Multiple Cannulated Screw Fixation of Femoral Neck Fractures with Comminution in Young and Middle Age Patients

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Abstract

Objective

To investigate the distribution and influence of comminutions on femoral neck fracture (FNF) patients after cannulated screw fixation (CSF).

Methods

From January 2019 to June 2020, a total of 473 patients with FNF treated by CSF, aged 23–65 years, were included in present study. Based on location of the cortical comminution, the FNF patients were assigned as comminution group (anterior comminution, posterior comminution, superior comminution, inferior comminution, multiple comminutions) and without comminution group. The incidence of postoperative complications, quality of life and functional outcomes were recorded in different groups at 1 year-follow up.

Results

The comminution was more likely to appear in displaced FNF patients (86.8%) compared with non-displaced FNF patients (8.9%), while occurrence rate of comminution was also closely associated with Pauwels classification (3.2% vs 53.5% vs 83.9%, $P<0.05$). Besides, the incidence of osteonecrosis of femoral head (ONFH, 11.3% vs 2.9%, $P<0.05$), nonunion (7.5% vs 1.7%, $P<0.05$), femoral neck shortening (21.6% vs 13.4%, $P<0.05$) and internal fixation failure (11.8% vs 2.9%, $P<0.05$) in FNF patients with comminutions, especially with multiple comminutions, was significantly higher than those in FNF patients without comminution. Furthermore, there was a prominently difference in Harris hip score (HHS, 85.6 ± 15.6 vs 91.3 ± 10.8 , $P<0.05$) and EuroQol five dimensions questionnaire (EQ-5D, 0.85 ± 0.17 vs 0.91 ± 0.18 , $P<0.05$) score between FNF patients with comminution and FNF patients without comminution, whereas there was seem to be no significantly difference in Visual analogue scale (VAS, 1.46 ± 2.49 vs 1.13 ± 1.80 , $P>0.05$) score between two groups at 1 year after surgery.

Conclusion

In our view, the comminution, easily happened in displaced FNF and Pauwel type III FNF, which was deemed to be a risk factor for postoperative complications in young and middle-aged patients underwent CSF, consequently causing an influence on recovery of hip function and life quality. However, further evaluation with better study design, larger sample and long-term follow-up was still imminently applied.

Introduction

Femoral neck fractures (FNFs) are a devastating injury in all ages, which are increasing not only in elderly people with lower-energy trauma but also in young people with higher-energy trauma [1, 2]. It has been estimated that the number of new hip fractures worldwide will increase dramatically to 6.3 million by 2050, FNF of which account for about 50% [3, 4]. Due to the special blood supply system and biomechanical characteristic in the neck of the femur, it is tending to result in a series of complications as nonunion and osteonecrosis of femoral head (ONFH), which has become a leading cause of pain and dysfunction [5]. These poor outcomes of FNF have been gradually recognized as serious socio-economic burden because of its high disability rate and health-care resource use [4].

The therapeutic strategies for FNFs are either arthroplasty or internal fixation, according to a number of factors, such as the patient's age, fracture pattern and functional requirements. In stark contrast to the management of elderly patients with FNF, multiple cannulated screw fixation (CSF) is a widely accepted approach based on its easy operation, less tissue damage and preserving original joints in young patients [6, 7]. Unfortunately, incidences of complications including nonunion, ONFH and implant failure of internal fixation following FNFs occur at rates of 9–30%, which may contribute to disability and frequently

necessitating revision surgery or conversion to arthroplasty procedures at rates of 20-36% [8–10]. A plenty of evidence believes that high failure rate of internal fixation for FNF maybe closely relate to inadequate reduction, fracture type, bone quality and loosening of fixation [9–11].

