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hamdan3802@hotmail.com

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META-ANALYSIS

Efficacy of the femoral neck system in femoral neck fracture treatment in adults: A systematic review and meta-analysis

Zhi-Fang Wu, Zi-Heng Luo, Liu-Chao Hu, Yi-Wen Luo

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Zhi-Fang Wu, Zi-Heng Luo, Liu-Chao Hu, Yi-Wen Luo, Department of Orthopedics and Trauma, The Third Affiliated Hospital of Guangzhou University of Chinese Medicine (Guangdong Research Institute for Orthopedics and Traumatology of Chinese Medicine), Guangzhou 510378, Guangdong Province, China

Corresponding author: Yi-Wen Luo, PhD, Chief Doctor, Department of Orthopedics and Trauma, The Third Affiliated Hospital of Guangzhou University of Chinese Medicine (Guangdong Research Institute for Orthopedics and Traumatology of Chinese Medicine), No. 261 Longxi Road, Liwan District, Guangzhou 510378, Guangdong Province, China.
gzzyydxlyw@126.com

Abstract

BACKGROUND

Controversy remains around the available choices for the internal fixation of a femoral neck fracture. The femoral neck system (FNS) was developed in 2018 and has been widely applied since then as it can provide rigid fixation stability with less damage to the bone mass around the fracture. However, no systematic reviews and meta-analyses have investigated the efficacy of the FNS in comparison with that of traditional internal fixation in the treatment of femoral fractures.

AIM

To assess the efficacy of the FNS in comparison with that of cannulated compression screws (CCS) in the treatment of femoral fractures through systematic review and meta-analysis.

METHODS

Five electronic databases (PubMed, Embase, Cochrane Central Register of Controlled Trials, China National Knowledge Infrastructure, and Wanfang) were searched from the earliest publication date to December 31, 2021. Reference Citation Analysis (https://www.referencecitationanalysis.com/) was used to check the results and further analyze the related articles. Controlled trials were included if the FNS was applied for the femoral neck fracture in adults and if it was compared with CCS for the achievement of internal fixation. The measurement outcomes included the required operation time, observed patient's blood loss, extent of fracture healing, patient's Harris Hip score (HHS) at the last follow-up, and records of any complications (such as failure of internal fixation, femoral neck shortness, avascular necrosis of the femoral head, and delayed union

or nonunion).

RESULTS

Ten retrospective controlled studies (involving 711 participants) were included in this meta-analysis. The meta-analysis showed that compared with CCS, use of the FNS could not decrease the operation time [standardized mean difference (SMD): -0.38, 95% confidence interval (CI): -0.98 to 0.22, P = 0.21, I^2 = 93%), but it could increase the intraoperative blood loss (SMD: 0.59, 95%CI: 0.15 to 1.03, P = 0.009, I^2 = 81%). The pooled results also showed that compared with CCS, the FNS could better promote fracture healing (SMD: -0.97, 95%CI: -1.65 to -0.30, P = 0.005, I^2 = 91%), improve the HHS at the last follow-up (SMD: 0.76, 95%CI: 0.31 to 1.21, P = 0.0009, I^2 = 84%), and reduce the chances of developing femoral neck shortness (OR: 0.29, 95%CI: 0.14 to 0.61, P = 0.001, I^2 = 0%) and delayed union or nonunion (OR: 0.47, 95%CI: 0.30 to 0.73, P = 0.001; I^2 = 0%) in adult patients with femoral neck fractures. However, there was no statistically significant difference between the FNS and CCS in terms of failure of internal fixation (OR: 0.49, 95%CI: 0.23 to 1.06, P = 0.07, I^2 = 0%) and avascular necrosis of the femoral head (OR: 0.46, 95%CI: 0.20 to 1.10, P = 0.08, I^2 = 0%).

CONCLUSION

Compared with CCS, the FNS could decrease the chances of developing femoral neck shortness and delayed union or nonunion in adults with femoral neck fractures. Simultaneously, it could accelerate fracture healing and improve the HHS in these patients.

Key Words: Femoral neck fracture; Internal fixators; Treatment outcome; Systematic review; Meta-analysis

Core Tip: This study aimed to investigate the efficacy of the femoral neck system (FNS) in comparison with cannulated compression screws (CCS) in the treatment of femoral neck fractures in adults. A total of 10 studies involving 711 participants were included. This study revealed that compared with CCS, the FNS could decrease the chances of developing short femoral neck and delayed union or nonunion as well as accelerate fracture healing and improve the Harris Hip score at the last follow-up in adult patients with femoral neck fractures. These results could help in the selection of the most appropriate treatment for patients with femoral neck fractures.

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INTRODUCTION

Femoral neck fracture is one of the most common traumatic injuries, and it is believed to occur in 150000 patients per year in the United States (US) alone[1]. The incidence of this type of injury is increasing among elderly patients, and it is expected to exceed 250000 cases per year in the next 25 years, thereby accounting for approximately 50% of hip fracture cases in the US[2,3]. A femoral neck fracture can seriously affect the patient's quality of life and increase the risk of severe complications[4].

Patients with femoral neck fractures tend to be treated surgically. Most elderly patients with displaced femoral fractures receive the golden standard treatment involving hemiarthroplasty or total hip arthroplasty[5]. However, there remains controversy regarding the choice of treatment for nondisplaced femoral neck fractures in the elderly and younger adult patients. Recent studies have demonstrated that the issues associated with existing internal fixation methods, such as the lack of an antirotation force, nail back, and loosening, can have a negative impact on the offset of femoral neck fractures, which may ultimately necessitate reoperation[6,7]. Several commonly used implants for establishing internal fixation in the femoral neck fracture include cannulate screws, dynamic hip screws, compression locking plates, and other newer plate systems.

In recent years, the femoral neck system (FNS; DePuy-Synthes, Johnson & Johnson Medical Devices, New Brunswick, NJ, United States) has been developed for the treatment of femoral neck fractures. The FNS requires minimal invasion and exerts antirotation, antisliding, and antishearing forces. However, there is insufficient evidence on the efficacy of the FNS in the treatment of femoral fractures when

compared with traditional internal fixation methods. The aim of this study was to provide a systematic review of the literature in order to examine the efficacy of the FNS in the treatment of femoral neck fractures in adults.

