Original Research Article

Analysis of the therapeutic effects of percutaneous compression plate for femoral neck fractures in young and middle-aged patients: A multicenter and >2-year follow-up study

Abstract

Introduction: Traditional internal fixators include hollow compression screw (HCS) and sliding hip screw] for femoral neck fractures have a high incidence of complications, and are not conducive to postoperative early rehabilitation and weight-loading of patients. Therefore, femoral neck fractures are referred to as 'unresolved fractures'. However, single-center results of percutaneous compression plate (PCCP) have showed a significant improvement in efficacy. We retrospectively analyzed the therapeutic effects of PCCP for femoral neck fractures in young and middle-aged patients in a multi-center and >2-year follow-up.

Materials and Methods: Between January 2010 and December 2017, 331 patients with femoral neck fractures in young and middle-aged patients fixed with HCS and PCCP in four hospitals were studied retrospectively.

Results: There were 182 men and 149 women, with an average age of 47.69 years (age range, 20-65 years). HCS group vs. PCCP group (170 vs. 161). There was no significant difference in the baseline data between the two groups ($P>0.05$). All patients were followed-up for 24-60 months (mean, 36 months). The operative time and intraoperative bleeding were significantly decreased, whereas the hospital stay significantly longer in HCS group than those in PCCP group ($P<0.05$). Nonunion in

17 cases and fixation failure in 14 cases in HCS group, whereas 3 and 0 cases, respectively, in PCCP group, showing significant difference (P<0.05). Avascular necrosis (AVN) in 17 cases in HCS group while 15 cases in PCCP group, showing no significant difference (P>0.05). The overall complications in HCS group were greater than that in PCCP group (P<0.05). The Harris hip scores at 6- and 12-month follow-up in group PCCP were significantly improved than those in group HCS (P<0.05), but not significant at 18-, 24- month and last follow-up between the two groups (P>0.05).

Conclusion: Our results suggest that PCCP is a stable and reliable internal fixation device with sliding compression effect for femoral neck fractures, which has satisfactory short and mid-term therapeutic effects, but AVN remains unsolved.

Key words: Femoral neck fracture, Multicentre, Percutaneous compression plate, Therapeutic effect

1.INTRODUCTION

Femoral neck fracture accounts for 3.8% of all fractures[1,2]. For relatively young patients or patients with good bone condition, the primary aims of treatment are to preserve the femoral head, to achieve bone healing and to avoid avascular necrosis (AVN) of the femoral head[2-4]. However, the incidence of nonunion, fixation failure and AVN of traditional internal fixators, which involve hollow compression screw (HCS) and sliding hip screw (SHS) is as high as 25-53% [1,3,5], mainly due to the poor stability of the internal fixators. Therefore, femoral neck fractures are referred to as 'unresolved fractures' [1,6]. In recent years, percutaneous compression plate (PCCP) [7-10], Targon-FN[11] and PH intramedullary nails [12], which have stronger stability, have been used for femoral neck fractures. The results of these aforementioned treatments have showed improved efficacy compared with traditional internal fixators. Among them, PCCP had the lowest incidence of nonunion (1%-2%). However, most were mid-term follow-up results, to the best of our knowledge, no multi-center study assessing PCCP for femoral neck fractures has been performed. Hence, the primary objective of this study was to investigate the therapeutic effects of PCCP vs. HCS for femoral neck fractures in young and middle-aged patients in a multi-center and mid-term follow-up.

2. MATERIALS AND METHODS

2.1 Ethical approval

The study was approved by the Ethics Committees of Wuxi No. 9 People's Hospital Affiliated to Suzhou University (No. WXSDJYY-LY20190034) and Jiangnan University Affiliated Hospital (No. JDFFYY-2019-00126), Jiangyin People's Hospital (No. JY201900120)and Yixing People＇s Hospital (No. LXYY-2019-00217) and in accordance to the Declaration of Helsinki. As a retrospective study, this study was exempt from the informed consent from patients.

2.2 Study design

This study retrospectively analyzed the clinical data of patients of femoral neck fractures fixed with HCS or PCCP in the four hospitals between January 2010 and December 2017. The inclusion criteria were as follows: i) Patients with recent traumatic femoral neck fractures undergoing closed reduction and internal fixation; ii) 20<age<65 years old; iii) no history of hip disease; iv) unilateral femoral neck fractures; and v) >2 years of postoperative follow-up. Exclusion criteria included: i) Pathological or old fractures; ii) autologeous bone-flap; iii) patients who have autoimmune diseases or were treated with hormone therapy for internal medical diseases; iv) severe osteroposis; v) poor reduction of fractures; and vi) incomplete clinical and radiological data.