Growing studies indicated that disruption of the cortex of the femoral neck was extensive existence in patients with FNFs, for instance, Collinge et al. found that 96% of 33 patients with vertical shear FNF existed comminutions in femoral neck, mostly located in inferior (94%) and posterior (82%) [12]; Huang et al. declaimed that 36.5% of 104 displaced FNF patients simultaneously accompanied with disrupted posterior cortex, acting as an independent risk factor for postoperative ONFH, union and shortening [5]. Synchronously, several investigations also showed that comminution of femoral neck is a notably hazardous factor for loss of cortical support of cannulated screws, resulting in internal fixation failure even when adequate reduction is achieved [6, 11]. Therefore, the integrity of cortex of femoral neck is now thought to be a pivotal factor for successful surgical management for patients with FNF of all ages.

However, the distribution and influence of comminutions in femoral neck on FNF patients with CSF remains largely unknown. The goals of present study were to discuss the characteristics of distribution of cortical defect in femoral neck of FNF patients, and determine if there was a certain correlation between different parts of comminutions and prognosis. In our view, a deeply understanding of these findings could be conducive to a better cognition of the injury mechanism of FNF, which might eventually improve treatment strategies and reduce postoperative complications.

Materials And Methods

Participants

This retrospective cohort study included patients with FNF in Tianjin Hospital from January 2019 to June 2020, which was in accordance with the Helsinki Declaration and approved by the Ethics Committee of Tianjin Hospital. All participants were fully aware of the nature, purpose, procedures and risks of the study and signed informed consent. The flow chart of participants is shown in **Figure 1**.

The Inclusion and exclusion Criteria

Inclusion criteria:(1) age ranging from 18-65 years old; (2) with a unilateral FNF;(3) underwent multiple CSF fixation and achieved acceptably reduction quality; (4) completed 1 year follow-up; (5) consent to be included in the study.

Exclusion criteria: (1) pathological fracture or old fracture (more than 14 days); (2) previous ipsilateral hip diseases; (3) bilateral FNF or combined with femoral shaft fracture; (4) a bone metabolism disorder; (5) the occurrence of diseases affecting the function of lower limbs or death or loss of follow-up;(6) serious nervous or mental diseases as cognitive impairment, dementia, or Parkinson disease; (7) pregnant or lactating women;(8) incomplete clinical data.

Radiographic assessment and grouping

The anteroposterior (AP) radiographs were employed to estimate fractures based on the Garden classification [13] and Pauwels classification [14].The postoperative three-dimensional computed tomograph (3D-CT) reconstruction was performed to evaluate existence and location of comminution in femoral neck (**Figure 2**). All imaging was separately reviewed and morphologic assessed by two radiologists and two orthopedic trauma surgeons. All disagreements were resolved by discussion. According to the location of comminution in femoral neck, the patients were divided into 6 groups as following: (1) anterior comminution; (2) posterior comminution; (3) superior comminution; (4) inferior comminution; (5) multiple comminutions;(6) without comminution.

Operative and postoperative procedures

Closed reduction or open reduction with three standard CSF fixation of the FNF were carried out in all our patients under either general or epidural anaesthesia. On the basis of Haidukewych et al. described [15], the reduction quality (excellent, good and fair) of FNF was considered to be acceptable. The patients were encouraged to rehabilitation in bed immediately after surgery with

non-weight bearing mobilisation over 8 weeks, allowing to bear weight with walker/crutches until verified radiographic evidence of callus formation, and full weight bearing depending on the fracture healing at monthly postoperative re-examination.

Follow-up and outcome measurement

After discharge, the patient was required to go to the special follow-up clinic once a month until fracture healed. After the fracture healed, the patient was rechecked at 1 year after surgery, who were surveyed by radiographic and clinical examinations, recorded the complications, quality of life, pain and hip function. If the participant could not get to the clinic for re-examination, they were asked to undergo X-ray imaging at local hospital and mailed images to the surgeons by E-mail. Finally, primary and secondary outcomes were measured at 1 year after surgery.