MATERIALS AND METHODS

Search strategy

Five electronic databases (PubMed, Embase, Cochrane Central Register of Controlled Trials, China National Knowledge Infrastructure, and Wanfang) were searched from the earliest publication date to December 31, 2021. The PubMed search strategy was as follows: (((((femoral neck fracture[Title/Abstract]) OR (femoral neck fractures[Title/Abstract])) OR (femur neck fracture[Title/Abstract])) OR (femur neck fractures[Title/Abstract])) OR ("femoral neck fractures"[MeSH])) AND ((femoral neck system[Title/Abstract]) OR (FNS[Title/Abstract])) AND ((internal fixation[Title/Abstract]) OR (implant[Title/Abstract])). Additionally, references of the included studies were screened to collect as many relevant studies as possible. There were no restrictions on the language of the screened studies. The search was independently conducted by two authors. Any cases of disagreements were resolved by the third author. Reference Citation Analysis (https://www.referencecitationanalysis.com/) was used to check the results and further analyze the related articles.

Study selection

Inclusion criteria: A study was included if: (1) It was a randomized controlled trial (RCT) or a controlled clinical trial; (2) It discussed patients aged > 18 years with femoral neck fractures; (3) The patients were treated with internal fixation; (4) There was a comparison between the FNS and cannulated compression screws (CCS); and (5) It was available as a full-text article.

Exclusion criteria: A study was excluded if: (1) The patients did not suffer from a femoral neck fracture; (2) It was not a clinical study (*e.g.*, basic research articles, review articles, case reports, *etc.*); (3) The patients suffered from pathological fractures and necrosis of the femoral head; (4) The control group did not refer to patients treated with CCS; and (5) The statistical methodologies used were inappropriate.

Data extraction and outcome measures

Data extraction from the included studies was independently undertaken by two authors. Data included the first author's name, publication year, patient sample size, patients' age, intervention group characteristics, control group characteristics, follow-up time, test type, outcome measurements, and fracture types. The outcome measurements included operation time, intraoperative blood loss, fracture healing time, hip function outcomes, and recorded complications. The failure of internal fixation of complications was defined by incidents involving screw loosening, back-offs, and penetration.

Assessment of bias risk and methodological quality of the included studies

The methodological quality of the included studies was independently assessed by two authors. The quality of each nonrandomized controlled study was assessed according to the methodological index for nonrandomized studies (MINORS) entry based on the MINORS scores: Studies with scores of > 12 were included[8]. The quality of each RCT was assessed by using the Cochrane Collaboration tool based on the following factors: random sequence generation, allocation concealment, participant and personnel blinding, outcome assessment blinding, incomplete outcome data, selective reporting, and other biases. Any dispute between the two authors was resolved *via* mutual discussion or with the assistance of the third author.

Statistical analysis

Both the meta-analysis and statistical analysis were performed using RevMan version 5.3 (Cochrane London, United Kingdom). Odds ratio (OR) and 95% confidence interval (CI) were used for dichotomous data analyses. Continuous data were presented as mean difference (MD) or standardized MD (SMD) and 95%CI. The Cochrane I^2 test was used for assessing heterogeneity among the analyzed studies. Quartile data were converted into median and deviation with the use of an online resource (https://www.math.hkbu.edu.hk/); if the data skewed away from normality, they were subsequently excluded from the meta-analysis[9,10]. A random-effects model was applied if I^2 was > 50%; otherwise, a fixed-effects model was applied. A P value of < 0.05 was considered to indicate statistical significance. This study was a systematic review and meta-analysis and did not require ethical approval. All data were obtained from published papers.

RESULTS

Study selection

A total of 94 studies were initially identified from the search of the aforementioned 5 electronic databases. After eliminating duplicates, the titles and abstracts of 71 relevant studies were screened. Of these, 61 studies were excluded for various reasons (*e.g.*, studies referring to nonclinical trials, studies that were not RCTs or controlled trials, studies including a different diagnosis, studies using a different intervention, studies presenting duplicate data, and studies characterized by data defects). Based on their full text, 10 studies[11-20] conformed to the set inclusion criteria. The literature search procedure followed herein is illustrated in Figure 1.

Characteristics of the included studies

As shown in Table 1, the included studies were 10 retrospective controlled studies with a total of 711 participants. All of these studies compared use of the FNS with the use of CCS. Other detailed characteristics of these studies are presented in Table 1.

Risk of bias assessment

The RCTs' risk of bias assessment was evaluated using the Cochrane Collaboration tool. The results showed that there were no RCTs among the included studies. For the retrospective controlled studies, MINORS was used to assess the methodological quality. The interval scores of these were 17-19 points. Among these studies, two scored 17 points, six scored 18 points, and two scored 19 points in the MINORS assessment. Thus, the current meta-analysis is characterized by methodological quality limitations.

Operation time

In the meta-analysis presented in Figure 2A, 10 articles were included to analyze the operation time required for the surgical treatment of femoral neck fractures. The pooled results of included articles showed that compared with CCS, the FNS could not decrease the required operation time (SMD: -0.38, 95%CI: -0.98 to 0.22, $P = 0.21$, $I^2 = 93\%$).

Blood loss

Seven studies reported blood loss, as presented in Figure 2B. The random-effects model was used due to the high level of heterogeneity observed ($P < 0.001$, $I^2 = 81\%$). The pooled results of these trials revealed that compared with CCS, the FNS could increase intraoperative blood loss (SMD: 0.59, 95%CI: 0.15 to 1.03, $P = 0.009$, $I^2 = 81\%$).

Fracture healing time

Among the studies included in this meta-analysis, seven studies, which included 510 participants, reported the fracture healing time (see Figure 2C). The random-effects model was used due to the high level of heterogeneity observed ($P < 0.001$, $I^2 = 91\%$). The pooled results of these trials revealed that compared with CCS, the FNS could shorten the fracture healing time (SMD: -0.97, 95%CI: -1.65 to -0.30, $P = 0.005$, $I^2 = 91\%$).

