

Comparison of Early Clinical Results of Femoral Neck System and Cannulated Screws in the Treatment of Unstable Femoral Neck Fractures

Xiaoqiang Zhou

Nanjing Medical University Affiliated Suzhou Hospital: Suzhou Municipal Hospital

Zhiqiang Li

Nanjing Medical University Affiliated Suzhou Hospital: Suzhou Municipal Hospital

Renjie Xu

Nanjing Medical University Affiliated Suzhou Hospital: Suzhou Municipal Hospital

Yuanshi She

Nanjing Medical University Affiliated Suzhou Hospital: Suzhou Municipal Hospital

Xiangxin Zhang

Nanjing Medical University Affiliated Suzhou Hospital: Suzhou Municipal Hospital

Guangxiang Chen

Nanjing Medical University Affiliated Suzhou Hospital: Suzhou Municipal Hospital

Xiao Yu (✉ yuxiao-szmh@139.com)

The Affiliated Suzhou Hospital of Nanjing Medical University

Research article

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Abstract

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

Methods: A retrospective analysis was conducted on 81 patients who received FNS or cannulated screws internal fixation for Pauwels Type-3 femoral neck fracture in our hospital from January 2019 to December 2019. A pair-matched clinical research was performed. People who received FNS were test group and people received cannulated screws were control group. Matching requirements were as follows: the same gender, the similar age and the similar BMI. A total of 30 pairs were successfully matched, with an average age of 53.84 years old. The operation time, intraoperative blood loss, hospital stay, hospitalization cost, postoperative VAS score, time walking without crutches, Harris score, femoral head necrosis rate and complication rate were compared between the two groups.

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

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

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Introduction

Femoral neck fractures are often caused by high-energy trauma in young adults. For patients with femoral neck fracture under 65 years old, internal fixation with femoral head preservation is considered to be the first choice [1]. Compared with hip arthroplasty, internal fixation has the advantages of less trauma, short operation time, less bleeding and low cost, and accords with the concept of hip preservation. Nevertheless, current opinions on the selection of internal fixation approaches for better outcomes of the stability of fracture end, bone union, decreasing incidences of femoral head necrosis and complications are still inconsistent [2]. So far, 7.5 mm cannulated screws (Triad) are the mostly applied approach for the internal fixation. Through compressing the fracture end, fixation with three cannulated screws contribute to anatomical reduction, rigid internal fixation and union of femoral neck fractures [3]. However, there are still some problems in the fixation of partial unstable femoral neck fractures with three cannulated screws [4, 5].

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

Literatures about the clinical application of the newly developed FNS are rarely reported. This study aims to retrospectively analyze the therapeutic efficacy of FNS and cannulated screw fixation in the treatment of unstable femoral neck fracture in young patients, hoping to provide some evidence-based references for clinical treatment.

Materials And Methods

Inclusion and exclusion criteria.

Inclusion criteria: (i) Patients with fresh unilateral femoral neck fracture; (ii) Patients were younger than 65 years; (iii) Pauwels type-3 femoral neck fracture; (iv) Patients did not have fractures in other sites; (v) Follow-up data were completely recorded.

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

Baseline characteristics

A retrospective analysis was made on 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 from January 2018 to December 2019. Among them, 30 patients were treated with FNS and 51 patients were treated with traditional three cannulated screws. Patients with FNS were selected as the experimental group and patients with cannulated screws were control group. A pair-matched clinical research was performed. Matching requirements were as follows: the same gender, age ± 3 years old, BMI(Body Mass Index) $\pm 2\text{kg/m}^2$. 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, and the BMI was $23.24\pm 2.12\text{ kg/m}^2$. In the cannulated screw group, the average age of the patients was 53.14 ± 7.19 years, and the BMI was $22.73\pm 2.13\text{ kg/m}^2$. No significant differences were identified in their preoperative baseline characteristics.

Perioperative management.

Femoral neck fracture surgery was conducted within 48 h of admission by the same group of surgeons. Patients received to spinal anesthesia and fixed in a supine position. The operated limb was placed on the traction frame in an abducted, internally rotated position. Postoperative reduction was observed using C-arm localization.