The primary outcomes were postoperative complications including nonunion, ONFH, shortening and failure of fixation. Fracture nonunion was defined as the fracture line was clearly visible or absence of bridging cortical bone at 6 months postoperatively, which was evaluated by imaging examination [16, 17]. ONFH was identified using magnetic resonance imaging (MRI) or radiography, following the radiological criteria by Arlet et al [18]. According to the description by Zlowodzki et al [19], the length of femoral neck was measured, and femoral neck shortening was supposed as shortening length exceeding 5mm in immediate postoperative film compared with last follow-up plain radiograph [19]. The failure of internal fixation was evaluated by last radiographs, including screw withdraw, implant cut out, screw loose, varus deformity $>10^\circ$ and re-displacement $>5\text{mm}$.

The second outcomes were the Harris Hip Score (HHS), EQ-5D (EuroQol five dimensions questionnaire) score and Visual Analogue Score (VAS) at 1 year after operation. HHS was widely used to appraise hip function, including four aspects: pain (1 item, 0-44 points), function (7 items, 0-47 points), deformity (1 item, 0-4 points) and range of activity (2 items, 0-5 points) [20]. EQ-5D is known as a patient reporting tool to measure quality of life, developed by the EuroQol team [21]. The questionnaire contains five questions covering five different aspects: mobility, self-care, daily activities, pain/discomfort, and anxiety/depression, and specific value set by EQ-5D questionnaire for Chinese patients is obtained by Luo et al [22]. VAS (score from 0 to 10) is usually employed to evaluate the pain intensity in patients, the meaning of which as follow: 0 is painless; less than 3 is mild pain that the patient can endure; 4-6 is pain that the patient can bear and can sleep; and 7-10 is severe pain that the patient cannot bear [23].

Statistical analysis

All statistical analyses were performed by Statistical Package for Social Sciences (SPSS) version 25.0 (SPSS Inc., Chicago, IL, USA). The categorical variables of clinical data and outcomes were assessed using Pearson's chi-squared test or Fisher's exact test. The continuous variable data were assessed for a fit to a normal distribution and for homogeneity of variance using the Shapiro-Wilk test and Bartlett test, which was represented as mean $\pm$ SD. Then, Student's t-test or the analysis of variance (ANOVA) was used for inter-group comparisons. P value less than 0.05 was considered as statistically significant.

Results

Initially, a total of 473 patients with fresh FNF were identified during January 2019 to June 2020, 82 patients were lost to follow-up, 6 patients declined participation, 1 patient dropped out due to re-fracture. A total of 384 patients finally completed 1-year follow-up and included in this study, containing 14 patients with anterior comminution, 88 patients with posterior comminution, 16 patients with superior comminution, 60 with inferior comminution, 34 patients with multiple comminutions, and 172 patients without comminution (Figure 1). There was no significant difference in regard to age, sex, body mass index (BMI), injury mechanism, American Society of Anesthesiologists (ASA) score, from initial injury to operation, operative time, duration of hospitalization and follow-up time among the all groups ($P>0.05$, Table 1). However, intraoperative blood loss and open reduction rate were remarkable increased in the multiple comminution group compared with other groups ($P<0.05$, Table 1)

