Short-Term Clinical Efficacy of Femoral Neck System Versus Multiple Cannulated Compression Screws in the Treatment of Garden III and IV Femoral Neck Fractures

Xuefeng Zhou

The First Affiliated Hospital of USTC(Anhui Provincial Hospital)

Sichao Gu

The First Affiliated Hospital of USTC(Anhui Provincial Hospital)

Li Li

The First Affiliated Hospital of USTC(Anhui Provincial Hospital)

Lei Xu

The First Affiliated Hospital of USTC(Anhui Provincial Hospital)

Xujin Wang

The First Affiliated Hospital of USTC(Anhui Provincial Hospital)

Gang Wang

First Affiliated Hospital of Anhui Medical University

Xinzhong Xu

Second Hospital of Anhui Medical University

Jiazhao Yang

The First Affiliated Hospital of USTC(Anhui Provincial Hospital)

Shiyuan Fang (✉ fangshiyuan2008@126.com)

The First Affiliated Hospital of USTC(Anhui Provincial Hospital)

Research Article

Keywords: Femoral neck system, GardenIII and IV femoral neck fractures, intraoperative fluoroscopy

Posted Date: January 12th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1229275/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Femoral neck system (FNS) , as a novel minimally invasive internal fixation device, has been gradually applied in the treatment of femoral neck fracture. However, there are few related clinical studies on FNS at present, especially there is no clinical report on FNS in treating Garden III and IV femoral neck fractures. The aim of the present study was to compare the short-term clinical efficacy of FNS and multiple cannulated compression screws (MCCS) in the treatment of Garden III and IV femoral neck fractures. The data of 78 patients with femoral neck fracture who were admitted to three teaching hospitals affiliated to Anhui Medical University and received internal fixation with FNS and MCCS from June 2019 to December 2020 were collected for a retrospective study. There were 39 patients in both the FNS and MCCS groups. The basic data, perioperative data were recorded and compared between the two groups of patients. The results of the study are encouraging. The operation time was shorter in FNS group than that in MCCS group ($p < 0.001$). The post-operative partial and complete weight-bearing time was earlier in FNS group than that in MCCS group ($p < 0.001$). The Harris hip score in FNS group was higher than that in MCCS group ($p < 0.001$). The incidence rate of lateral thigh irritation in FNS group and MCCS group was 0 (0/39) and 33.3% (13/39), respectively ($\chi^2 = 15.600$, $p < 0.001$). The length of femoral neck shortening was significantly shorter in FNS group than that in MCCS group ($t = -5.093$, $p < 0.001$). In conclusion, The application of FNS for Garden III and IV femoral neck fractures can shorten the operation time, reduce the frequency of intraoperative fluoroscopy, and facilitate the recovery of hip joint function, so it provides a novel choice for the treatment of Garden III and IV femoral neck fractures in young people.

Background

With the rapid growth of population and the trend of aging, as well as the increased traffic accidents and fall injuries in the construction industry, the incidence rate of hip fractures has been rising annually. It is estimated that the worldwide incidence of hip fractures will increase to 2.6 million per year by 2025, of which about 50% are femoral neck fractures¹. By 2050, the number of patients with femoral neck fractures is expected to reach 6.5 million², which will impose an economic burden on society and become a major challenge facing orthopedic surgeons. Femoral neck fractures often occur in the elderly suffering from low-energy injuries such as a slight tumble³, while those in younger people are mostly caused by high-energy injuries such as car accident injuries and falls⁴. Femoral neck fracture in young people is mostly Garden III or IV type, namely partially or completely displaced fracture, and often presents a higher Pauwels angle, relatively vertical fracture cross-section and incomplete calcar femorale, and 96% of the patients have comminuted posterior and inferior femoral neck cortex⁵. In general, internal fixation with femoral head preservation, with advantages of less trauma, shorter operation time and less bleeding, is preferred for patients with femoral neck fracture below 65 years old. Moreover, it is also in line with the concept of preserving hip joint advocated by some scholars⁶. However, due to blood supply and special morphological anatomy of the femoral head, as well as the above characteristics of femoral neck fracture in young people, the overall incidence rate of post-operative complications and secondary operation rate are relatively high⁷, seriously affecting the quality of life and aggravating the burden of the

family. Therefore, how to improve the curative effect for the treatment of femoral neck fractures, especially femoral neck fractures with Garden III and IV complete fracture accompanied by displacement, and reduce the incidence rate of post-operative complications, has always been a hot issue in clinical research.