Harris Hip score at the last follow-up

Eight studies were included in the analysis of the Harris Hip score (HHS) at the last follow-up (Figure 2D). The random-effects model was used due to the high level of heterogeneity observed ($P < 0.001$, $I^2 = 86\%$). The meta-analysis revealed that compared with CCS, the FNS could improve the HHS recorded at the last follow-up (SMD: 0.76, 95%CI: 0.31 to 1.21, $P = 0.0009$, $I^2 = 84\%$).

Femoral neck shortening

Eight studies were included in the analysis of femoral neck shortening (Figure 2E). The fixed-effects model was used due to the low level of heterogeneity observed ($P = 0.89$, $I^2 = 0\%$). The incidence of femoral neck shortening was lower after surgical treatment with the FNS than after surgical treatment with CCS (OR: 0.29, 95%CI: 0.14 to 0.61, $P = 0.001$, $I^2 = 0\%$).

Failure of internal fixation

Seven studies were included in the analysis of failure of internal fixation (Figure 2F). The fixed-effects model was used due to the low level of heterogeneity observed ($P = 0.95$, $I^2 = 0\%$). The included studies revealed that compared with CCS, the FNS could not reduce the incidence of the failure of internal fixation (OR: 0.49, 95%CI: 0.23 to 1.06, $P = 0.07$, $I^2 = 0\%$).

Delayed union or nonunion

Seven studies were included in the meta-analysis of the occurrence of delayed union or nonunion (Figure 2G). The fixed-effects model was used due to the high level of heterogeneity observed ($P = 0.71$,

Table 1 Characteristics of the studies analyzed in the current meta-analysis

Complications		**A; B; C; D; E**	**A; B; C; F; G**	**A; B; D; E**	**A; B; E**	**B; I**
Outcomes		Operation time; intraoperative blood loss; fracture healing time; HHS at the last follow-up	Operation time; intraoperative blood loss; fracture healing time; HHS at the last follow-up	Operation time; intraoperative blood loss; fracture healing time; HHS at the last follow-up	Operation time; intraoperative blood loss; fracture healing time; HHS at the last follow-up	Operation time; intraoperative blood loss; fracture healing time; HHS at the last follow-up
Type of fracture		Garden II/III/IV	Pauwels I/II/III	Garden II/III/IV	Garden II/III/IV	Garden I/II/III/IV
Study type		Retrospective study	Retrospective study	Retrospective study	Retrospective study	Retrospective study
Follow-up time		≥ 6 mo	5-18 mo	≥ 12 mo	3-18 mo	Unknown
G2		CCS	CCS	CCS	CCS	CCS
G1		FNS	FNS	FNS	FNS	FNS
Participants (*n*, age: mean ± SD)	G2	38, 48.8 ± 10.1	47, 43.7 ± 13.1	57, 53.2 ± 11.3	58, 49	19, 41.2
(*n*, age: mean ± SD)	G1	32, 49.4 ± 11.0	47, 47.8 ± 9.8	62, 54.0 ± 13.0	24, 52	15, 42.0
First author, year		Ren C (2021) [11]	Yang J (2021) [12]	Xiong W (2021) [13]	Yan C (2021) [14]	Yang Y (2021) [15]
Complications		**A; B; E; H**	**A; D; E**	**B; E; H; I**	**A; B; E; D**	**B**
Outcomes		Operation time; intraoperative blood loss; fracture healing time; HHS at the last follow-up	Operation time; intraoperative blood loss; HHS at the last follow-up	Operation time; fracture healing time; HHS at the last follow-up	Operation time; intraoperative blood loss; fracture healing time; HHS at the last follow-up	Operation time
Type of fracture		Pauwels I/II/III	Pauwels III	Garden I/II/III/IV	Pauwels I/II/III	Garden I/II
Study type		Retrospective study	Retrospective study	Retrospective study	Retrospective study	Retrospective study
Follow-up time		≥ 6 mo	10-22 mo	12-24 mo	14-24 mo	3-6 mo
G2		CCS	CCS	CCS	CCS	CCS
G1		FNS	FNS	FNS	FNS	FNS
Participants (*n*, age: mean ± SD)	G2	24, 50.46 ± 9.26	30, 53.14 ± 7.19	36, 47.58 ± 10.31	45, 54.8 ± 11.7	32, 85 ± 6.6
(*n*, age: mean ± SD)	G1	20, 50.45 ± 8.45	30, 54.53 ± 6.71	33, 50.61 ± 10.30	47, 57.4 ± 15.0	15, 86.1 ± 4.6
First author (year)		Hu H (2021) [16]	Zhou X (2021) [17]	He C (2021) [18]	Tang Y (2021) [19]	Vazquez O (2021) [20]

G1: Treatment group; G2: Control group; HHS: Harris Hip score; A: Avascular necrosis of the femoral head; B: Femoral neck shortening; C: Deep venous thrombosis; D: Loosening of screws; E: Delayed union or nonunion; F: Thigh irritation; G: Postoperative infection; H: Screw penetration; I: Screw back-off.

I^2 = 0%). Compared with CCS, the FNS reduced the incidence of delayed union or nonunion (OR: 0.47, 95%CI: 0.30 to 0.73, P = 0.001; I^2 = 0%).

Avascular necrosis of the femoral head

The development of avascular necrosis of the femoral head was reported in 7 studies, including 6 and 16 cases in the FNS and CCS groups, respectively (Figure 2H). No heterogeneity was observed (P = 1.00, I^2 = 0%) and, as such, the fixed-effects model was used. The obtained results revealed that there was no statistically significant difference in terms of the incidence of avascular necrosis of the femoral head between the two studied groups (OR: 0.46, 95%CI: 0.20 to 1.10, P = 0.08, I^2 = 0%).

Other complications

Other complications were also analyzed in this meta-analysis, and the obtained results are summarized in Table 2.