Table 1
Characteristics of participants

Variables	Anterior comminution	Posterior comminution	Superior comminution	Inferior comminution	Multiple comminution	Without comminution	P value
	(n= 14)	(n= 88)	(n=16)	(n=60)	(n=34)	(n=172)	
Age (years)	51.7±9.6	52.1±7.3	51.5±7.3	49.6±10.3	49.9±9.6	49.3±13.7	0.515
Female (%)	6 (42.9)	44 (50.0)	7 (44.8)	22 (36.7)	12 (35.3)	93 (54.1)	0.144
BMI (Kg/m ²)	23.1±3.8	23.5±4.3	22.8±4.1	23.9±4.7	23.2±4.6	22.9±3.7	0.659
Tobacco use (%)	3 (21.4)	18 (20.4)	4 (25.0)	10 (16.6)	8 (23.5)	32 (18.6)	0.951
Alcohol use (%)	2 (14.3)	12 (13.6)	1 (6.0)	7 (11.7)	6 (17.6)	25 (14.5)	0.913
Mechanism of injury (%)							0.800
Traffic accident	5 (35.7)	32 (36.4)	7 (43.8)	23(38.3)	15(44.1)	45(26.2)	0.505
Fall	9 (56.3)	54 (61.4)	9 (56.3)	35 (58.4)	18 (52.9)	124 (72.1)	
Others	0 (0.0)	2 (2.2)	0 (0.0)	2 (3.3)	1 (3.0)	3 (1.7)	
ASA class (%)	12 (85.7)	82 (93.2)	14 (87.5)	53 (88.3)	30 (88.2)	160 (93.0)	0.511
ASA I/II	2 (14.3)	6 (6.8)	2 (12.5)	7 (11.6)	4 (11.8)	12 (7.0)	
ASA III/IV							
Reduction Methods (%)							
CRIF	12 (85.7)	63 (71.6)	14 (87.5)	53 (88.3)	22 (64.7)*	159 (92.4)	<0.001
ORIF	2 (14.3)	15(28.4)	2 (12.5)	7 (11.7)	12 (35.3)*	13 (7.6)	
Time to surgery(d)	2.6±1.0	2.5±0.9	2.4±1.1	2.6±0.9	2.4±0.8	2.7±0.9	0.347
Operation time(min)	48.8±15.8	49.2±18.4	47.5±14.1	50.2±20.0	55.1±19.2	45.8±16.7	0.102
Intraoperative blood loss (ml)	85.4±55.1	83.7±53.9	79.2±47.5	80.6±53.3	123.5±82.4*	88.6±51.2	<0.001
Length of hospital stay (d)	5.6±2.3	5.8±1.9	6.0±1.9	5.7±2.2	5.5±2.4	5.6±2.0	0.942
Follow-up time (years)	1.6±0.4	1.5±0.3	1.6±0.2	1.6±0.3	1.5±0.3	1.6±0.4	0.237
CRIF, closed reduction and internal fixation; ORIF, open reduction and internal fixation. *: difference vs. Other groups (p<0.05)							

In order to analysis morphological characteristics of cortical defect in femoral neck, we surveyed the relationship between fracture type and comminution distribution. As shown in Table 2, for Garden classification, the proportion of comminution in displaced FNF was distinctly higher than that in non-displaced FNF (P<0.05). Moreover, the comminution was mainly concentrated on posterior and inferior of femoral neck in both non-displaced and displaced FNF (P<0.05), while there was no prominently disparity of comminution distribution between two types of fractures (P>0.05). For Pauwels classification, there was a dramatically difference in the proportion of comminution in each type, the amount of comminution increasing with elevation of

typing ($P<0.05$). Likewise, the incidence of posterior and inferior comminution was higher than other groups, where there was no noteworthy difference of comminution distribution in different fracture patterns ($P>0.05$).

Table 2
The relationship between fracture types and location of comminution

Variables	With comminution (n=212)					Without Comminution (n=172)	P value
	Anterior	Posterior	Superior	Inferior	Multiple		
	comminution (n=14)	comminution (n=88)	comminution (n=16)	Comminution (n=60)	Comminution (n=34)		
Garden classification							<0.001
No- displacement fracture (GardenⅡ/Ⅲ)	14(8.9)					142(91.1)	0.063
	0(0.0)	6(3.8)	0(0.0)	8(5.1)	0 (0.0)		
Displacement fractures (Garden Ⅲ/Ⅳ)	198(86.8)					30(13.2)	
	14(6.1)	82(36.0)	16(7.0)	52(22.8)	34(14.9)		
Pauwels classification							<0.001
Type I	2(3.2)					60(96.8)	0.330
	0(0.0)	0(0.0)	0(0.0)	2(3.2)	0(0.0)		
Type II	106(53.5)					92(46.5)	
	8(4.0)	44(22.2)	6(3.0)	34(17.2)	14(7.1)		
Type III	104(83.9)					20(16.1)	
	6(4.8)	44(35.5)	10(8.1)	24(19.4)	20(16.1)		

