The Probability of and Risk Factors for Femoral Neck Shortening and Internal Fixation Failure After Femoral Neck Fracture Treatment Using Cannulated Screws Combined With a Medial Buttress Plate

Jinglei Xu
Luoyang Orthopedic-Traumatological Hospital
Xue Bai
Zhengzhou University First Affiliated Hospital
Chenyang Xu
Luoyang Orthopedic-Traumatological Hospital
Xianzhong Ma (mxz0626@163.com)
Henan Provincial Luoyang Orthopedics Hospital

Research article

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Abstract

Background: A range of postoperative complications make femoral neck fracture difficult to treat. Femoral neck shortening and internal fixation failure are two most prevalent complications associated with many surgical strategies. This study evaluates the probability of and risk factors for these complications after the treatment of femoral neck fracture using cannulated screws combined with a medial buttress plate.

Methods: Data of 70 patients with femoral neck fractures treated using cannulated screws combined with a medial buttress plate in our hospital between March 2016 and March 2019 were retrospectively analyzed, and 40 patients who were followed up for more than 3 months were enrolled in the study. We evaluated the probability of postoperative femoral neck shortening and internal fixation failure and conducted multivariate logistic regression analysis to determine risk factors.

Results: All 40 patients had Garden III/IV or Pauwels II/III fractures. Of these patients, 11 had femoral neck shortening greater than 5 mm and 8 had fracture nonunion or screw cutout requiring reoperation. There were no differences in age, sex, fracture site, Pauwels classification, and reduction quality between the shortening and non-shortening groups; however, there were significant differences in screw quality. Similarly, there were no differences in age, sex, Pauwels classification, reduction quality, and screw quality between the fixation failure and non-failure groups, but there were significant differences in fracture site and shortening. According to the multivariate analyses, screw quality was an independent risk factor for femoral neck shortening (odds ratio [OR]: 8.58; 95% confidence interval [CI]: 1.35–50.57; P=0.022), and femoral neck shortening was an independent risk factor for internal fixation failure (OR: 11.82; 95% CI: 1.66–84.36; P=0.014).

Conclusions: Femoral neck fracture treatment using cannulated screws combined with a medial buttress plate led to a femoral neck shortening rate lower than that of other internal fixation methods and an internal fixation failure rate lower than or equivalent to that of other internal fixation methods. The quality of cannulated screws is a risk factor for postoperative shortening of the femoral neck, and femoral neck shortening is a risk factor for postoperative internal fixation failure.

Background

Femoral neck fractures account for almost half of all hip fractures and are most common in the elderly; in young adults, these fractures are often caused by high-energy trauma [1]. The treatment of femoral neck fractures is still challenging for clinicians. Although these treatment strategies and methods are constantly improving, a variety of postoperative complications still exist, with the most common being fracture nonunion, malunion, failure of internal fixation, and femoral head necrosis [2–5]. Parker et al. [6] reported that the nonunion rate of displaced femoral neck fractures after internal fixation was up to 30.1%, which is a rate that increases with age. At present, surgeons generally believe that obtaining anatomic reduction and firm fixation is the key to the treatment of femoral neck fracture [7]. Therefore, a variety of operation strategies and internal fixation methods have been developed in recent years, including the "inverted triangle" parallel arrangement of three cannulated screws [8], a commonly used simple and minimally invasive technique, and the proximal femur angle plate and sliding hip screw (SHS) [9]. On the other hand, biplanar non-parallel screws have recently been reported to have better biomechanical and clinical healing rates than parallel screws; however, long-term follow-up results for this approach are still lacking [10, 11]. Although most patients can achieve anatomic reduction through closed reduction, this is often difficult in young patients and in cases of comminuted femoral neck fractures [12, 13]. For such patients, an incision is required to achieve anatomical reduction, and the most commonly used method is the direct anterior approach (modified Smith-Petersen) introduced by Molnar et al. [14]. Since Hassan Mir [15] first proposed the concept of the medial buttress plate, the clinical application of cannulated screws combined with a medial buttress plate for the treatment of femoral neck fractures, especially displaced femoral neck fractures with high shear force, has been increasing and achieving good results [16]. However, a follow-up study showed that although this treatment approach for femoral neck fractures significantly improved postoperative stability [17], postoperative femoral neck shortening, and fracture nonunion/internal fixation failure were still prevalent.