Table 2 Other complications reported in the analyzed studies

Complications	Number of cases (FNS/other implants)	OR (95%CI)	*P*	I^2 (%)
Deep venous thrombosis	3/5	0.64 (0.15, 2.78)	0.55	0
Thigh irritation	0/15	0.02 (0.00, 0.38)	/	/

FNS: Femoral Neck System; OR: Odds ratio; CI: Confidence interval.

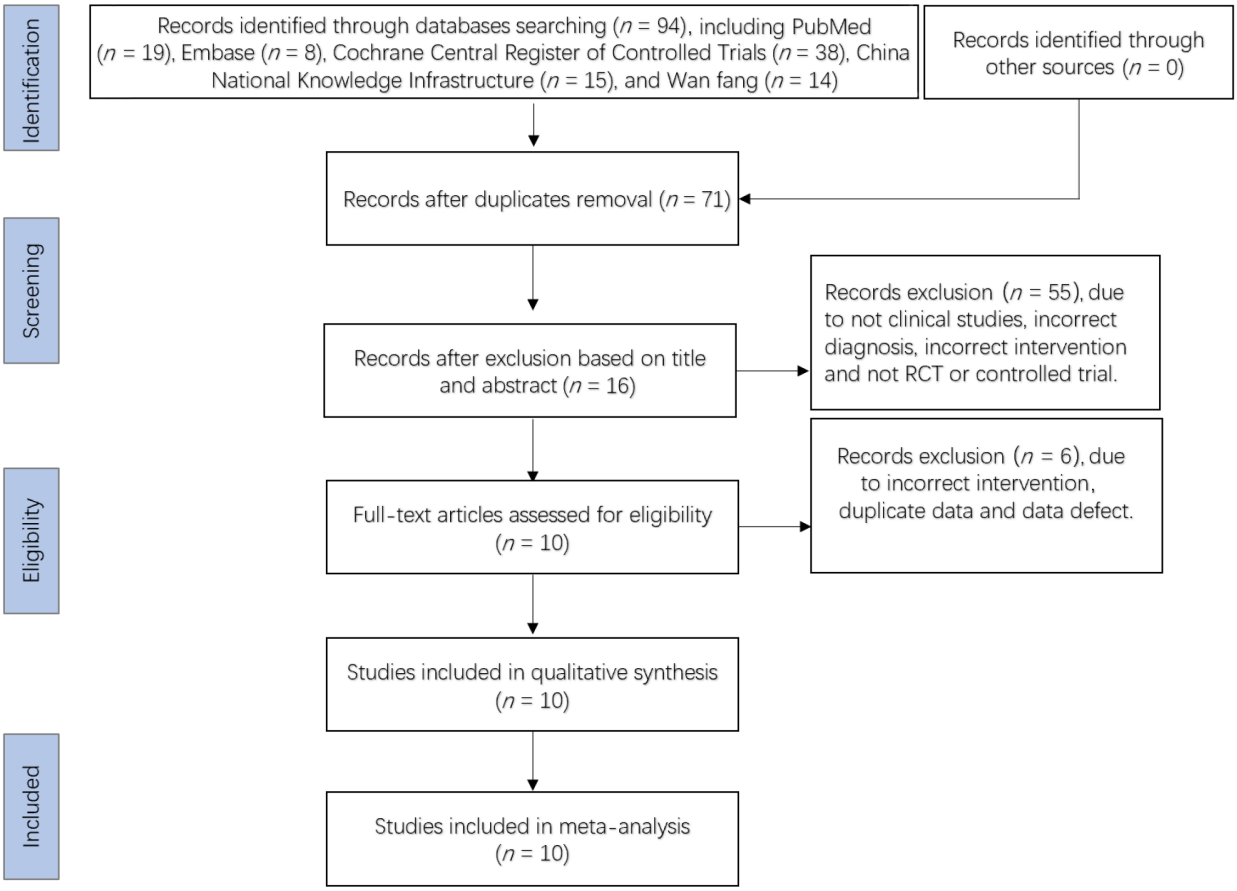

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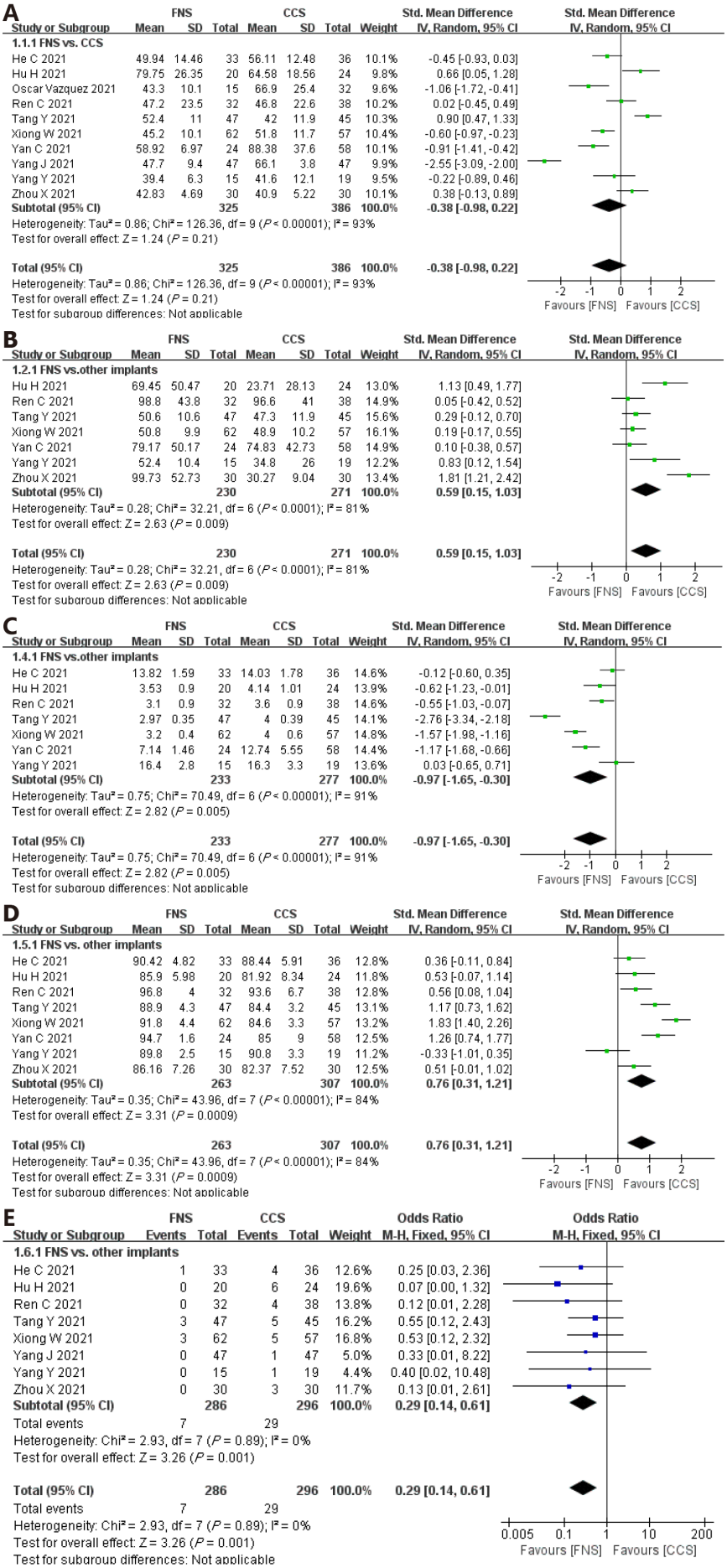
Figure 1 Flow diagram of the study selection process followed based on entries retrieved from five databases.