For Garden III and IV femoral neck fractures in young people, in spite of closed or open reduction and internal fixation, anatomical reduction and effective fixation are of great significance in obtaining good prognosis and function and reducing the incidence rate of complications⁸. As verified by numerous studies, improving reduction quality and achieving stable internal fixation contribute to the treatment of femoral neck fractures with satisfactory efficiency. In recent years, several different internal fixation implants such as multiple cannulated compression screws (MCCS), dynamic hip screw (DHS), sliding hip system (SHS) and proximal locking plate have been extensively applied to treat femoral neck fractures in young patients. Nevertheless, the proportion of patients undergoing revision surgery remains high⁹.

MCCS has been the most widely used internal fixation implant to date. In particular, three cannulated compression screws implanted in parallel in an inverted triangle manner are mostly commonly utilized for internal fixation in clinical practice. Cannulated compression screws have the features of less trauma and less interference with local blood supply and can provide greater tension. However, they cannot provide enough support for the femoral neck and prolong the post-operative healing time due to their dynamic compression characteristics⁹. Relevant studies have indicated that cannulated compression screws are available for patients with Garden I+II and Pauwels I+II femoral neck fractures¹⁰⁻¹². However, due to the lack of angular stability and poor shear stress resistance, their therapeutic efficiency for femoral neck fractures with Garden III and IV complete fracture accompanied by displacement and unstable femoral neck fractures with Pauwels angle $>50^{\circ}$ is not good enough, and the incidence rate of complications is relatively high. In recent years, based on locking steel plates combined with sliding compression principle, some new locking compression steel plate systems, such as Kangli hollow screws with sliding compression locking plate system (KHS)¹³ and proximal femoral internal fixation system (Targon® FN)¹⁴, have favorable biomechanical properties for Garden III and IV and vertical unstable femoral neck fractures, but larger incisions and relatively cumbersome operations are required for implantation. In order to take into account the two advantages of biomechanics and minimally invasive implantation, and dynamically fix the femoral neck fracture, the Swiss Hip Research Group and Depuy Synths Product Research Association have developed a novel minimally invasive implantable internal fixation device, called femoral neck system (FNS). Combined angular stability with minimally invasive surgical methods, this new implant is characterized by less trauma and stable resistance to shear and rotation^{1,15}, which may be a major advancement in the treatment of femoral neck fractures (Fig. 1).

However, there is limited clinical research on FNS at present, and the clinical effect remains unclear. In particular, there is no clinical case study on FNS for the treatment of Garden III and IV femoral neck fractures in young people. Based on the above, this current study aimed to compare the clinical outcomes of FNS and MCCS in the treatment of Garden III and IV femoral neck fractures, and to evaluate the short-

term efficacy of FNS in the treatment of Garden III and IV femoral neck fractures, so as to provide some evidence-based bases for clinical treatment and a reference for the selection of therapeutic options for femoral neck fractures in young patients.

Methods

Ethics approval This study has been approved by the Medical Ethics Committee of the three hospitals (Provincial Hospital Affiliated to Anhui Medical University: 2021-ER-042, The First Affiliated Hospital of Anhui Medical University: 202105313, and The Second Affiliated Hospital of Anhui Medical University: SL-LC2020-001). All procedures and methods performed in studies involving human participants were in accordance with the ethical standards of the institution or practice at which the studies were conducted. Informed consent was obtained from all individual participants included in the study. All baseline characteristics and clinical data of these patients were collected retrospectively from the electronic medical record system and imaging database of the hospital.

Hospital and Patients The inclusion criteria were as follows: a) patients aged 18-60 years old, b) those who received internal fixation with FNS or MCCA, c) those whose affected hip joint suffered fresh closed unilateral Garden III and IV femoral neck fracture caused by a first-time trauma, d) those with normal hip function before injury, e) those with no other injuries on the ipsilateral lower limb, and f) those with more than 6 months of follow-up and complete imaging data.

The exclusion criteria involved: a) patients with open fracture, b) those with old fracture, bone nonunion or internal fixation failure, c) those with pathological fracture, d) those with severe metabolic diseases such as diabetes or hyperthyroidism, or long-term medication of hormone drugs, e) those who were unable to complete the questionnaire due to communication disorders, or f) those who refused to participate in the study or were lost for follow-up.

Study design The data of 78 patients with femoral neck fracture who were admitted to three teaching hospitals affiliated to Anhui Medical University and received internal fixation with FNS and MCCA from June 2019 to December 2020 were collected for a retrospective study. There were 39 patients (male 27, female 12, aged 48.2 ± 7.2 years old) in FNS group, including 26 cases of Garden type III and 13 cases of type IV, and 39 patients of MCCA group, including 25 males, 14 females, aged 46.5 ± 8.5 years old, 24 cases of Garden III and 15 cases of Garden IV. The general data such as gender, age, BMI, injury cause, injured side, history of smoking and drinking, pre-operative Garden's classification, Pauwels angle and injury-to-operation duration showed no statistically significant differences between the two groups ($p > 0.05$), which were comparable (Table 1).