There are numerous reports on the probability and risk factors of femoral neck shortening and internal fixation failure after the use of multiple screws and SHS fixation treatment approach [18–20], but not after the use of cannulated screws combined with a medial buttress plate. Therefore, the purpose of this study was to evaluate the probability of and risk factors for femoral neck shortening and internal fixation failure after treatment of femoral neck fracture using cannulated screws combined with a medial buttress plate. The findings of this study could provide a theoretical basis for clinical treatment decision-making.

Patients And Methods

Patients

Data from 70 femoral neck fracture patients who were treated with cannulated screws combined with a medial buttress plate in our hospital from March 2016 to March 2019 were retrospectively analyzed. All patients were Garden III/IV or Pauwels II/III. The inclusion criteria were: (1) having follow-up data of ≥3 months and (2) having complete clinical and imaging data. The exclusion criteria included: (1) pathologic fracture of the femoral neck, (2) ipsilateral intertrochanteric fracture of the femoral neck, (3) removal of internal fixators for postoperative incision infection, and (4) follow-up data of <3 months. Ultimately, 40 patients were selected as research subjects, with 22 males and 18 females. The mean follow-up period was 19.5 months (range: 3–36 months);the average age at the time of injury was 37 years (range: 12–62 years); the average operation time was 1.5 hours (range: 1–2 hours), and the average blood loss during surgery was 90 mL (range: 30–150 mL).

Surgical technique

All internal fixations were performed using the standard basic technique and were completed by the same senior physician. Each patient was placed in the supine position on a radiolucent table. The healthy limb was placed on the abductor frame, the C-arm was set up in advance, and it was verified that good anteroposterior and lateral or axial positions of the hip joint could be obtained. All patients first underwent closed reduction three times, upon failure of which, open reduction using direct anterior approach was adapted. A 10–15 cm skin incision was made approximately 2 cm lateral and 2 cm distal to the anterior superior iliac spine. The incision extended distally toward the lateral aspect of the patella. The space between the tensor fascia latae and sartorius was identified after subcutaneous incision, and the lateral femoral cutaneous nerve should be carefully protected. The rectus femoris was then exposed, and its lateral origin was cut. The sartorius and rectus femoris were pulled to the medial side, and the tensor fascia latae were pulled to the lateral side. The ascending branch of the lateral femoral circumflex artery was ligated, the hip capsule was exposed, and a “T”-shaped capsulotomy was sharply made through the anterior capsule, following which the hematoma was evacuated. A 2.5 mm Kirschner wire was placed into the femoral head and used as a joystick to manipulate the femoral head, aiding in achieving anatomic reduction. Traction, internal rotation, and adduction of the affected limb were performed when necessary. Once the femoral neck fracture had been anatomically reduced, a 2.5 mm Kirschner wire was drilled from the lateral thigh parallel to the femoral neck to maintain the reduction. Then, three cannulated screw guide needles were drilled under the supervision of fluoroscopy, and these guide needles were arranged in parallel and in an inverted triangle; the distance to the femoral neck cortex was no more than 5 mm. The appropriate length of the guide needles was determined after which three 6.5 mm cannulated screws, corresponding to that length, were screwed in. The fracture end was directly examined, confirming fracture reduction without loss. Hip abduction, rotation, and flexion were also confirmed, such that the medial side of the femoral neck can be exposed. A suitable length of one third tubular or reconstructed medial buttress plate had been pre-bent and was placed on the medial side of the femoral neck. First, a cortical bone screw was drilled into the distal end of the fracture line to press the plate to the medial side of the femoral neck. Then, a cortical bone screw was screwed into the femoral head through the plate, and the final screw passed through the hole at the distal end. Fluoroscopy confirmed proper positioning of the plate and screw. The incision was rinsed and sutured after drainage.

After surgery, a tolerable range of hip motion was immediately permitted. Partial weight bearing of the affected limb was allowed 6 weeks after surgery, but only under the guidance of a physician. Patients were postoperatively followed-up at 6 weeks, 3 months, 6 months, and 12 months, and then every 6 months thereafter.