DISCUSSION

With the increase in the aging population, femoral neck fractures are becoming increasingly common every year; they are typically treated *via* internal fixation surgery, which tends to have several complications, such as fracture nonunion, femoral neck avascular necrosis, femoral neck shortening, and hip deformity[21,22]. To date, no harmonized standards exist regarding the choice of the right internal fixation technique. The FNS, which has superior biomechanical characteristics, was introduced in China in 2018, but there is insufficient evidence of its efficacy in the treatment of femoral fractures compared with traditional internal fixation techniques, such as CCS[23]. Thus, this study aimed to assess the efficacy of the FNS in comparison with that of CCS in the treatment of femoral fractures through systematic review and meta-analysis.

We searched 5 databases and identified 10 retrospective controlled studies (with a total of 711 participants) that met the inclusion criteria. In this meta-analysis, we found that there was no significant difference in the operation time between the FNS and CCS. Although the FNS has been introduced recently, it features simple operation (short learning curve) and low-level trauma[18]. CCS requires better spatial distribution of three screws, which may warrant the repeated adjustment of guidewires and increase the number of intraoperative fluoroscopies[18]. These may be the reasons why both required similar operation times. However, the pooled results revealed that intraoperative blood loss was higher when using the FNS than when using CCS. It is possible that all patients treated with the