A total of 331 patients were included in the study. Among them, 170 patients were in HCS group and 161 patients were in PCCP group. 146 cases (85.88%) in HCS group underwent operation before 2014, and 126 cases (78.26%) in PCCP group underwent operation since 2014. The demographic characteristics and clinical profiles including age, sex, fracture type (based on Pauwels' classification), course (time from injury to surgery), Singh index, fracture side and co-existing diseases were recorded. All surgeries in the two groups were performed by one of four orthopaedic surgeons who were similarly experienced in hip surgery (> 15 years), assisted by one or two junior fellows. And all surgeons were familiar with both HCS and PCCP.

2.3 Treatment

On admission to hospital, tibial tubercle traction was performed in patients with displaced fractures while T-strap were used in patients with undisplaced fractures. Patients were placed in a supine position under lumbar anesthesia or/and continuous epidural anesthesia. Standard anteroposterior (AP) and lateral images were obtained by C-arm fluoroscopy to confirm fracture reduction and internal fixator placement. For displaced fractures, satisfactory reduction can usually be achieved via longitudinal traction and internal rotation.

In HCS group, three K-wires, parallel and inverted as possible, were inserted into the femoral neck and head under X-ray control. Then three hollow compression screws were placed through a small incision among the K-wires. Patients were confined to bed-rest for 6 weeks, and then ambulated with crutches and partial weight bearing for another 6 weeks postoperatively. Complete weight bearing was allowed when the fracture healed.

In PCCP group, a PCCP plate connecting to the introducer was introduced to the lateral of the femur after subperiosteal dissection through a 2-cm incision inferior to the greater trochanter，then a 3-cm distal incision of the plate was made and the plate was fixed to the femoral shaft with a bone hook. The distal neck screw was first placed near the calcar femorale, then, screws in the proximal, middle and distal areas of the femoral shaft were placed, and finally the proximal neck screw was placed. Patients were instructed to ambulate with walking sticks or a walker within 3 days of surgery. This was followed by a gradual increase to full weight bearing by 2-3 months, postoperatively.

After discharge, all patients were followed-up monthly to assess fracture healing and then every 3 months after fracture healing. Patients were followed-up every 6 months after 0.5 year of fracture healing. Each patient was evaluated clinically and radiologically.

2.4 Observation index and outcome evaluation

Operative time was defined as the time from the beginning of skin incision to the closure of the incision. Intraoperative bleeding was measured by summation of the hemorrhage via the suction instruction and the bleeding volume of the gauzes. Moreover, quality of reduction was defined using the Garden alignment index, as previously described by Haidukewych *et al* [13]. Hospital stay was assessed by the number of days from admission to discharge. Complications included nonunion, fixation failure and AVN. Fixation failure involved the obvious displacement or hip varus at the fracture site (displacement ≥2 mm, or angle ≥10°). AVN was evaluated radiographically according to Ficat criteria [15]. Union of the fracture was defined as fracture line having completely disappeared and with a bone trabecular structure consistent with that of healthy individuals, whereas nonunion was defined as persistence of the fracture line 6 months after the surgical procedure. Harris hip score (HHS) [14] was used to assess functionary recovery of patients.

2.5 Data analysis

All statistical analyses were performed using SPSS 21.0 software (IBM Corp.). For categorical variables, a χ^2 test and Fisher's exact test were used. For quantitative variables, data are presented as the mean ± SD, and were compared using Student's t test or ANOVA between two groups. $P<0.05$ was considered to indicate a statistically significant difference.

3. RESULTS

3.1 General characteristics

There were 189 men and 142 women, with an average age of 47.69 years (age range, 21-64 years). The general characteristics of the enrolled patients are described in Table1. There were no statistically significant differences in age, sex, course, fracture type, Singh index, fracture side and co-existing diseases.

Table 1 General characteristics of two groups

Characteristics	HCS group (n=170)	PCCP group (n=161)	P -value

Age (years)	47.07 ± 15.23	48.33 ± 16.11	0.464
Gender(cases)			
Male/female	96/74	86/75	0.577
Course(days)	4.95 ± 1.61	4.75 ± 1.55	0.249
Fracture type(cases)			
I/II/III	36/84/50	32/81/48	0.832
Singh index(cases)			
IV/V /VI	48/71/51	44/74/43	0.771
Fracture side(cases)			
Left/right	81/89	76/85	0.936
Coexisting disease(cases)	57	56	0.810

Perioperative outcomes

There were no local or general intraoperative complications. There were three cases of postoperative superficial infections and 6 cases of deep vein thrombosis, but no postoperative pulmonary embolism and decubitus ulcers. There was no significant difference in the quality of reduction between the two groups (P=0.935). The operative time and intraoperative bleeding in HCS group were reduced, whereas the hospital stay was longer than those in PCCP group, showing significant difference ((P=0.002, P=0.001, and P=0.001, respectively).The results were showed in Table 2.