Surgical methods Doctors, who are highly experienced in reduction and internal fixation surgery for femoral neck fracture and have received FNS course training and operation exercise, were selected for the surgery. All patients received skin traction braking or temporary fixation with anti-rotation shoes, standard analgesia and anticoagulation treatments before operation. If the patients were complicated with

underlying diseases, relevant departments would assist in the diagnosis and treatment, and those with fracture in other parts were treated as usual.

Operative technique of the FNS group The main steps for FNS group are shown as follows. A) Reduction: The patient was usually first treated with abduction and external rotation and then adduction and internal rotation under traction, and the angles of internal and external rotation and adduction were adjusted according to the fluoroscopic conditions. If the position was unsatisfactory, percutaneous Kirschner-wire pry-poking reduction would be taken into account. Femoral neck reduction was confirmed by the front and lateral radiographs according to the Garden index, Lowell curve and the cortical support of the fracture end (positive support and negative support)¹⁶, and after satisfactory reduction, an anti-rotation guide pin was temporarily placed along the anterior upper part of the femoral neck to prevent femoral head rotation and reduction lost during subsequent operations. B) Incision: The positioning needle was placed outside the skin on the projection of lesser trochanter and medial axis of the femoral shaft, and an incision about 4 cm in length was made to separate the vastus lateralis muscle. C) Placement of central guide pin: After a 130° angled director was set close to the femoral shaft, the second guide pin was placed, on the axis line of femoral neck on the front fluoroscopic view, and on the medial axis of femoral neck and femoral head on the lateral fluoroscopic view, within 5 mm (in depth) of the subchondral bone. If the position of the central guide pin was not satisfactory, it would be slightly adjusted by a guide adjuster. D) Measurement of depth: Based on the principle of "preferably short rather than long", the power control rod closet to the model was selected according to the actually measured depth minus 5 mm (e.g. measured depth: 97 mm, 97-5=92, then 90 mm was selected). E) FNS placement: After drilling along the central guide pin to the lateral femur cortex using a reamer, the assembled power control rod and locking bone plate system were slightly knocked in along the direction of guide pin. Next, the anterior and posterior femur cortexes were touched to confirm that the steel plate was centered, followed by measuring depth, screwing the locking screw, and screwing the anti-rotation screw equal to the power control rod in length. F) Fracture end compression: The anti-rotation guide pin was removed, the traction was relaxed, the multi-function rod was placed through the director hole of anti-rotation screw and screwed, and finally the nut inserted into the handle was rotated counterclockwise to increase compression on the fracture end. The degree and effect of compression were determined by fluoroscopy.

The technical operation of the MCCS group is in accordance with the common practice of orthopaedic surgeons.

Outcome measurements and evaluation indicators The following data were collected from the electronic medical records and medical order system: incision length, intraoperative bleeding, operation time, fracture reduction quality, length of stay (LOS), hospitalization costs and early complications. The frequency of intraoperative fluoroscopy was collected from the C-arm image storage database in the operating room. The main observation indicators, including weight-bearing time, fracture healing, femoral neck shortening, femoral neck-shaft angle change, lateral thigh irritation symptoms, Harris hip score, internal fixation failure, osteonecrosis of the femoral head (ONFH), *etc.*, were evaluated at the final follow-up visit.

Early complications included infection of operative incision, urinary tract infection (UTI), pulmonary infection, DVT, *etc.*

Femoral neck shortening was measured according to the exposed screw length measuring method of Sepehri *et al*¹⁷. Due to the integrity of FNS design, the power control rod and the anti-rotation screw served as a cross-integrated structure, so that the distance between the tail end of power control rod and the outer edge of locking steel plate could be measured directly to evaluate the femoral neck shortening.

Statistical approach All statistical analyses were performed using SPSS 25.0 (SPSS Inc., Chicago, IL, USA). The measurement data following normal distribution were expressed as mean $\pm$ standard deviation, and independent-samples *t* test was adopted for intergroup comparisons. The measurement data without normal distribution were expressed as median (interquartile range), and rank sum test was conducted for intergroup comparisons. Intergroup rates were compared through χ^2 test or Fisher's exact test. Moreover, rank sum test was carried out to compare intergroup grade data. Significance level was defined as $\alpha=0.05$.

Results

The general data such as gender, age, BMI, history of smoking and alcohol abuse, injured side, fracture classification, injury cause and injury-to-operation duration showed no statistically significant differences between the two groups ($p>0.05$), which were comparable (Table 1).