Measurements

Femoral neck shortening was defined as a shortening distance >5 mm and was measured using the method described by Zlowodzki et al. [21]; using the screw with the greatest amount of lateral protuberance in the follow-up radiographs compared with initial fixation (Figure 1). Internal fixation failure was defined as fracture nonunion or screw cutout requiring reoperation. All radiographic evaluations and measurements were performed by all the authors of this study. In case of disagreements, the corresponding author made the final decision. For continuous data, the average of all measurements was calculated after eliminating the two most extreme values, and this average was used in subsequent analyses. Digimizer 4.5.1 (MedCalc Software, Belgium) was used to measure the shortening distance. All images were calibrated using the known screw diameter (6.5 mm). To determine the associated risk factors for shortening, we assessed patients' age, sex, reduction quality, cannulated screw quality, fracture site, and Pauwels classification. In addition, shortening was evaluated as a risk factor for internal fixation failure. Reduction quality was based on the Garden classification [22] and was rated as anatomic, acceptable (within the range of 155°–180° in both anteroposterior and lateral radiographs), borderline acceptable (<155° or >180° in either view), or unacceptable (<150° or >185° in the anteroposterior radiograph alone). Screw position was scored based on subjective evaluation of screw location adequacy and spread in an inverted triangle configuration based on the intraoperative fluoroscopic images [23]. The screw position was given a score of 3 if it was excellent and represented optimal surgical technique(three screws obtained 3-point fixation), 2 if it was sub-optimal but acceptable(two screws obtained 3-point fixation), and 1 if it was poor(only one or no screw obtained 3-point fixation) [18]. Since the number of cases scored with 1 point was small, the cases were divided by score into two groups only: “=3” and “≤2.” Similarly, because there were fewer cases of basicervical femoral neck fractures, the cases were divided by fracture site into subcephalic and non-subcephalic (transcervical and basicervical). According to the Pauwels classification [24], all patients in the study were diagnosed as either Pauwels II or III, and no surgery for type I was required. Similarly, all patients were either Garden types III/IV, and no surgery for Garden type I/II was required.

Statistical Analyses

Independent two-sample t-test was performed for continuous variables, and the chi-square or Fisher exact test was performed for categorical variables. For all tests, a 2-sided p-value of 0.05 was considered significant. Multivariate regression analysis was performed for variables with a p-value less than 0.1. Statistical analyses were performed using SPSS statistics software (version 22.0; SPSS, Chicago, IL, USA).

Results

Among 40 patients enrolled in the study, 11 had femoral neck shortening of > 5 mm and 8 had femoral neck shortening of > 10 mm. Moreover, 8 patients had fracture nonunion or screw cutout, requiring reoperation (Fig. 2). Among them, 6 patients underwent joint replacement and 2 underwent valgus-producing osteotomy. The average time from surgery to identification of nonunion was 4 months (range: 3–5 months). Due to open reduction, postoperative X-rays showed that all fracture reductions were either anatomic or acceptable, and none were borderline acceptable and unacceptable.

According to univariate analyses, there were no differences in age, sex, fracture site, Pauwels type, and reduction quality, but there were significant differences in screw quality between the shortening and non-shortening groups. Similarly, there were no differences in age, sex, Pauwels type, reduction quality, and screw quality, but there were significant differences in fracture site and shortening between the fixation failure and non-failure groups (Table 1).