As illustrated in Table 3, the occurrence of postoperative complications, including nonunion, ONFH, shortening and failure of fixation, in FNF with comminution group was significantly higher than those in FNF without comminution group ($P<0.05$). As demonstrated by the further intergroup analysis, the incidence of postoperative complications in FNF with multiple comminutions were all markedly higher than those in other four groups ($P<0.05$). Simultaneously, there seemed to be no clearly correlation between site of single comminution in femoral neck and postoperative complications ($P>0.05$).

Table 3
Comparison of primary outcomes in different groups

Variables	With comminution (n=212)					Without Comminution (n=172)	P value
	Anterior Comminution (n=14)	Posterior Comminution (n=88)	Superior Comminution (n=16)	Inferior Comminution (n=60)	Multiple Comminution (n=34)		
Nonunion (%)	16(7.5) 1 (7.1)	6(6.8)	0(0.0)	4 (6.7)	5(14.7)*	3(1.7)	0.009
ONFH (%)	24(11.3) 0(0.0)	10(11.3)	0(0.0)	5(8.3)	9(26.4)*	5(2.9)	0.002
Shortening (%)	46(21.6) 2(14.2)	18(20.4)	2(12.5)	10(16.6)	14(41.2)*	23(13.4)	0.044
IF failure (%)	19(11.8) 0(0.0)	6(6.8)	1(6.2)	4(6.6)	8(23.5)*	5(2.9)	0.020
ONFH, Osteonecrosis of the Femoral Head; IF, internal fixation. *: difference vs. Other groups with comminution (p<0.05)							

The HHS, EQ-5D index and VAS score, the secondary outcomes, was respectively measured in patients at 1 year postoperatively. As displayed in Table 4, there was a significantly difference in the HHS and EQ-5D index between FNF with comminution group and FNF without comminution group ($P<0.05$). However, there were no notably difference in the VAS score between FNF with comminution group and FNF without comminution group ($P>0.05$), while there was no closely relationship between secondary outcomes and FNF patients with different comminution locations at 1 year after surgery ($P>0.05$).

Table 4
Comparison of secondary outcomes in different groups

Variables	With comminution (n=212)					Without Comminution (n=172)	P value
	Anterior comminution (n=14)	Posterior comminution (n=88)	Superior comminution (n=16)	Inferior Comminution (n=60)	Multiple Comminution (n=34)		
HHS	85.6±15.6 89.3±6.5	84.5±15.3	87.2±13.9	88.1±16.1	81.7±18.0	91.3±10.8	<0.001
EQ-5D	0.85±0.17 0.89±0.10	0.84±0.19	0.85±0.13	0.87±0.18	0.82±0.16	0.91±0.18	<0.001
VAS score	1.46±2.49 1.15±1.23	1.51±2.89	1.37±1.86	1.41±2.25	1.59±2.46	1.13±1.80	0.146
Results are expressed as Mean ± SD; HSS: Harris Hip Score; VAS: visual analogue scale.							

Discussion

With the increasing number of patients with high-energy trauma, the incidence of FNF in young and middle-aged people is growing year by year, which will seriously affect quality of life, hip function and labor capacity of them, and may subsequently bring critical economic burden to the global society [24, 25]. Despite advances in head-preserving surgical techniques and implants for FNF, the high occurrence rates of postoperative osteonecrosis, nonunion, and femur shortening are still problematic