The operation time was shorter in FNS group than that in M CCS group [(46.5 $\pm$ 8.6) min vs. (64.3 $\pm$ 12.5) min], showing a statistically significant difference ($Z=-7.326$, $p<0.001$). The incision length in FNS group was greater than that in M CCS group, and the difference was statistically significant ($Z=2.159$, $p=0.031$). The frequency of intraoperative fluoroscopy in FNS group (24.5 $\pm$ 6.4) was less than that in M CCS group [36.7 $\pm$ 7.1], suggesting a statistically significant difference ($p<0.001$). The hospitalization costs (45896 $\pm$ 2673 CNY) in FNS group were higher than those (17689 $\pm$ 1853 CNY) in M CCS group, indicating statistically significant differences. The differences in the intraoperative bleeding, Garden index, cortical support rate of the fracture end, LOS and early complications were of no statistical significance between the two groups ($p>0.05$). No patients were found with the infection of operative incision. There was 1 case of DVT and 2 cases of UTI in the FNS group, and 2 cases of DVT, 1 case of UTI and 1 case of pulmonary contusion with pulmonary infection in the M CCS group. All of the abovementioned cases were cured after symptomatic treatment through consultation by related departments (Table 2).

The patients were followed up for 8-22 months [(11.4 $\pm$ 2.8) months averagely] in FNS group and for 9-24 months [(11.6 $\pm$ 2.4) months averagely] in M CCS group, and the difference was not statistically significant. Both groups of patients acquired good fracture healing at the final follow-up visit, and there were no statistically significant differences in incidence rate of ONFH and internal fixation failure. However, the fracture healing time of FNS group was shorter than that of M CCS group, and the difference was statistically significant. The Harris hip score in FNS group was higher than that in M CCS group

[94.0(92.0,95.0) vs.91.0(89.0,94.0)] ($z=5.371$, $p<0.001$). Moreover, the post-operative complete and partial weight-bearing time in FNS group was about 4 weeks earlier than that in M CCS group ($p<0.001$). The incidence rate of lateral thigh irritation in FNS group and M CCS group was 0 (0/39) and 33.3% (13/39), respectively ($\chi^2=15.600$, $p<0.001$), and the length of femoral neck shortening in FNS group and M CCS group was (4.1 ± 2.2) mm and (7.2 ± 3.1) mm, respectively ($t=-5.093$, $p<0.001$), suggesting statistically significant differences. Although femoral neck-shaft angle change in FNS group was smaller than that in M CCS group, the difference was of no statistical significance ($p=0.116$) (Table 3). The typical case in FNS group is presented (Fig. 2).

Discussion

According to the latest information released by the World Health Organization, young people are defined as those who are 18-65 years old¹⁸. Clinically, femoral neck fracture occurring in people aged 18-65 years old is usually referred to as femoral neck fracture in young people. Due to high femoral neck bone mineral density and hard bone substance, the fracture in young people is mostly caused by high-energy injuries, namely violent injuries, resulting in fracture displacement and seriously impaired local blood supply, along with bony defect in the posterior neck of the femur, which is generally called Garden III and IV fractures in clinical practice. It is well known that the internal fixation of femoral neck fracture has been a major difficulty faced by orthopedists due to the high incidence rate of post-operative complications and secondary operation rate. Femoral neck fracture in young patients less than 65 years old is more challenging because of high-energy traumatic mechanism and fracture displacement, and after internal fixation, femoral neck fracture is prone to serious complications, such as bone unhealing, femoral neck shortening, internal fixation failure, coxa vara and coxa valga deformities and ONFH^{19,20}, so it is called "unsolved fracture"²¹, which has greatly driven scholars to continuously explore the treatment of femoral neck fractures. The studies have mainly focused on the following three aspects: fracture reduction, selection of internal fixation methods, and blood supply of femoral head. The anatomical reduction of fracture and secure and stable internal fixation are the key factors reducing the abovementioned complications. Based on favorable fracture reduction, the selection of internal fixation methods and implants, without any doubt, is the most important influencing factor. Recent studies have also shown that the therapeutic effect can be affected by the selection of implants, over which controversies still exist²². With the advancement of studies, ideal implants conforming to the internal fixation of femoral neck fracture should not only accord with the concept of minimally invasive implantation but also have good biochemical properties, which is a general consensus gradually reached by scholars.