Table 1

Patient Demographic and Clinical Characteristics

Variables	Total (n = 40)	Femoral neck shortening			Fixation failure		
		Yes (n = 11)	No (n = 29)	p-value	Yes (n = 8)	No (n = 32)	p-value
Age(years)	37.95±16.06	45.09±13.5	35.24±16.32	0.083	46.25±16.00	35.88±15.63	0.103
Sex (no.[%])				0.499			0.709
Male	22(55.0)	7(63.6)	15(51.7)		5(62.5)	17(53.1)	
Female	18(45.0)	4(36.4)	14(48.3)		3(37.5)	15(46.9)	
Fracture site (no.[%])				0.056			0.020
Subcephalic type	4(10.0)	3(27.3)	1(3.4)		3(37.5)	1(3.1)	
Non-subcephalic type	36(90.0)	8(72.7)	28(96.6)		5(62.5)	31(96.9)	
Reduction quality (no.[%])				0.137			0.227
Anatomic	29(72.5)	6(54.5)	23(79.3)		4(50.0)	25(78.1)	
Acceptable	11(27.5)	5(45.5)	6(20.7)		4(50.0)	7(21.9)	
Screw position score (no.[%])				0.014			0.229
=3	24(60.0)	3(27.3)	21(72.4)		3(37.5)	21(65.6)	
≤2	16(40.0)	8(72.7)	8(27.6)		5(62.5)	11(34.4)	
Pauwels typing (no.[%])				0.704			1.000
Pauwels type III	28(70.0)	7(63.6)	21(72.4)		6(75.0)	22(68.7)	
Pauwels type II	12(30.0)	4(36.4)	8(27.6)		2(25.0)	10(31.3)	
Femoral neck shortening (no.[%])							0.003
Yes	11(27.5)				6(75.0)	5(15.6)	
No	29(72.5)				2(25.0)	27(84.4)	

Independent two-sample t-test was performed for continuous variables, and the chi-square or Fisher exact test was performed for categorical variables.

On the other hand, according to the multivariable analysis, screw quality was an independent risk factor for femoral neck shortening (odds ratio [OR]: 8.58; 95% confidence interval [CI]: 1.35–50.57; P = 0.022). Shortening of the femoral neck was an independent risk factor for internal fixation failure (OR: 11.82; 95% CI: 1.66–84.36; P = 0.014) (Table 2).

Table 2
Multivariate Analysis of the Influence of variables on the Likelihood of femoral neck shortening and fixation failure (N = 40)

Variables	Femoral neck shortening		Fixation failure	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Age(years)				
< 55	Reference			
≥ 55	1.18(0.15,9.27)	0.872		
Fracture site				
Subcephalic type	15.05(0.98,231.90)	0.052	9.65(0.58,162.06)	0.115
Non-subcephalic type	Reference		Reference	
Screw position score				
= 3	Reference			
≤ 2	8.28(1.35,50.57)	0.022		
Femoral neck shortening				
Yes			11.82(1.66,84.36)	0.014
No			Reference	

Discussion

Femoral neck shortening is a common phenomenon after internal fixation of femoral neck fractures. Weil et al. [19] reported a shortening rate of 56% (> 5 mm) and a severe shortening rate of 22% (> 10 mm) after using multiple cannulated screws to fix femoral neck fractures. Moreover, Stockton et al. [20] found that femoral neck shortening and severe shortening rates could go up to 54% and 32%, respectively, after using multiple cannulated screws or an SHS + anti-rotating screw, with the former being lower than the latter. Zlowodzki et al. [25] also found, through a multi-center joint study, that the postoperative shortening and severe shortening rates of femoral neck fractures fixed by cannulated screws were up to 66% and 30%, respectively. Furthermore, study showed that the shortening of the femoral neck permanently affects hip function after surgery, primarily impacting gait velocity and gait symmetry [26], with older patients tending not to have the ability to compensate for the impact. Therefore, determining the appropriate internal fixation method to minimize the shortening of the femoral neck has become a research focus.

Since Hassan Mir [15] first proposed the concept of the medial buttress plate of the femoral neck, relevant anatomical and biomechanical studies have been continuously conducted, verifying the effectiveness of this method[16, 17]. Currently, the focus of debate in this type of surgeries is whether open reduction can impair the blood supply of the femoral head, thus increasing the possibility of femoral head necrosis. In this regard, the The direct anterior approach has been proven safe and reliable. In 2019, Utnam et al. [27] further confirmed through human autopsy that the placement of the buttress plate on the medial side of the femoral neck had been safe and did not destroy the blood supply to the femoral head, with the optimal placement position being at 6 o'clock of the femoral neck.