and challenging for physiologically young and active adult [26, 27]. It is commonly believed that the satisfactory reduction, accurate positioning and placement of implant and appropriate rehabilitation are the crucial keys to achieve fracture healing and function recovery, prevent varus collapse and ONFH [9–11]. Moreover, the cortical deficiency of femoral neck is gradually recognized as an important factor for biological healing and biomechanical stability for FNF with internal fixation, which attracts the attention of many orthopedists [6, 28]. Abundant evidence have shown that 50-96% of FNF patients have femoral neck comminution, most of which is posterior comminution with the incidence as high as 50-82% [5, 12, 29–31]. The reasons for above phenomenon may be explained as: young and middle-aged people with FNF are usually subjected to high-energy violence, which exceed the stress that the femoral neck can bear, resulting in the comminuting of the bone; In the elderly population, cortex of femoral neck is evidently thicker than that in young people, which lead to weaker anti-strike ability, easier comminution in femoral neck subjected to low-energy injury. By the reason of the inherent instability of FNF with comminution [36], we supposed that, exploring the correlation between morphological characteristics of deficiency in femoral neck and prognosis, might ultimately provide information to improve the therapeutic strategies for future patients with similar injuries.

To our knowledge, this is the first systematic study to describe the distribution of cortical comminution in FNF. Similar to previous studies, our results showed that cortical comminution widely existed in displaced FNF compared with non-displaced FNF, while the posterior comminution was the most common type of cortical deficiency in femoral neck. The comminution mechanism of posterior cortex in FNF had been explained in different ways. Garden et al. [32] believed that extremely external rotation of the distal fragment would make an impact on fragile posterior cortical shell near junction with the head fragment, bring forth posterior comminution and fracture, resulting in an intracapsular fracture. Kocher et al. [33] indicated that, in the course of the injury, at the moment of the vertical violence in femoral neck simultaneous with external rotation of limb, the femoral head was restricted by iliofemoral ligament and capsule and impinged by acetabulum's posterior ring, finally leading to posterior cortical comminution. Additionally, several studies considered that, regional cortical comminution was related to the characteristics of cortical bone structure in femoral neck, for example, because of the cortex of femoral neck was getting thinner from the anterior inferior to the posterior, the greatest cortical damage would be appeared in posterior side when femoral neck subjected to violence and impacted [34, 35]. Unexpectedly, our results found that inferior comminution was second most common in FNF, which had been never reported before. In our opinion, the injured mechanism of FNF with inferior comminution might be delineated as follow: when proximal femur suffered both vertical violence with varus, stress concentration would be emerged in inferior of femoral neck, subsequently causing the cortical comminution; besides, inferior cortex in femoral neck was relative thinner where the cortical damage would be happened in this weak area when femoral neck subjected to violence and impacted.

Furthermore, our study explored the relationship between Pauwels classification and distribution of cortical comminutions in FNF patients. Surprisingly, the incidence rate of cortical comminution increased with the elevation of fracture types. Therefore, our findings implicated that, in vertical FNFs, not only higher-degree lesions but also cortical deficiency would increase worsening instability, progressive fracture displacement and risk of varus collapse, resulting in serious postoperative complications and failure of fixation.

ONFH, was always regarded as a common and disastrous complication after internal fixation of FNF, especially in the young patients [36], incidence of which in this population was as high as 8.9% [37]. A great deal of evidence indicated that the occurrence of ONFH was the result of two major reasons, one was interruption of the blood supply of the femoral head due to vascular traumatic injury or the insufficient blood supply caused by the increase of intracapsular pressure after fracture, another was stressed concentration of the femoral head caused by instability of the normal structure of proximal femur, resulting in exceeding the range of its physiological load and mechanical destruction of bone trabeculae, finally leading to collapse and ONFH [38–40]. Growing studies realized that cortical comminution was an important influence factor of ONFH in FNF patients after surgery, for example, Scheck et al declared posterior comminution would increase risk of postoperative ONFH in FNF patients [28]; Huang et al. found that the ONFH after internal fixation in FNF patients with posterior cortical comminution was 34.2%, which was much higher than that in patients without comminution (4.8%) [5]. Similar to previous studies, our findings showed that incidence of ONFH in FNF patients with comminution was significantly higher than that in patients without comminution. In particular, the FNF patients with multiple comminutions had an extremely higher risk for ONFH comparing with single comminution, while there was no significant correlation between the location of the comminution and incidence rate of ONFH. Regrettably, paucity of studies explored the possible influences of cortical deficiency on FNF after internal fixation. In our