The advantages of FNS and the reasons for their formation are analyzed as follows. First, FNS has biomechanical advantages. FNS, which is mainly composed of four components: power control rod, anti-rotation screw (ARS), bone plate and locking screw, integrates the merits of multiple internal fixation devices. The cylindrical power control rod designed to maintain the reduction in the implantation process presents a 130° angle with the bone plate, which ensures angular stability. Besides, the cross-over design of the power control rod presenting a 7.5° angle with ARS guarantees rotational stability. Meanwhile, the

"Z" effect of femoral head truncation is avoided, and the overall stability is enhanced. In a biomechanical study, Stoffel K *et al*¹. verified that the mechanical stability of FNS was equivalent to that of DHS, and its rotational stability and support strength were 1.5 times and twice those of M CCS, respectively. By comparing FNS with Hansson pins in a study, Schopper C *et al*¹⁵. also proved that FNS showed a higher stability than Hansson pins in the treatment of femoral neck fracture and FNS was an effective alternative method for treating displaced and unstable femoral neck fractures, and capable of reducing mechanical instability-induced revision. The above viewpoints were also verified in this study as follows: A) The post-operative partial and complete weight-bearing time in FNS group was 4 weeks earlier than that in M CCS group, manifesting the superior mechanical stability of FNS. B) The initial fracture morphology of one patient in M CCS group was Garden IV type. This patient experienced position loss, internal fixation failure and Varus deformity of hip in the follow-up visit which was considered as a mechanical failure. FNS fixation was performed during revision surgery, and satisfying therapeutic effect was achieved, powerfully proving the biomechanical advantages of FNS. C) Related studies²³⁻²⁵ have revealed that the occurrence of post-operative femoral neck shortening is directly influenced by the reduction quality of femoral neck fracture and the biomechanical stability of internal fixation. In this study, the incidence rate of femoral neck shortening in FNS group was evidently lower than that in M CCS group, which may be associated with the better biomechanical properties in FNS group. Previous biomechanical studies¹ have also proved that the FNS structure plays a critical role in the resistance against femoral neck shortening. D) In comparison with M CCS group, the loss of femoral neck-shaft angle in FNS group was reduced, which may be ascribed to the insufficient shear force used by M CCS to withstand femoral neck fracture. Some recent biomechanical studies have also displayed that FNS is of favorable vara resistance by virtue of its angular stability, so the loss of neck-shaft angle can be reduced.

Secondly, while providing sliding compression, FNS can effectively prevent implant protrusion and mitigate the irritation caused by the implant protrusion to the soft tissues of thighs. The power control rod and ARS of FNS are slidable, where the maximum sliding distance of the former is 20 mm, and the backward sliding within the first 15 mm can ensure that the power control rod does not protrude outward at all. This design of FNS avoids the irritation generated by implant protrusion to the soft tissues of thighs and reduces the incidence rate of pain in thighs, which accords with the results in this study. Moreover, it was believed in this study that it might also be one of the reasons why the Harris hip score in FNS group was higher than that in M CCS group.

Thirdly, the implant characterized by small volume and safety design can better prevent the loss of bone mass in the femoral neck. The diameters of power control rod and ARS in FNS are 10 and 6.4 mm, respectively, so the implant volume in FNS is obviously smaller than that of 3 and even 4 cannulated compression screws (the diameter is generally 7.5 mm). Moreover, the cylinder design of power control rod and the round blunt design at the top of ARS effectively avoid the cutting phenomenon and prevent the screws from protruding out of femoral head. In addition, the compact combination and small size of son-mother screws are capable of effectively reducing the injury of femoral head and reserving the bone mass of femoral neck.

In addition, the operation is relatively simple and convenient, along with short learning curve and reduced operation time. The repeated fluoroscopy and adjustment can be effectively avoided during operation, thus reducing the radiant quantity of X rays, which has been reported by Yang et al²⁶. and also well embodied in our study. Moreover, it has been realized in clinical practice that the operation time and frequency of fluoroscopy will be relatively further reduced with the increased operation cases and enhanced technical proficiency.

Finally, the trauma is small thanks to the minimally invasive implantation. The whole operation can generally be completed just by a small incision with the length of about 4-5 cm. It is only necessary to cut partial vastus lateralis muscle open, which will not result in the tendon injury of gluteus medius or post-operative irritation of gluteus medius²⁷. Besides, the small outer bone plate of FNS can shrink the footprint surface of implant while ensuring the secure fixation with the femoral shaft, which can, to some extent, alleviate the irritation induced by the implantation to the surrounding soft tissues and the post-operative foreign body sensation generated by the implant.

