such as internal fixation loosening[15]. We believe that the pronounced efficacy in femoral head fracture patients might be explained by the better biomechanical performance of FNS. At the last follow-up in our study, the Harris score was significantly higher and the incidence of complications lower in the FNS group. Overall, the combination of FNS bolts with anti-rotation screws avoids the "Z" effect on the cutting of the femoral head and increases the overall stability and anti-rotation effect. In addition, the unique sliding compression mechanism of FNS allows the fracture ends to closely contact each other, promoting fracture healing.

In this study, femoral head necrosis did not occur in the FNS group but did occur in 1 patient in the cannulated screw group. Some studies have found that the stability of femoral neck fractures is of great significance for revascularization of the femoral head and plays an important role in promoting bone healing and in reducing the rate of femoral head necrosis[16, 17]. Moreover, it has been reported that a large implant volume may interfere with revascularization of the femoral head and increase the incidence of femoral head necrosis[18]. The diameters of the screw bolt and the anti-rotation screw of the FNS in this study were 10 mm and 6.4 mm, respectively; thus, the volume of the FNS implant was significantly smaller than that of the three cannulated screws. In addition, the combination and smaller size of the
son-mother nail can effectively reduce damage to the femoral head, and it is also beneficial for preserving bone mass in the femoral neck. Nevertheless, no significant difference in the incidence of femoral head necrosis was identified between the groups, which may be attributed to the small sample size and short follow-up period.

Deficiencies in this retrospective analysis should not be neglected. First, the surgeon independently selected the implants, leading to potential selection bias. However, we adopted a 1:1 pairing method to eliminate the interference of many factors to the greatest extent, to reduce the level of individual variation, and to make the test group and the control group comparable. Second, because of the short time on the market and the high price of FNS, the accuracy of this study may be limited by a small sample size and short follow-up period. Reasons for internal fixation failure and femoral head necrosis could not be definitively ascertained. In future studies, a large sample size and longer follow-up are necessary to validate our findings.

**Conclusion**

This study found that compared with cannulated screws, FNS is a suitable option for the treatment of Pauwels type-3 femoral neck fractures. This approach is characterized by its accurate efficacy, simple procedure, reduced trauma, faster recovery and fewer complications, though it is more expensive. FNS's excellent biomechanical performance and clinical efficacy make it a new choice for the treatment of unstable femoral neck fractures.

**Abbreviations**

FNS: femoral neck system  
DHS: dynamic hip screw  
BMI: body mass index  
VAS: visual analogue scale

**Declarations**

**Ethics approval**

This trial was approved by the Ethic Committee of Suzhou Municipal Hospital (IEC-C-008-A07-V1.0).

**Consent for publication**

Not application
Availability of data and materials

The dataset analyzed during the current study are not publicly available due to patient’s privacy but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing

Funding

This study was funded by the Key medical research project of Jiangsu Health Committee (K2019010).

Authors' contributions

Zhou Xiaoqiang: Conceptualization, Data Curation, Formal analysis, Writing - Original Draft, Writing - Review & Editing

Yu Xiao: Conceptualization, Data Curation, Formal analysis, Writing - Original Draft, Writing - Review & Editing

Li Zhiqiang: Investigation, Formal analysis, Writing - Review & Editing

Chen Guangxiang: Conceptualization, Funding acquisition, Writing - Review & Editing, Supervision

Xu Renjie: Investigation

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Acknowledgements

Not applicable.

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