In our study, 40 patients with complete follow-up data who received cannulated screws combined with a medial buttress plate were selected for analysis. For this cohort, we found that the postoperative femoral neck shortening rate (> 5 mm) of this internal fixation method was 27.5% and that the severe shortening rate was 20%. It can be seen that the shortening rate of this internal fixation method is lower than that of other previously reported internal fixation methods; however, the severe shortening rate is less than or equal to that in previous reports [19, 20, 25]. These findings suggest that cannulated screws combined with a medial buttress plate can provide higher stability but cannot prevent the shortening of the femoral neck after internal fixation.

Stockton et al. [20] conducted a study on femoral neck shortening after fixation using the SHS + anti-rotating screw and multiple screws, suggesting that the degree of fracture displacement and internal fixation method are independent risk factors for femoral neck shortening. Similarly, our study involving Garden III/IV fractures showed that the quality of cannulated screws was an independent risk factor for femoral neck shortening and that there was no significant correlation with age, sex, fracture site, Pauwels type, and reduction quality. These findings suggest that despite the use of a medial buttress plate, the quality of the cannulated screws still plays the most important role. Risk factors for femoral neck shortening after internal fixation have not been reported.

Postoperative internal fixation failure of femoral neck fracture is another issue, with a reported failure rate of 10–30% [28]. The nonunion rate of fixation using three cannulated screws alone was 21.8% [29]. In our study, all patients had Pauwels type II/III or Garden III/IV fractures, although all had displaced fractures and high shear force, with an internal fixation failure rate that was 20% lower than that of fixation using simple cannulated screws. The nonunion rate of fractures after fixation with cannulated screws, SHS + screw, and locking compression plate is up to 11.9% according to a previous report [30]. However, many patients with Garden II femoral neck fractures had been included in this previous report, and thus, the results are not directly comparable with those of our study.

Numerous studies [28, 29, 31] have reported that the internal fixation method, degree of fracture displacement, and poor reduction are risk factors for postoperative internal fixation failure of femoral neck fractures. However, the risk factors for postoperative internal fixation failure of femoral neck fractures, specifically treated using cannulated screws combined with a medial buttress plate, have not yet been reported. Our study found that femoral neck shortening is an independent risk factor for internal fixation failure; however, it was not related to age, sex, reduction quality, Pauwels type, fracture site, or screw quality. Therefore, the prevention of femoral neck shortening should be the main approach for preventing internal fixation failure. Nevertheless, more stable internal fixation methods still need to be studied.

This study has some limitations. First, due to the lack of multicenter data, as well as our low number of cases and short follow-up times, femoral head necrosis could not be analyzed. Second, since all patients treated with this internal fixation method were Garden type III/IV or Pauwels type II/III, Garden type I/II and Pauwels type I have been excluded from the comparative analysis. Due to the adaption of open reduction, all reduction qualities have been categorized as anatomic and acceptable, whereas borderline acceptable and unacceptable were excluded from the comparative analysis. Finally, because image examination in some patients was not standard, there was inevitable error in this data subset.

Conclusions

Despite its limitations, our study demonstrated that the treatment of femoral neck fractures using cannulated screws combined with a medial buttress plate led to a femoral neck shortening rate that is lower than that observed in other internal fixation methods and an internal fixation failure rate that is lower than or equivalent to that of other internal fixation methods. The quality of cannulated screws is a risk factor for postoperative shortening of the femoral neck, and femoral neck shortening is a risk factor for postoperative internal fixation failure.

Abbreviations

OR : odds ratio

CI : confidence interval

SHS : sliding hip screw

Declarations

Ethics approval and consent to participate:

This research work was approved by the Medical Research Ethics Committee of our hospital and was performed in accordance with the Declaration of Helsinki.

Consent for publication:

Not applicable

Availability of data and materials:

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

Jinglei Xu analyzed and interpreted the patient data regarding the femoral neck fracture and the transplant. Xue Bai provided financial support and writing guidance, and was a major contributor in writing the manuscript. Chenyang Xu did the work of the cases to collect. Xianzhong Ma is a guide to the whole idea of the article. All authors read and approved the final manuscript.