It should be pointed out that in terms of length of operative incision, the open incision (4-5 cm) in FNS group was longer than that in M CCS group, with a statistically significant difference. Nevertheless, the difference between the two groups in concrete numerical value was small, and the amounts of intraoperative bleeding were equivalent, so it was reflected that both internal fixation methods embodied the concept of minimally invasive treatment. Meanwhile, an inevitable problem was that the current cost of one set of FNS components is significantly higher than that of three cannulated screws, so the study results revealed that the hospitalization costs in FNS group were higher than those in M CCS group, which was one of the very few disadvantages of FNS in comparison with M CCS.

This study was a multicenter retrospective study, but there were some limitations. First, the cases were not randomly selected in the retrospective study, which may cause selection bias. Second, The clinical results may also be affected by the relatively small sample size and short follow-up period. In the end, three main complications, namely ONFH, femoral neck shortening and bone nonunion, should be observed after the internal fixation of femoral neck fracture. Due to the short follow-up period in this study, only femoral neck shortening and fracture healing can be reported through an early study, while the further follow-up observation of ONFH remains to be done. In addition, the long-term function of internal fixation for femoral neck fracture should be followed up and further evaluated.

To sum up, by comparing FNS with M CCS in treating Garden III and IV femoral neck fractures, it is reflected that FNS is featured by simple and convenient operation, shorter operation time and earlier post-operative weight bearing. Meanwhile, FNS displays superior biomechanical properties and clinical effects, providing a new treatment choice for femoral neck fractures in young people, especially the complete fracture accompanied by displacement.

Declaration

Acknowledgements

The authors would like to thank all study participants who were enrolled in this study.

Author contribution

S.Y.F., J.Z.Y. and X.F.Z. developed the study concept. All authors were responsible for the design of the study. X.F.Z. and J.Z.Y. collected the case data and imaging data. X.F.Z. and S.C.G. performed the analysis and wrote the manuscript. All authors commented on the manuscript and approved the final version.

Additional Information

Competing interests The authors declare no competing interests.

Correspondence and requests for materials should be addressed to S.R.F. or J.Z.Y.

Reference

1. Stoffel, K. *et al.* Biomechanical Evaluation of the Femoral Neck System in Unstable Pauwels III Femoral Neck Fractures: A Comparison with the Dynamic Hip Screw and Cannulated Screws. *Journal of Orthopaedic Trauma* **31**, 131–137 (2017).
2. Cooper, C., Campion, G. & Melton, L. J. Hip fractures in the elderly: A world-wide projection. *Osteoporosis Int* **2**, 285–289 (1992).
3. Stevens, J. A. & Rudd, R. A. The impact of decreasing U.S. hip fracture rates on future hip fracture estimates. *Osteoporos Int* **24**, 2725–2728 (2013).
4. Slobogean, G. P., Sprague, S. A., Scott, T. & Bhandari, M. Complications following young femoral neck fractures. *Injury* **46**, 484–491 (2015).
5. Ni, M., Sun, W. & Ye, Y. Research progress of medial buttress plate assisted fixation for femoral neck fractures in young adults. *Chinese Journal of Reparative and Reconstructive Surgery* **34**, 1454–1457 (2020).
6. Gavaskar, A. S. & Chowdary, N. T. Valgus sliding subtrochanteric osteotomy for neglected fractures of the proximal femur; surgical technique and a retrospective case series. *J Orthop Surg Res* **8**, 4 (2013).
7. Gao, Z., Wang, M., Shen, B., Chu, X. & Ruan, D. Treatment of Pauwels type III femoral neck fracture with medial femoral neck support screw: a biomechanical and clinical study. *Sci Rep* **11**, 21418 (2021).
8. Hegazy, M. *et al.* Treatment of non-united femoral neck fracture by a novel subtrochanteric angulation lateral translation valgus osteotomy (SALVA osteotomy). *International Orthopaedics (SICOT)* **44**, 2421–2430 (2020).
9. Zhou, X., Li, Z. & Xu, R. Comparison of Early Clinical Results for Femoral Neck System and Cannulated Screws in the Treatment of Unstable Femoral Neck Fractures. *Orthopaedic Surgery* **13**,

1802-1809 (2021).