A
FNS
CCS
Std. Mean Difference
Std. Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
1.1.1 FNS vs. CCS
He C 2021 49.94 14.46 33 56.11 12.48 36 10.1% -0.45 [-0.93, 0.03]
Hu H 2021 79.75 26.35 20 64.58 18.56 24 9.8% 0.66 [0.05, 1.28]
Oscar Vazquez 2021 43.3 10.1 15 66.9 25.4 32 9.6% -1.06 [-1.72, -0.41]
Ren C 2021 47.2 23.5 32 46.8 22.6 38 10.2% 0.02 [-0.45, 0.49]
Tang Y 2021 52.4 11 47 42 11.9 45 10.3% 0.90 [0.47, 1.33]
Xiong W 2021 45.2 10.1 62 51.8 11.7 57 10.4% -0.60 [-0.97, -0.23]
Yan C 2021 58.92 6.97 24 88.38 37.6 58 10.1% -0.91 [-1.41, -0.42]
Yang J 2021 47.7 9.4 47 66.1 3.8 47 9.9% -2.55 [-3.09, -2.00]
Yang Y 2021 39.4 6.3 15 41.6 12.1 19 9.5% -0.22 [-0.89, 0.46]
Zhou X 2021 42.83 4.69 30 40.9 5.22 30 10.1% 0.38 [-0.13, 0.89]
Subtotal (95% CI) 325 386 100.0% -0.38 [-0.98, 0.22]
Heterogeneity: Tau² = 0.86; Chi² = 126.36, df = 9 (P < 0.00001); I² = 93%
Test for overall effect: Z = 1.24 (P = 0.21)
Total (95% CI) 325 386 100.0% -0.38 [-0.98, 0.22]
Heterogeneity: Tau² = 0.86; Chi² = 126.36, df = 9 (P < 0.00001); I² = 93%
Test for overall effect: Z = 1.24 (P = 0.21)
Test for subgroup differences: Not applicable
-2 -1 0 1 2
Favours [FNS] Favours [CCS]
B
FNS
CCS
Std. Mean Difference
Std. Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
1.2.1 FNS vs.other implants
Hu H 2021 69.45 50.47 20 23.71 28.13 24 13.0% 1.13 [0.49, 1.77]
Ren C 2021 98.8 43.8 32 96.6 41 38 14.9% 0.05 [-0.42, 0.52]
Tang Y 2021 50.6 10.6 47 47.3 11.9 45 15.6% 0.29 [-0.12, 0.70]
Xiong W 2021 50.8 9.9 62 48.9 10.2 57 16.1% 0.19 [-0.17, 0.55]
Yan C 2021 79.17 50.17 24 74.83 42.73 58 14.9% 0.10 [-0.38, 0.57]
Yang Y 2021 52.4 10.4 15 34.8 26 19 12.2% 0.83 [0.12, 1.54]
Zhou X 2021 99.73 52.73 30 30.27 9.04 30 13.4% 1.81 [1.21, 2.42]
Subtotal (95% CI) 230 271 100.0% 0.59 [0.15, 1.03]
Heterogeneity: Tau² = 0.28; Chi² = 32.21, df = 6 (P < 0.0001); I² = 81%
Test for overall effect: Z = 2.63 (P = 0.009)
Total (95% CI) 230 271 100.0% 0.59 [0.15, 1.03]
Heterogeneity: Tau² = 0.28; Chi² = 32.21, df = 6 (P < 0.0001); I² = 81%
Test for overall effect: Z = 2.63 (P = 0.009)
Test for subgroup differences: Not applicable
-2 -1 0 1 2
Favours [FNS] Favours [CCS]
C
FNS
CCS
Std. Mean Difference
Std. Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
1.4.1 FNS vs.other implants
He C 2021 13.82 1.59 33 14.03 1.78 36 14.6% -0.12 [-0.60, 0.35]
Hu H 2021 3.53 0.9 20 4.14 1.01 24 13.9% -0.62 [-1.23, -0.01]
Ren C 2021 3.1 0.9 32 3.6 0.9 38 14.6% -0.55 [-1.03, -0.07]
Tang Y 2021 2.97 0.35 47 4 0.39 45 14.1% -2.76 [-3.34, -2.18]
Xiong W 2021 3.2 0.4 62 4 0.6 57 14.8% -1.57 [-1.98, -1.16]
Yan C 2021 7.14 1.46 24 12.74 5.55 58 14.4% -1.17 [-1.68, -0.66]
Yang Y 2021 16.4 2.8 15 16.3 3.3 19 13.6% 0.03 [-0.65, 0.71]
Subtotal (95% CI) 233 277 100.0% -0.97 [-1.65, -0.30]
Heterogeneity: Tau² = 0.75; Chi² = 70.49, df = 6 (P < 0.00001); I² = 91%
Test for overall effect: Z = 2.82 (P = 0.005)
Total (95% CI) 233 277 100.0% -0.97 [-1.65, -0.30]
Heterogeneity: Tau² = 0.75; Chi² = 70.49, df = 6 (P < 0.00001); I² = 91%
Test for overall effect: Z = 2.82 (P = 0.005)
Test for subgroup differences: Not applicable
-2 -1 0 1 2
Favours [FNS] Favours [CCS]
D
FNS
CCS
Std. Mean Difference
Std. Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
1.5.1 FNS vs. other implants
He C 2021 90.42 4.82 33 88.44 5.91 36 12.8% 0.36 [-0.11, 0.84]
Hu H 2021 85.9 5.98 20 81.92 8.34 24 11.8% 0.53 [-0.07, 1.14]
Ren C 2021 96.8 4 32 93.6 6.7 38 12.8% 0.56 [0.08, 1.04]
Tang Y 2021 88.9 4.3 47 84.4 3.2 45 13.1% 1.17 [0.73, 1.62]
Xiong W 2021 91.8 4.4 62 84.6 3.3 57 13.2% 1.83 [1.40, 2.26]
Yan C 2021 94.7 1.6 24 85 9 58 12.5% 1.26 [0.74, 1.77]
Yang Y 2021 89.8 2.5 15 90.8 3.3 19 11.2% -0.33 [-1.01, 0.35]
Zhou X 2021 86.16 7.26 30 82.37 7.52 30 12.5% 0.51 [-0.01, 1.02]
Subtotal (95% CI) 263 307 100.0% 0.76 [0.31, 1.21]
Heterogeneity: Tau² = 0.35; Chi² = 43.96, df = 7 (P < 0.00001); I² = 84%
Test for overall effect: Z = 3.31 (P = 0.0009)
Total (95% CI) 263 307 100.0% 0.76 [0.31, 1.21]
Heterogeneity: Tau² = 0.35; Chi² = 43.96, df = 7 (P < 0.00001); I² = 84%
Test for overall effect: Z = 3.31 (P = 0.0009)
Test for subgroup differences: Not applicable
-2 -1 0 1 2
Favours [FNS] Favours [CCS]
E
FNS
CCS
Odds Ratio
Odds Ratio
Study or Subgroup Events Total Events Total Weight M-H, Fixed, 95% CI
M-H, Fixed, 95% CI
1.6.1 FNS vs. other implants
He C 2021 1 33 4 36 12.6% 0.25 [0.03, 2.36]
Hu H 2021 0 20 6 24 19.6% 0.07 [0.00, 1.32]
Ren C 2021 0 32 4 38 13.8% 0.12 [0.01, 2.28]
Tang Y 2021 3 47 5 45 16.2% 0.55 [0.12, 2.43]
Xiong W 2021 3 62 5 57 16.8% 0.53 [0.12, 2.32]
Yang J 2021 0 47 1 47 5.0% 0.33 [0.01, 8.22]
Yang Y 2021 0 15 1 19 4.4% 0.40 [0.02, 10.48]
Zhou X 2021 0 30 3 30 11.7% 0.13 [0.01, 2.61]
Subtotal (95% CI) 286 296 100.0% 0.29 [0.14, 0.61]
Total events 7 29
Heterogeneity: Chi² = 2.93, df = 7 (P = 0.89); I² = 0%
Test for overall effect: Z = 3.26 (P = 0.001)
Total (95% CI) 286 296 100.0% 0.29 [0.14, 0.61]
Total events 7 29
Heterogeneity: Chi² = 2.93, df = 7 (P = 0.89); I² = 0%
Test for overall effect: Z = 3.26 (P = 0.001)
Test for subgroup differences: Not applicable
0.005 0.1 1 10 200
Favours [FNS] Favours [CCS]