For patients received to FNS, a longitudinal incision was cut on the lateral hip to expose the proximal femur. A Kirschner wire was inserted in the femoral head alongside the lateral femur to temporarily fixed the femoral neck fracture with a satisfactory reduction. Under the guidance of a localizer at 130°, a Kirschner pin was inserted in the femoral neck, which was placed in the central of both femoral neck and femoral head in the anteroposterior view. FNS (DePuy Synthes Products, USA) was instrumented in after reaming and sounding. A locking screw was placed in the distal hole and rotated in the femoral neck, and then the temporarily fixed Kirschner pin was pulled out.

For patients received to cannulated screw fixation, a Kirschner wire was inserted diagonally upward in the cortical bone 5 cm, 7 cm and 9 cm distal to the apex of the greater trochanter of femur, respectively. They were placed in the central of the femoral neck and the femoral head, as well as 1 cm below the articular surface of the femoral head in a shape of triangle. A 1 cm incision was cut at the tip of the Kirschner pin. After exposing the lateral cortical bone, a hole was drilled till to the fracture end. An appropriate cannulated screw was rotated in under the guidance of the Kirschner wire, which was localized by X-ray. The Kirschner wire was finally pulled out.

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

Testing indexes

Quality of fracture reduction was assessed based on quantitative indicators proposed by Haidukewych et al. as the follows: (i) An excellent reduction: Displacement after reduction < 2 mm and deformity angle at any plane < 5°; (ii) A fair reduction: Displacement after reduction ranged 6-10 mm and deformity angle at any plane ranged 11-20°; (iii) A poor reduction: Displacement after reduction > 10 mm and deformity angle at any plane > 20°[6]. Operation time, intraoperative blood loss, 1st day postoperative VAS(Visual Analogue Scale) score, hospital stay, hospitalization cost, time 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.

SPSS 25.0 was used for statistical analysis. Data were expressed as $\bar{x} \pm s$. Age, BMI, operation time, intraoperative blood loss, length of stay, hospital stay, hospitalization cost, 1st day postoperative VAS score, time walking without crutches, and Harris score were compared by the Student's *t* test. Gender, postoperative reduction, femoral head necrosis rate and complication rate were compared by the χ^2 test or Fisher's exact test. $P < 0.05$ was considered as statistically significant.

Results

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

All patients were followed up for 10–22 months. Intraoperative blood loss was more in FNS group (99.73 ± 4.69) than that of cannulated screw group (30.27 ± 9.04) ($P < 0.001$). Patients in FNS group (46976 ± 2270) spent more than that of cannulated screw group (15626 ± 1732) ($P < 0.001$). No significant differences in operation time and hospital stay were detected between FNS group and cannulated screw group ($P > 0.05$, Table 1).

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

A higher incidence of complications was found in cannulated screw group than that of FNS group ($P = 0.042$). Complications occurred in two of the thirty patients in the FNS group. One patient with the delayed union was conservatively treated with drugs to promote fracture healing and fracture healed at 7 months after operation. The fracture reduction was lost after another fall. This patient was treated by total hip arthroplasty after removing the internal fixation. 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 the delayed union was conservatively treated with drugs to promote fracture healing and fracture healed at 8 months after operation. Two patients with the delayed union failed to treat conservatively and were treated by total hip arthroplasty after removing the internal fixation. Two patients lost reduction but the fractures were healed. They were followed up for further observation. The fracture of three patients with loosening of internal fixation were healed and the internal fixations were removed. During the follow-up period, one patient had osteonecrosis of the femoral head and underwent total hip arthroplasty.

Discussion

Our study recruited femoral neck fracture patients with young ages (< 65 years). They were either 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 in 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 expensive.