Table 2 Perioperative outcomes of two groups

Results	HCS group (n=170)	PCCP group (n=161)	*P*-value

Quality of reduction			
Excellent/good/fair	97/45/28	93/41/27	0.935
Operative time(min)	29.73±7.80	42.85±9.57	0.002
Intra-operative bleeding(ml)	35.19±10.28	81.55±25.41	0.001
Postoperative hospital time(days)	11.78±2.41	6.34±2.63	0.001

3.2 Follow-up outcomes

All patients were followed-up for 24-56 months (follow-up mean, 36 months). The HHSs at 6- and 12□month follow□up were 71.81 ± 14.78 and 79.93 ± 11.20, respectively, in HCS group, and 84.31 ± 5.55 and 88.59 ± 5.65, respectively, in PCCP group, and were significantly different between the two groups (P = 0.025, P = 0.044, respectively). However, the HHSs at 18-, 24 -month and last follow□up were 89.49 ± 8.40, 89.61 ± 7.60 and 89.51 ± 8.16, respectively, in HCS group, and, 91.74 ± 5.15, 91.76 ± 6.69 and 91.57 ± 6.62, respectively, in group PCCP, and were not significantly different between the two groups (P = 0.059, P= 0.053 and P= 0.071, respectively). The results were showed in Table 3.

Table 3 HHS of two groups

HHS	HCS group (n=170)	PCCP group (n=161)	*P*-value
6-month follow up	71.81±14.78	84.31±5.55	0.025
12-month follow up	79.93±11.20	88.59±5.65	0.044
18-month follow up	89.49±8.40	91.74±5.15	0.059

24-month follow up	89.61±7.60	91.76±6.69	0.053
Last follow up	89.51±8.16	91.57±6.62	0.071

3.3 Complications

17 cases nonunion and 14 cases fixation failure were observed in group HCS, whereas 3 and 0 cases, respectively, in PCCP group, the differences were significant (P=0.001, P=0.000, respectively). The 3 cases with nonunion had comminuted fractures with Singh index IV or V. Furthermore, 17 cases of AVN in group HCS while 15 cases in PCCP group were observed, showing no significant difference (P=0.833). The overall complications in HCS group was greater than that in PCCP group, showing significant difference (P=0.002). Of the 41 cases with complications, 8 cases had Pauwels II, 19 cases had Pauwels III and 14 cases had Pauwels IV femoral neck fractures; 35 cases required revision surgery, which included bone-flap or arthroplasty, and the other 6 cases were treated conservatively. The results were showed in Table 4.

Table 4 Complications of two groups

Complications	HCS group (n=170)	PCCP group (n=161)	*P*-value
Nonunion(cases)	17	3	0.001
Fixation failure(cases)	14	0	0.000
Head necrosis(cases)	17	15	0.833
Overall complication(cases)	41	18	0.002

4. DISCUSSION

An ideal internal fixator for femoral neck fractures should have reliable stability of anti-compression, anti-shear and anti-rotation properties, which is conducive to postoperative early rehabilitation and weight-loading of patients [8-11]. Furthermore, the internal fixator should have a continuous sliding compression ability, which is helpful to the fracture healing [5,7,8,16]. The strength of PCCP is higher because both of the screws and the plate are thick, and the structure between the screw and the plate has continuous sliding compression and locking connection, which is similar to that of SHS. A biomechanical experimental study [9]revealed that the torsion resistance of three HCSs was stronger than that of SHS, but the compression resistance of SHS was twice as much as three HCSs; PCCP can resist the axial compression and torsional composite stress twice as much as HCSs. Thus, the stability of PCCP on all axis is the highest. With regards to the reliable stability and sliding compression effect of PCCP, patients can receive postoperative early rehabilitation and bear weight.