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Figures

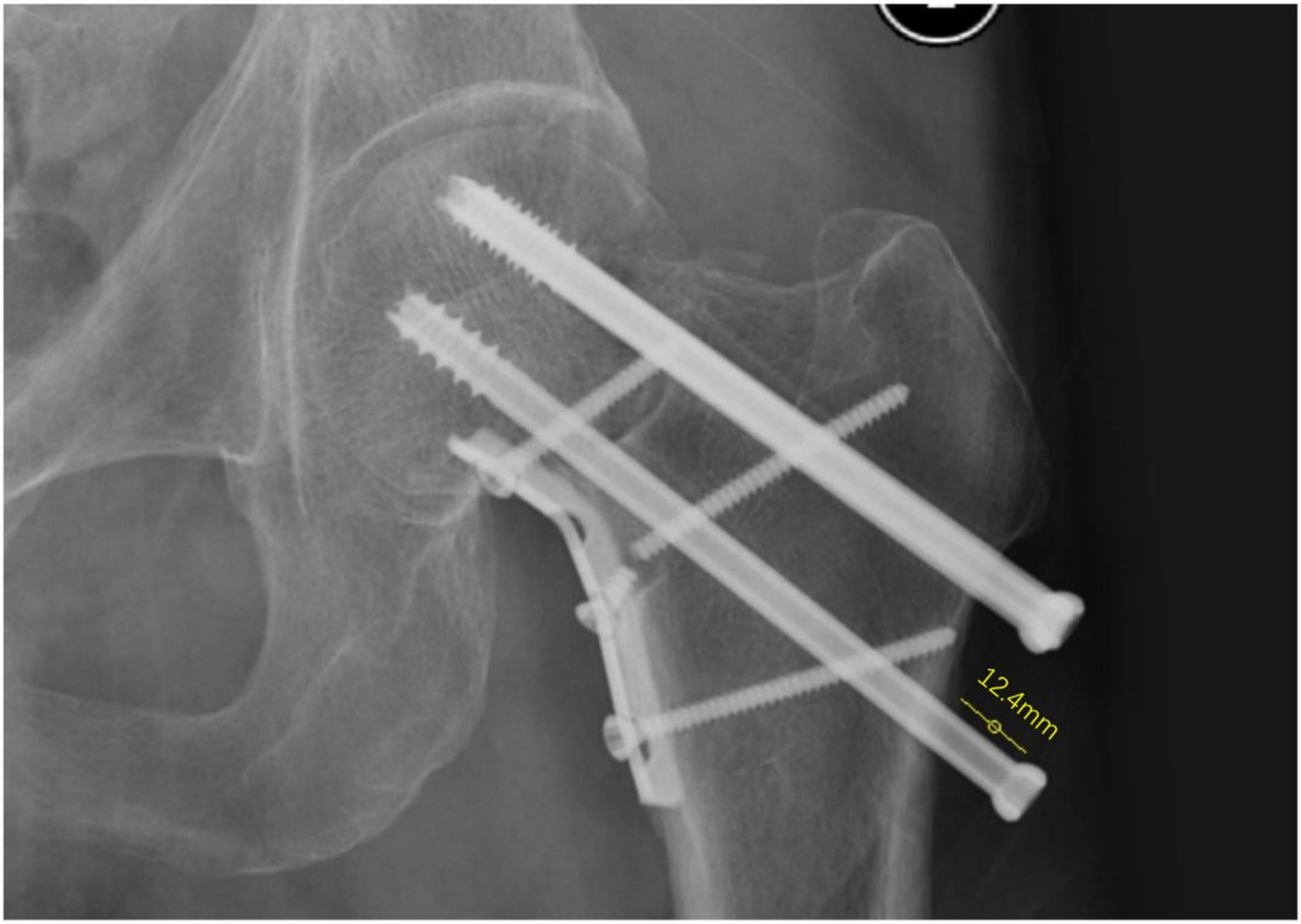

Figure 1

A 53-year-old man with a 12.4-mm femoral neck shortening 6 months after surgery.