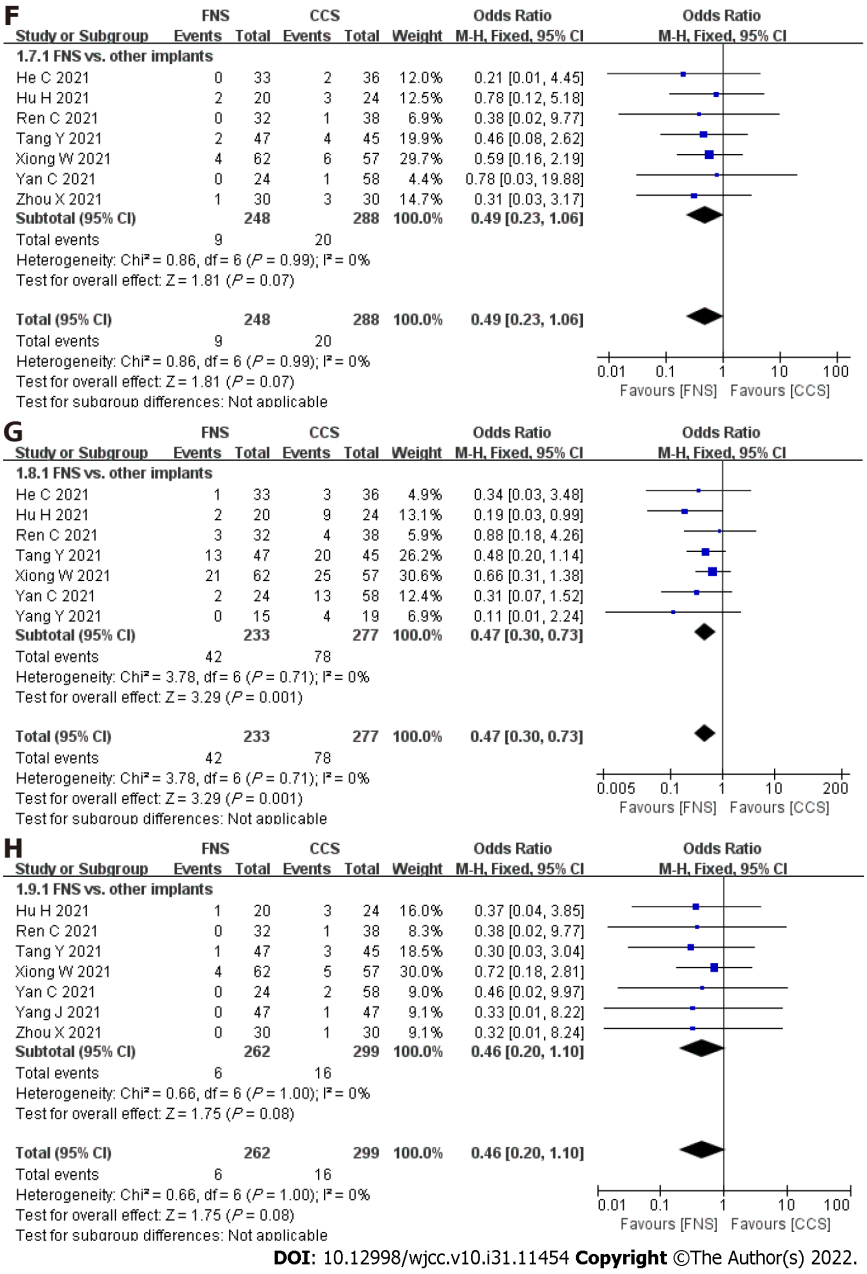


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Figure 2 Meta-analysis focusing on the efficacy of the femoral neck system *vs* cannulated compression screws for the surgical treatment of femoral neck fractures. A: Length of the recorded operation time; B: Blood loss; C: Fracture healing time; D: Harris Hip score recorded at the last follow-up; E: Femoral neck shortening; F: Failure of internal fixation; G: Delayed union or nonunion; H: Avascular necrosis of the femoral head.

FNS required open reduction, which could lead to surgical trauma with a small window of exposure. This may lead to similar operation times but more blood loss.

Our data indicated that the chances of femoral neck shortening were lower when using the FNS than when using CCS. CCS are widely used for internal fixation in patients with femoral neck fractures owing to the minimally invasive surgical procedure, low cost, and antirotation force[18]. However, recent research has reported poor biomechanical properties of CCS for unstable femoral neck fractures [24]. A biomechanical study suggested that the FNS is a reliable implant for femoral neck fractures as it has biomechanical characteristics similar to those of dynamic hip screws (DHS) as well as stability superior to that of CCS[23]. In addition, a finite element analysis showed that the FNS exerts a higher internal fixation stress than CCS, which is about 1.6-3.0 times that of CCS[25]. Taken together, the FNS (which is characterized by the angular stability constructs of its bolt, antirotation screws, a lateral plate, and locking screws), provides superior resistance against femoral neck shortening, and its sliding design of antirotation and locking screws allow the surgeon to achieve the maximum sliding compression of 20 mm during the operation[19]. Interestingly, the incidence of internal fixation failure for the FNS was the same as that for CCS. In this meta-analysis, fixation failure included screw loosening, back-off, penetration, *etc.* It is possible that the incidence of fixation failure associated with the FNS is actually

lower due to fracture type, bone quality and reduction, and implant position. However, we may have observed similar incidences for the FNS and CCS due to factors such as small sample size and short follow-up time.

Previous studies showed that the nonunion rate of femoral neck fracture treated with CCS was higher than that of femoral neck fracture treated with angle-stabilized internal fixators[26,27]. Our study identified that compared with CCS, use of the FNS for treating femoral neck fractures could shorten the required fracture healing time as well as decrease the incidence of delayed union or nonunion. Time to surgery, fracture type, and bone reduction and quality may be the major determinants of bone healing. In addition, current evidence has shown that the stability of the femoral neck fracture is also crucial for promoting bone healing[28,29]. In general, the mechanical stability of a fractured bone osteosynthesis is composed of the stability of the internal implant and the stability of the bone. The FNS meets the demand of stability of the implant in the osteosynthesis of bone fracture and conserves less strength at the femoral head than that of intact bone after bone healing[30,31]. It is thought that the FNS accelerated the healing of the fracture and reduced the incidence of delayed union or nonunion owing to the stability of the osteosynthesis construct in the fracture gap. The pooled results showed that compared with CCS, use of the FNS for treating femoral neck fractures could improve the HHS at the last follow-up. Previous studies have reported that femoral neck shortening can decrease hip function, especially in severe cases[26,32,33]. The FNS decreases the incidence of femoral neck shortening, and patients treated with the FNS could perform the timely postoperative weight-bearing activities[18]. Although the HHS was higher in the FNS group, no difference between the FNS and CCS groups was observed for the incidence of femoral head avascular necrosis in this meta-analysis. Apart from factors such as fracture type, stability, and bone reduction and quality, it is reported that the large volume of the implant could damage the blood vessels of the femoral head[34]. As far as the design of the FNS is concerned, the diameters of the screw bolt and antirotation screws were 6.4 mm and 10 mm, respectively. Therefore, similar to CCS, the FNS could also preserve the peripheral vessels in the femoral head.