Brandt *et al.* [8]were the first to report a patient with femoral neck fractures treated with PCCP and revealed that the patient was mobilized with full weight bearing from the first postoperative day without any limitations, and whose fractures healed without complications. In addition, Mukherjee and Ashworth [10] reported a patient with nonunion of femoral neck fractures, who was treated with PCCP in combination with autologous bone grafting, and was instructed to remain non-weight bearing for 6 weeks followed by a gradual increase to full weight bearing by 3 months. At 6 months, the nonunion healed. Zhu F *et al.* [17] were the persons who reported that largest number of cases of femoral neck fractures treated with PCCP. They examined 74 patients in single center study, 68 patients were followed-up, and the mean HHS was 92.9 at 18.8 month follow-up; 65 patients (98.5%) had excellent and good outcomes and there were no cases of nonunion, although two patients had delayed union and two developed AVN. Yin QD *et al.* [16] assessed 70 cases of femoral neck fractures treated with HCS and PCCP, the results showed that in the PCCP group, there was no nonunion and failure of fixation, but 2 cases had AVN; in HCS group, there were 3 cases of nonunion, 2 cases of failure of fixation, 4 cases of screw withdrawal and 4 cases of AVN. There was a significant difference in the nonunion, fixation failure and overall complications between the two groups ($P < 0.05$); furthermore, the HHS and VAS scores in PCCP group were improved compared with the HCS group at 12-month follow-up ($P < 0.05$).

Because PCCP has stronger fixation stability with sliding compression effect, the patients are permitted to take early postoperative rehabilitation and weight-bearing. Furthermore, it has a high rate of fracture healing (98.14%), no fixation failure, and less nonunion. Therefore, satisfactory functionary recovery of hip can be achieved in the early postoperative period (< 18 month postoperatively), which were improved compared with HCS in the study ($P < 0.05$). However, the difference in the functionary recovery of hip decreased gradually over time, until the difference was not significant at 18-, 24- month and last follow-up between the two groups ($P > 0.05$). This is because revision surgery had been performed in patients with nonunion and fixation failure, the hip function improved gradually during these periods, which reduced the gap of functionary recovery of hip between the two groups; moreover, most cases of AVN were identified in 18-24 months postoperatively and the difference in AVN was not significant between the two groups. The present results is in line with previous most studies that AVN is due to the disturbance of head blood circulation caused mainly by injury degree, operation timing, quality of reduction and other factors, rather than the internal fixation method [18-21]. That means AVN of femoral neck fractures remains unresolved and requires further investigation.

5. **CONCLUSION**

This study showed that PCCP was a stable and reliable internal fixation device with sliding compression effect for femoral neck fractures in young and middle-aged patients, which had satisfactory short and mid-term therapeutic effects, but AVN has not been solved.

CONSENT AND ETHICAL APPROVAL

This study was approved by Research Ethics Committee of the our four hospitals. All patient's information was kept confidential. Patient’s written consent has been collected and preserved by the author(s).

References

1. Slobogean GP, Sprague SA, Scott T, Bhandari M. Complications following young femoral neck fractures. Injury. 2014; 46: 484–491.
2. Florschutz AV, Langford JR, Haidukewych GJ, Koval KJ. Femoral neck fractures: current management. J Orthop Trauma. 2015; 29(3): 121–129.
3. Razik F, Alexopoulos AS, El-Osta B, Connolly MJ, Brown A, Hassan S, Ravikumar K. Time to internal fixation of femoral neck fractures in patients under sixty years--does this matter in the development of osteonecrosis of femoral head?. International orthopaedics. 2012;36(10),2127–2132.
4. Luo D, Zou W, He Y, Lin D. Modified dynamic hip screw loaded with autologous bone graft for treating Pauwels type-3 vertical femoral neck fractures. Injury. 2017;48: 1579–1583.
5. Zielinski SM, Keijsers NL, Praet SFE, Heetveld MJ, Bhandari M, Wilssens JP, et al. Femoral neck shortening after internal fixation of a femoral neck fracture.Orthopedics. 2013;36(7): e849-858.
6. Xiao YP, Shu DP, Bei MJ, Ji T, Kan WS, Li SG. The clinical application of a novel method of internal fixation for femoral neck fractures-dynamic locking compression system. J Orthop Surg Res. 2018;13(1):131.
7. Dong Q, Han Z, Zhang YG, Xiang S, XinLong M. Comparison of transverse cancellous lag screw and ordinary cannulated screw fixations in treatment of vertical femoral neck fractures. Orthop Surg. 2019;11(4):595–603.

8. Brandt SE. A new and stable implant in the treatment of intracapsular hip fracture:a case report.Injury Extra. 2008;39(4):137-139.

9. Brandt E,Verdonschot N,Vugt AV, Kampen AV. Biomechanical analysisi of the percutaneous compression plate and sliding hip screw in incapsular hip fractures:experimental assesment using synthetic and cadaver bones.Injury. 2006; 37(10):979-983.

10. Mukherjee P,Ashworth MJ. A new device to treat intra-capsular fracture neck of femur nonunion.Strategies Trauma Limb Reconstr. 2010;5(3):159-162.