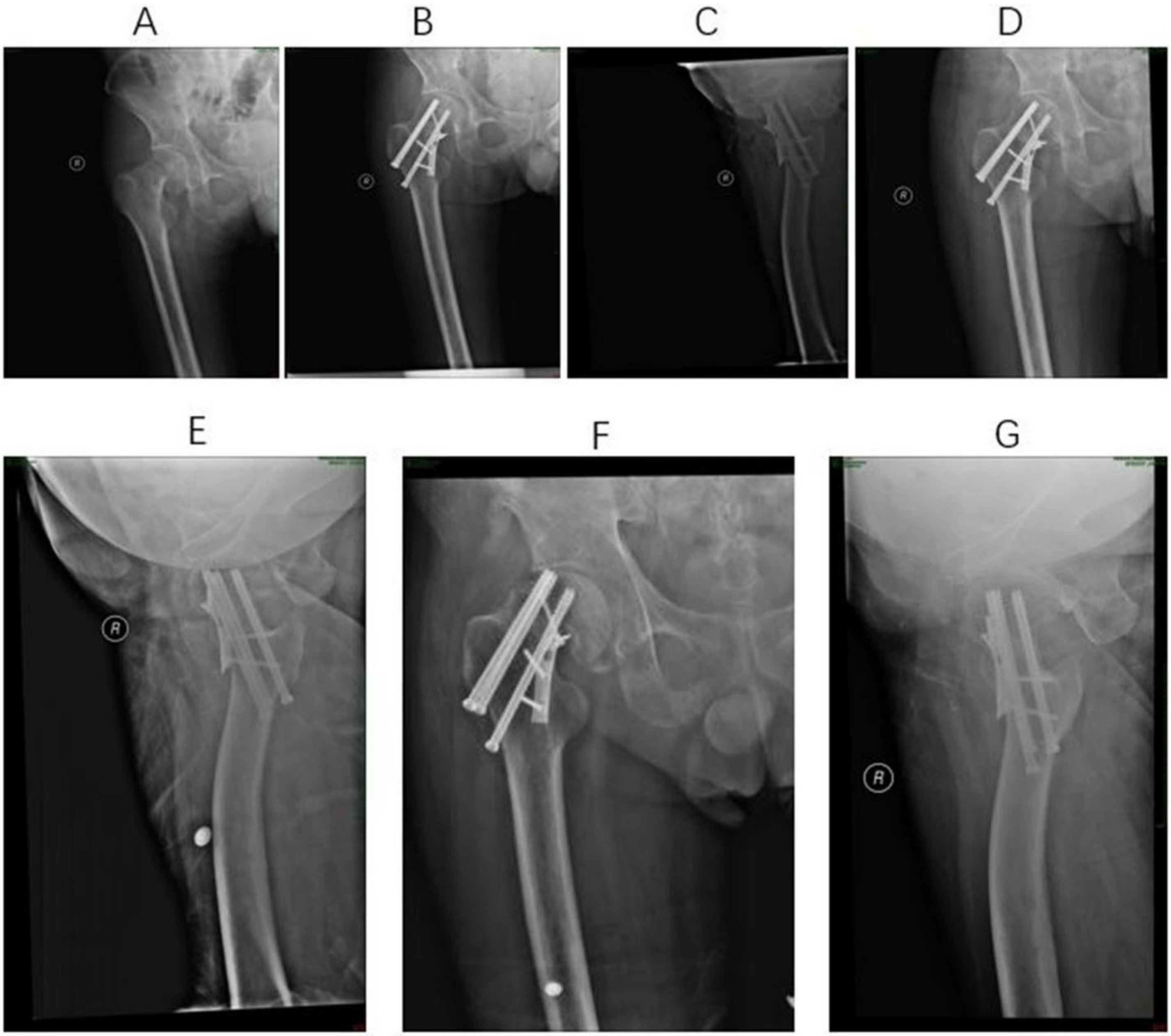

Figure 2

A 35-year-old man with femoral neck fracture. A: Preoperative anteroposterior radiograph showing Pauwels type II fracture. B-C:Anteroposterior radiograph and lateral radiograph after treatment with cannulated screws combined with a medial buttress plate. D-E: Anteroposterior radiograph and lateral radiograph at 6 weeks of follow-up showing no loss of reduction and no failure of internal fixation. F-G: Anteroposterior radiograph and lateral radiograph at 12 weeks of follow-up showing screw cutout and fracture redisplacement. The patient eventually underwent joint replacement.