opinion, the consequences caused by cortical comminution in femoral neck could be assumed as follows: Firstly, the destruction of the cortex in femoral neck in FNF patients, especially posterior cortex, might severely endanger and disruption of blood supply of the femoral head, regardless of whether the reduction was restored or not, eventually leading to ONFH. Epistemically, previous reports have discovered that, initial displacement and posterior comminution were both closely associated with damage of vessels upstream in femoral neck, simultaneously, with the fracture line extend and comminutions increased, devastating damages would be emerged in lateral epiphyseal artery and posterior retinacular vessels, which emerged as a risk factor in subsequent collapse of the head [41, 42]; Secondly, some researches noticed that cortical defect could become a fundamental factor for mechanically unstable of FNF after internal fixation [43], which might produce an impact on the surface stress distribution of the femoral head, particularly happen in the weight-bearing area, contributing to trabecular microfracture and collapse; Additionally, in clinical practice, it was usually difficult to reset FNF with comminutions by close reduction, hence, an open reduction was regarded as necessary to achieving a quality or anatomic reduction[44]. However, injuring of branches of the lateral femoral circumflex artery, disrupting retinacular vessels traversing and the periosteum and capsular reflections during the anterior and anterolateral approaches during open reduction in FNF [45], which might devascularize the partly blood supply in femoral head and greatly increasing risk of ONFH. Above all, more blood vessel damage, worse stability and higher open reduction rate in FNF with multiple comminutions were the main reasons for postoperative ONFH.

The prognosis of femoral neck fractures is plagued by several serious condition, and one of the most common is nonunion [46]. Generally, occurrence rate of this complication frequently is 10–30%, which ultimately gives rise to function disability and requires revision surgery [26, 37, 47]. At present, growing studies gradually realized that cortical deficiency was a crucial factor for nonunion in FNF, for example, Huang et al. found that, comparing with integrity posterior cortex, posterior comminution appeared in FNF would reduce axial load resistance, resulting in early fracture re-displacement and nonunion [5]; Rawall et al highlighted that young patients with significant posterior comminution were found to have higher non-union rates[48]. Likewise, our results showed that nonunion rate of FNF patients with comminution was significantly higher than that in FNF patients without comminution (7.5% vs 1.7%), while nonunion rate of FNF patients with multiple comminutions (14.7%) was markedly higher in comparison to FNF patients with single comminution. With respect to femoral neck comminution, which had long been considered as an important determinant of the fracture stability, especially the posteromedial comminution[28]. According to biomechanical findings, the decline in contact stability between internal fixation and cortex would happen in FNF with comminution, leading to rotation of the fragments and initial displacement, resulting in nonunion and osteosynthetic failure at last [49, 50]. Coincidentally, from our results, the number of internal fixation failure in FNF with comminution was distinctly more than that in FNF without comminution group, synchronously, FNF patients with multiple comminutions had a highest incidence of internal fixation failure (23.5%). Based upon the investigations of previous studies [12, 49, 51], whether or not anatomical reduction was achieved, comminutions would bring about difficulty reconstituting a bony buttress, and possibly return to the position of injury, eventually causing internal fixation failure. Additionally, the comminutions might produce a mechanical environment where implants would lose fixed-angle properties, fracture site bear more axial load and torsion load, leading to ineffective as a buttress against varus re-displacement.