This meta-analysis has several limitations. First, all the included studies were classified as retrospective controlled studies with MINORS scores between 17 and 19; hence, there is a high risk of bias and methodological quality limitations in these studies. Second, the overall sample size of the analyzed studies was small. Third, the follow-up time in most of the included studies was short. Fourth, fracture type, reduction quality, implant position, patient age, and time from injury to surgery were important factors in gaining good results in this meta-analysis; however, these could not be analyzed as the included studies did not describe these data specifically. Finally, "control" referred to only CCS; as a result, this study does not provide a definite conclusion on whether the FNS is a superior internal fixation method for the surgical treatment of femoral neck fractures compared with other implants (apart from CCS).

The results of this meta-analysis could help in the selection of the most appropriate treatment for patients with femoral neck fractures. However, considering the high risk of biases and poor methodological quality of the studies included in this meta-analysis, further studies (preferably RCTs) are required to draw more reliable conclusions on the efficacy of the FNS in the treatment of femoral neck fractures in adult patients.

CONCLUSION

This meta-analysis showed that compared with CCS, the FNS cannot shorten the operation time but increases intraoperative blood loss. The pooled results also revealed that compared with CCS, the FNS can better promote fracture healing, improve the HHS at the last follow-up, and reduce the chances of developing femoral neck shortness and delayed union or nonunion in adult patients with femoral neck fracture. Nevertheless, further studies (preferably RCTs) are required to validate the findings of our study.

ARTICLE HIGHLIGHTS

Research background

Controversy remains around the available choices for the internal fixation of a femoral neck fracture. The femoral neck system (FNS) was developed in 2018 and has been widely applied since then as it can provide rigid fixation stability with less damage to the bone mass around the fracture.

Research motivation

No systematic reviews and meta-analyses have investigated the efficacy of the FNS in comparison with that of traditional internal fixation in the treatment of femoral fractures.

Research objectives

The purpose of our study was to assess the efficacy of the FNS in comparison with that of cannulated compression screws (CCS) in the treatment of femoral fractures through systematic review and meta-analysis.

Research methods

Five electronic databases (PubMed, Embase, Cochrane Central Register of Controlled Trials, China National Knowledge Infrastructure, and Wanfang) were searched from the earliest publication date to December 31, 2021. Reference Citation Analysis (https://www.referencecitationanalysis.com/) was used to check the results and further analyze the related articles. Controlled trials were included if the FNS was applied to the femoral neck fracture in adults and if it was compared with CCS for the achievement of internal fixation. The measurement outcomes included the required operation time, observed patient blood loss, extent of fracture healing, patient's Harris Hip score (HHS) at the last follow-up, and records of any complications (such as failure of internal fixation, femoral neck shortness, avascular necrosis of the femoral head, and delayed union or nonunion).

Research results

Ten retrospective controlled studies (involving 711 participants) were included in this meta-analysis. The meta-analysis showed that compared with CCS, use of the FNS could not decrease the operation time [standardized mean difference (SMD): -0.38, 95% confidence interval (CI): -0.98 to 0.22, $P = 0.21$, $I^2 = 93\%$], but it could increase the intraoperative blood loss (SMD: 0.59, 95%CI: 0.15 to 1.03, $P = 0.009$, $I^2 = 81\%$). The pooled results also showed that compared with CCS, the FNS could better promote fracture healing (SMD: -0.97, 95%CI: -1.65 to -0.30, $P = 0.005$, $I^2 = 91\%$), improve the HHS at the last follow-up (SMD: 0.76, 95%CI: 0.31 to 1.21, $P = 0.0009$, $I^2 = 84\%$), and reduce the chances of developing femoral neck shortness (OR: 0.29, 95%CI: 0.14 to 0.61, $P = 0.001$, $I^2 = 0\%$) and delayed union or nonunion (OR: 0.47, 95%CI: 0.30 to 0.73, $P = 0.001$; $I^2 = 0\%$) in adult patients with femoral neck fractures. However, there was no statistically significant difference between the FNS and CCS in terms of failure of internal fixation (OR: 0.49, 95%CI: 0.23 to 1.06, $P = 0.07$, $I^2 = 0\%$) and avascular necrosis of the femoral head (OR: 0.46, 95%CI: 0.20 to 1.10, $P = 0.08$, $I^2 = 0\%$).

Research conclusions

Contemporary evidence indicates that compared with CCS, the FNS could decrease the chances of developing femoral neck shortness and delayed union or nonunion in adults with femoral neck fractures. Simultaneously, it could accelerate fracture healing and improve the HHS in these patients.

Research perspectives

The FNS is an internal fixation method with superior characteristics in the treatment of femoral neck fractures. The results of this meta-analysis could help in the selection of the most appropriate treatment for patients with femoral neck fractures.

FOOTNOTES

Author contributions: Wu ZF and Luo ZH were responsible for the data management and formal analysis; Wu ZF and Hu LC were responsible for the manuscript design, concept and methodology; Luo ZH and Hu LC searched the literature; Wu ZF wrote the original draft; Luo YW was responsible for manuscript writing, reviewing and editing.

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ORCID number: Zhi-Fang Wu 0000-0002-7170-2646; Zi-Heng Luo 0000-0001-7649-0024; Liu-Chao Hu 0000-0002-9881-

092X; Yi-Wen Luo 0000-0002-3832-7565.

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