10. Panteli, M., Rodham, P. & Giannoudis, P. V. Biomechanical rationale for implant choices in femoral neck fracture fixation in the non-elderly. *Injury* **46**, 445–452 (2015).
11. Ju, F. *et al.* Outcomes of Femoral Neck Fractures Treated with Cannulated Internal Fixation in Elderly Patients: A Long-Term Follow-Up Study. *Orthop Surg* **12**, 809–818 (2020).
12. Hoskinson, S., Morison, Z., Shahrokhi, S. & Schemitsch, E. H. Managing AVN following internal fixation: Treatment options and clinical results. *Injury* **46**, 497–506 (2015).
13. Hu, J.-l. *et al.* Evaluation of Kangli hollow screws with sliding compression locking plate system for treatment of femoral neck fractures. *Chinese Journal of Orthopaedic Trauma* **21**, 939-944 (2019).
14. Matar, H. E. & Chandran, P. Outcomes of internal fixation of intracapsular hip fractures using dynamic locking plate system (Targon® FN). *Journal of Orthopaedics* **15**, 829–831 (2018).
15. Schopper, C. *et al.* Higher stability and more predictive fixation with the Femoral Neck System versus Hansson Pins in femoral neck fractures Pauwels II. *Journal of Orthopaedic Translation* **24**, 88–95 (2020).
16. Xiong, W.-F., Chang, S.-M., Zhang, Y.-Q., Hu, S.-J. & Du, S.-C. Inferior calcar buttress reduction pattern for displaced femoral neck fractures in young adults: a preliminary report and an effective alternative. *J Orthop Surg Res* **14**, 70 (2019).
17. Sepehri, A. *et al.* Measuring Lateral Screw Protuberance Is a Clinically Accurate Method for Quantifying Femoral Neck Shortening. *Journal of Orthopaedic Trauma* **34**, 600–605 (2020).
18. Medda, S., Snoap, T. & Carroll, E. A. Treatment of Young Femoral Neck Fractures. *Journal of Orthopaedic Trauma* **33**, S1–S6 (2019).
19. Duffin, M. & Pilson, H. T. Technologies for Young Femoral Neck Fracture Fixation. *Journal of Orthopaedic Trauma* **33**, S20–S26 (2019).
20. Slobogean, G. P. *et al.* Femoral neck shortening in adult patients under the age of 55 years is associated with worse functional outcomes: Analysis of the prospective multi-center study of hip fracture outcomes in China (SHOC). *Injury* **48**, 1837–1842 (2017).
21. Li, M. & Cole, P. A. Anatomical considerations in adult femoral neck fractures: how anatomy influences the treatment issues? *Injury* **46**, 453-458 (2015).
22. Alizade, C., Jafarov, A., Alizada, F., Gülsen, M. & Togrul, E. Efficiency of an implant: new criterion of objective assessment of implants for osteosynthesis of femoral neck fracture. *International Orthopaedics (SICOT)* **44**, 569–575 (2020).
23. Weil, Y. A. *et al.* Femoral Neck Shortening and Varus Collapse After Navigated Fixation of Intracapsular Femoral Neck Fractures. *Journal of Orthopaedic Trauma* **26**, 19–23 (2012).
24. Min, B.-W. *et al.* Result of Internal Fixation for Stable Femoral Neck Fractures in Elderly Patients. *Hip Pelvis* **28**, 43 (2016).
25. Sung, Y.-B., Jung, E.-Y., Kim, K.-I. & Kim, S.-Y. Risk Factors for Neck Shortening in Patients with Valgus Impacted Femoral Neck Fractures Treated with Three Parallel Screws: Is Bone Density an Affecting

Factor? *Hip Pelvis* **29**, 277 (2017).

26. Yang, Y.-J. et al. Short-term effectiveness of femoral neck system in the treatment of femoral neck fracture. *Chinese Journal of Reparative and Reconstructive Surgery* **35**, 539-543 (2021) .
27. de Jong, L., Klem, T. M. A. L., Kuijper, T. M. & Roukema, G. R. The minimally invasive anterolateral approach versus the traditional anterolateral approach (Watson-Jones) for hip hemiarthroplasty after a femoral neck fracture: an analysis of clinical outcomes. *International Orthopaedics (SICOT)* **42**, 1943–1948 (2018).

Tables

Table 1. Comparison of general data between the two groups. *FNS* femoral neck system, *MCCS* multiple cannulated compression screws, *BMI* body mass index. Note In the Cause of injury, A stands for Fall, B stands for Traffic accident, C stands for Falling.

Factor	FNS group	MCCS group	Statistics	P value
Total number(n)	39	39		
Gender				
Male	27	25	0.231	0.631
Female	12	14		
Age years, $\bar{x} \pm s$	48.2±7.2	46.5±8.5	0.953	0.344
Smoking (n,%)	15[38.5%]	12[30.8%]	0.510	0.475
Alcohol abuse (n,%)	16[41.0%]	12[30.8%]	0.891	0.345
BMI[$\bar{x} \pm s$]	22.5±2.3	21.8±2.1	1.404	0.165
Injured side				
Left	24	15	0.212	0.645
Right	22	17		
Garden classification				
I	26	13	0.223	0.637
II	24	15		
Pauwels angle°, $\bar{x} \pm s$	52.5±9.7	51.1±11.2	0.590	0.557
Cause of injury				
A	9	7	1.145	0.564
B	22	20		
C	8	12		
Time from injury to operation [<i>d</i> , <i>M</i> (<i>P</i> ₂₅ , <i>P</i> ₇₅)]	3[2.0,4.0]	3[2.0,4.0]	1.267	0.205

Table 2. Comparison of perioperative data and clinical indexes between the two groups.