This study found no significant difference in operation time and length of stay was detected between patients treated with FNS and cannulated screw fixation. The average intraoperative blood loss in group FNS was 99.73 ml. Although the difference was statistically significant, but the amount of blood loss was little, which had no effect on the postoperative rehabilitation and clinical effect of the patients. Fast operation time and little trauma show that in FNS-treated patients suggested the simple procedures and less trauma. FNS effectively reduced soft tissue exposure, usually only need a lateral incision of about 4-5cm to complete the operation and only need to partially cut open the lateral vastus muscle without damaging the gluteus medius muscle.

Based on the fast-track program, all patients were operated within 48 h of admission. Postoperative multimodal analgesia and anti-coagulation were routinely administrated. Patients were encouraged to early exercise of hip joint, aiming to prevent postoperative thrombosis. As a result, no evidences of deep vein thrombosis and pulmonary embolism were identified in this study. Some studies have found that A poor reduction following femoral neck fracture is a risk factor for complications and femoral head necrosis[7]. In our study, all patients achieved a satisfactory reduction by the 1st day postoperatively and there was no significant difference between the two groups.

Pauwels angle reflects the interaction between compressive stress and shear force during the healing process of femoral neck fractures, which 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[8]. At present, it is considered that 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 other internal fixations on the treatment of vertical femoral neck fractures, and it may lead to shortening of the femoral neck and hip function damage, especially in osteoporosis patients[9]. Other evidences have shown that cannulated screw fixation is particularly suitable for the treatment of Garden $\square+\square$ and Pauwels $\square+\square$ femoral neck fractures[5, 10, 11]. According to our clinical experience, the effect of cannulated screws in the treatment of stable femoral neck fractures is basically satisfactory, but there are some problems in unstable femoral neck fractures. Due to the high price of FNS, we used FNS and cannulated screws for a comparative study for unstable femoral neck fractures (Pauwels type-3). We believe that a single cannulated screw lacks the angular stability, showing a poor ability against shear stress. Besides, a single screw is prone to longitudinally cut distal fractures, so the incidence of complications in the treatment of Pauwels type-3 femoral neck fracture is high.

FNS showed better biomechanical properties in the treatment of Pauwels type-3 femoral head fractures, which was consistent with previously reported studies. Karl et al. performed a biomechanical testing with a 0.1 N increase per cycle[12]. They compared the axial compression load and the cycle times for shortening 15 mm of femoral neck, respectively. It was found that FNS showed better overall structural stability than three cannulated screws. FNS is featured not only by the angular stability, but also the rotational stability. 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 had complications such as internal fixation loosening[13]. At the last follow-up in this study, the Harris score was significantly higher and the incidence of complications was lower in the FNS group. 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 allow fracture ends to closely contact each other and promote fracture healing.

In this study, there was no femoral head necrosis in the FNS group and 1 patient in the cannulated screw group. Some studies have found that the stability of femoral neck fractures is of great significance to the revascularization of the femoral head, and plays an important role in promoting bone healing and reducing the rate of femoral head necrosis[14, 15]. Moreover, It is reported that a large volume of implants may interfere with the revascularization of the femoral head and increase the incidence of femoral head necrosis[16]. The diameter of the screw bolt and the anti-rotation screw of FNS was 10 mm and 6.4 mm, respectively. The volume of FNS implants was significantly smaller than that of three cannulated screws. The combination and smaller size of the son-mother nail can effectively reduce the damage to the femoral head, and it is also beneficial to preserve the bone mass in the femoral neck. However, no significant difference in the incidence of femoral head necrosis was identified among groups, which may be attributed to a small sample size and a short period of follow-up.

Deficiencies in this retrospective analysis should not be neglected. First of all, the operating surgeon could independently select the implants, leading to a potential selection bias. However, we adopt a 1:1 pairing method to eliminate the interference of many factors to the experiment to the greatest extent, reduce the level of individual variation, and make the test group and the control group comparable. Secondly, because of the short time of appear on the market and 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 definitely ascertained. In the future study, a large sample size for a longer follow-up is 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, which is featured by accurate efficacy, simple procedures, less trauma, faster recovery and fewer complications, although 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

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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

She Yuanshi: Investigation

Zhang Xiangxin: Investigation

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Tables

Due to technical limitations, table 1 and table 2 are only available as a download in the Supplemental Files section.