Increasingly strong evidence suggests that femoral neck shortening takes place as high as 32–65.7% in FNF patients after internal fixation, contributing to gait disorder, hip dysfunction and decline the quality of life [52, 53]. Curiously, Huang et al found that the incidence of femoral neck shortening in FNF patients with comminution was significantly higher than that in patients without comminution [5]. In accordance with conclusion of Zlowodzki et al[19], Our study found that the incidence of femoral neck shortening was 18.0% in all cases, and the incidence neck shortening in FNF with disrupted cortex (21.6%) was much higher than that in FNF without disrupted cortex (13.4%), especially in FNF with multiple. We believed that, cortical deficiency in femoral neck might make an impact on stable in fracture sites after reduction, prone to cause fragments to slide along the implant and permit impaction at the fracture site, particularly when patients sustained with an axial loading forced during early weight bearing.

The functional outcomes and health-related quality of life in FNF patients with comminution have been ignored and not well investigated in previous studies. In our study, we firstly found that HSS and EQ-5D index was significantly worse in patients with comminutions than those without comminution, whereas there were no prominently differences in VAS score between two groups. Unsuspiciously, the FNF patients with multiple comminutions possessed the relatively worse HSS, EQ-5D index and VAS

score in comparison to those with single comminution. In our view, the higher incidence of ONFH, nonunion and femoral neck shortening in FNF patients with multiple comminutions might have great influences on operative recovery of hip function, leading to poor function score.

Indeed, there are several limitations in this study as following: primarily, the major limitation of the present study is its retrospective design, short follow-up duration and small sample size, which might lead to some deviations emerged in clinical outcomes. Besides, relatively high proportion of patients did not complete our followed-up (89 out of 473 patients, 18.8%), with the main reasons including change of contact number, incomplete imaging and refuse to participate, which might influence our data collective. Additionally, although we authenticated fracture morphology relied on 3D-CT scan, there was still no clear definition or description for characteristics of cortical comminution in femoral neck, resulting in inaccurate grouping of fractures and bias. Therefore, we hoped that, larger sample size, multicenter, and long follow-up randomized studies should be established as quickly as possible to further confirm the effects of comminutions on FNF after internal fixation.

Conclusion

In present study, we found that, the comminution in femoral neck was commonly occurred in displaced FNF comparing with non-displaced FNF, while the posterior comminution and inferior comminution were the most frequent patterns. As we hypothesized, the comminution in femoral neck, especially multiple comminutions, was seemed to be a hazardous factor for postoperative ONFH, nonunion, femoral neck shortening and internal fixation failure in young and middle-aged FNF patients underwent surgery, consequently causing an influence on recovery of hip function and life quality. We hoped that, these findings could remind clinicians to pay more attention and make appropriate decisions in management of these fractures, accordingly avoiding unnecessarily postoperative failures and effectively promoting functional recovery in FNF patients.

Abbreviations

FNF: femoral neck fracture; CSF: patients after cannulated screw fixation; HHS: Harris hip score; EQ-5D: EuroQol five dimensions questionnaire; VAS: Visual analogue scale; ONFH: osteonecrosis of femoral head; AP: anteroposterior; 3D-CT: three-dimensional computed tomograph; MRI: magnetic resonance imaging; SPSS :Statistical Package for Social Sciences; ANOVA: analysis of variance; BMI: body mass index; ASA :American Society of Anesthesiologists.

Declarations

Ethics approval and consent to participate

Not applicable. All analyses were based on previous published studies; thus, no ethical approval and patient consent are required.

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

ZH, XLM and QD contributed to the study design. WT, CH, and XS contributed to the imaging analysis. ZH, WT, NNJ, and DDC contributed to clinical follow-up. ZH, WT, CH, and XS contributed to data analysis. ZH and WT contributed to the article writing. XLM and QD made the final decision. All authors read and approved the final manuscript.

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Figures

Figure 1

Flowchart of patients in 6 groups. FNF: femoral neck fracture.

Figure 2

The 3D-CT showing that different distribution of comminutions in femoral neck on FNF patients. (A): anterior comminution; (B) posterior comminution; (C) superior comminution; (D) inferior comminution; (E) multiple comminutions;(F) without comminution.