Parameter	FNS group	MCCS group	Statistics	P value
Total number(n)	39	39		
Operation time⌈min, $\bar{x}\pm s$ ⌋	46.5±8.6	64.3±12.5	-7.326	<0.001
Incision length [cm, $M(P_{25}, P_{75})$]	4.0(3.0,5.0)	3.0(2.0,5.0)	2.159	0.031
Intraoperative blood loss [ml, $M(P_{25}, P_{75})$]	24(16.0,32.0)	22(15.0,30.0)	1.912	0.056
The frequency of intraoperative fluoroscopy ⌈n, $\bar{x}\pm s$ ⌋	24.5±6.4	36.7±7.1	-7.971	<0.001
Garden index⌈n⌋				
I	28	21	-1.618	0.106
II	7	11		
III	4	7		
Cortical support of the fracture end				
Positive	14	16	-0.263	0.793
Anatomica	22	19		
Negative	3	4		
Hospitalization stay [$d, M(P_{25}, P_{75})$]	3.0(2.0,4.0)	3.0(2.0,4.0)	1.583	0.113
Hospitalization costs⌈CNY, $\bar{x}\pm s$ ⌋	45896±2673	17689±1853	54.160	<0.001
Early complications (n,%)	3(7.7%)	4(10.3%)	-	1.000*

* Fisher's exact probability method was used. "-" indicates no data.

Table 3. Comparison of prognostic data and clinical indexes between the two groups.

Parameter	FNS group	MCCS group	Statistics	P value
Total number(n)	39	39		
Follow-up time [months, $\bar{x} \pm s$]	11.4 $\pm$ 2.8	11.6 $\pm$ 2.4	-0.339	0.736
Fracture healing time [months, $M(P_{25}, P_{75})$]	3.0(2.0,4.0)	3.0(2.0,4.0)	2.876	0.004
Harris score [points, $M(P_{25}, P_{75})$]	94.0(92.0,95.0)	91.0(89.0,94.0)	5.371	<0.001
Lateral thigh irritation (n,%)	0(0%)	13(33.3%)	15.600	<0.001
Post-operative weight bearing time				
Partly [$M(P_{25}, P_{75})$]	2.0(1.0,3.0)	7.0(3.0,10.0)	-14.573	<0.001
Completely [$\bar{x} \pm s$]	5.4 $\pm$ 1.8	9.7 $\pm$ 2.4	-8.951	<0.001
Femoral neck shortening length[mm, $\bar{x} \pm s$]	4.1 $\pm$ 2.2	7.2 $\pm$ 3.1	-5.093	<0.001
Change of caput-collumdiaphysis angle [$M(P_{25}, P_{75})$]	3.0(2.0,5.0)	3.8(2.1,7.6)	-1.572	0.116
ONFH [%n]	0(0/39)	2.6(1/39)	-	1.000*
Internal fixation failure (n,%)	0(0/39)	2.6(1/39)	-	1.000*

ONFH osteonecrosis of the femoral head. * Fisher's exact probability method was used. "-" indicates no data.

Figures

Figure 1

Design features of FNS Integrated assembly: (i) the plate and locking screw in the angular stable structure (neck-shaft angle = 130°, size of the locking screw = 5.0 mm); (ii) a round, blunt-headed bolt (diameter = 10 mm); (iii) a round, blunt-headed antirotation screw that can be locked to the bolt (diameter = 6.4 mm, antirotation screw-bolt angle = 7.5°) (a). Physical diagram of FNS (b). Separate components of FNS: Locking Screw, Antirotation ARScrew, Bolt, Plate (c).

Figure 2

A 50-year-old female patient with a left femoral neck fracture by traffic accident (Garden type II, Pauwels type III) in the FNS group. Pre-operative anteroposterior X-ray film of bilateral hip joints (**a**). Pre-operative CT three-dimensional reconstruction of left hip joint—it can be seen that the fracture is completely displaced (**b**). Intraoperative anteroposterior and lateral X-ray films showed fracture reduction and internal fixation were in good position (**c-d**). The length of intraoperative incision is about 2cm (**e**). Anteroposterior X-ray film of bilateral hip joints at 2 days after operation (**f**). Anteroposterior X-ray film of bilateral hip joints at 12 months after operation showed fracture healing and no shortening of the femoral neck (**g**).