11. Osarumwense D, Tissingh E, Wartenberg K, Aggarwal S, Ismail F, Orakwe S. The Targon FN system for the management of intracapsular neck of femur fractures: minimum 2-year experience and outcome in an independent hospital. Clin Orthop Surg. 2015;7(1):22-28.

12. Gotfried Y, Kovalenko S, Fuchs D. Nonanatomical reduction of displaced subcapital femoral fractures (Gotfried reduction). Journal of Orthopaedic Trauma. 2013; 27(11):e254-e259.

13. Haidukewych GJ, Rothwell WS, Jacofsky DJ, Torchia ME, Berry DJ. Operative treatment of femoral neck fractures in patients between the ages of fifteen and fifty years. J Bone Joint Surg Am. 2004;86: 1711–1716.

14. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am. 1969;51: 737–755.

15. Ficat RP. Idiopathic bone necrosis of the femoral head. Early diagnosis and treatment. J Bone Joint Surg Br. 1985; 67: 3– 9.

16. Chen Y, Li H, Dai L, et al. Imaging observation of percutaneous compression plate use in promoting femoral neck fracture healing. J Int Med Res. 2021;49(8):3000605211033501.

17. Zhu F, Liu G, Shao HG, et al. Wang YJ, Li RQ, Yang HL, Geng DC, Xu YZ. Treatment of femoral neck fracture with percutaneous compression plate: Preliminary results in 74 patients. Orthopaedic Surgery. 2015;7(2):132-137.

18. Wang W, Wei J, Xu Z, Zhuo W, Zhang Y, Rong H, Cao X, Wang P. Open

reduction and closed reduction internal fixation in treatment of femoral neck fractures: a meta-analysis. BMC Musculoskelet Disord. 2014;15: 167.

19. Lein T, Bula P, Jeffries J, Engler K, Bonnaire F. Fractures of the femoral neck. Acta Chir Orthop Traumatol Cech. 2011;78: 10–19.

20. Ramadanov N, Toma I, Herkner H, Klein R, Behringer W, Matthes G. Factors that influence the complications and outcomes of femoral neck fractures treated by cannulated screw fixation.Scientific Reports volume. 2020;10(1):758.

21. Wang Y, Ma JX, Yin T, Han Z, Cui SS, Liu ZP, Ma XL. Correlation between reduction quality of femoral neck fracture and femoral head necrosis based on biomechanics. Orthop Surg. 2019;11(2):318–324.

Image 1 . X-ray Image

Figure legends

Figure 1: Preoperative radiographs showed Pauwels Ⅲ femoral neck fractures (A1, A2); Postoperative radiograph showed excellent reduction of fractures at 1 month treated with HCS(B1,B2). Postoperative radiograph (C) and CT scan (D)showed nonunion, failure of fixation and screw withdrawal at 5 months.

Figure 2: Preoperative radiographs showed Pauwels Ⅲ femoral neck fractures (A1,A2); Postoperative radiograph showed union at 6 month treated with PCCP (B1, B2).

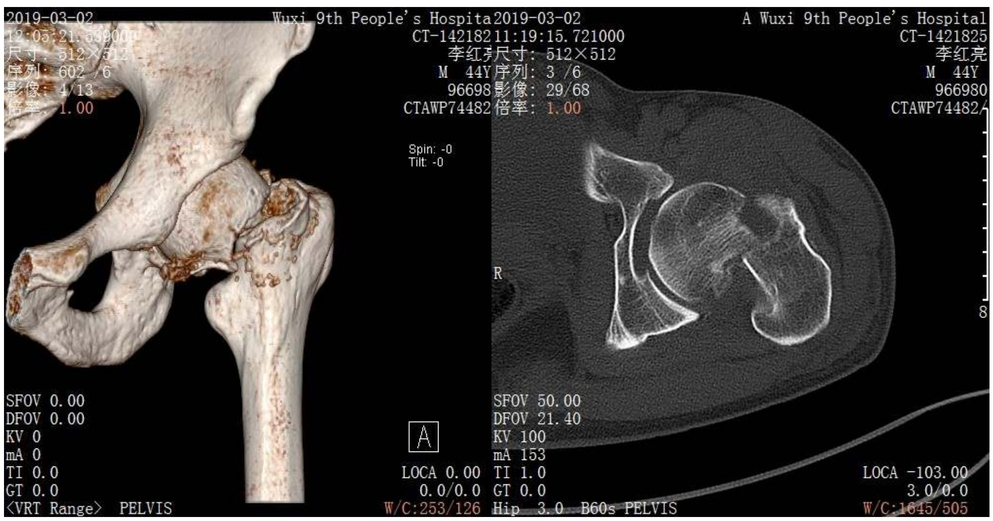
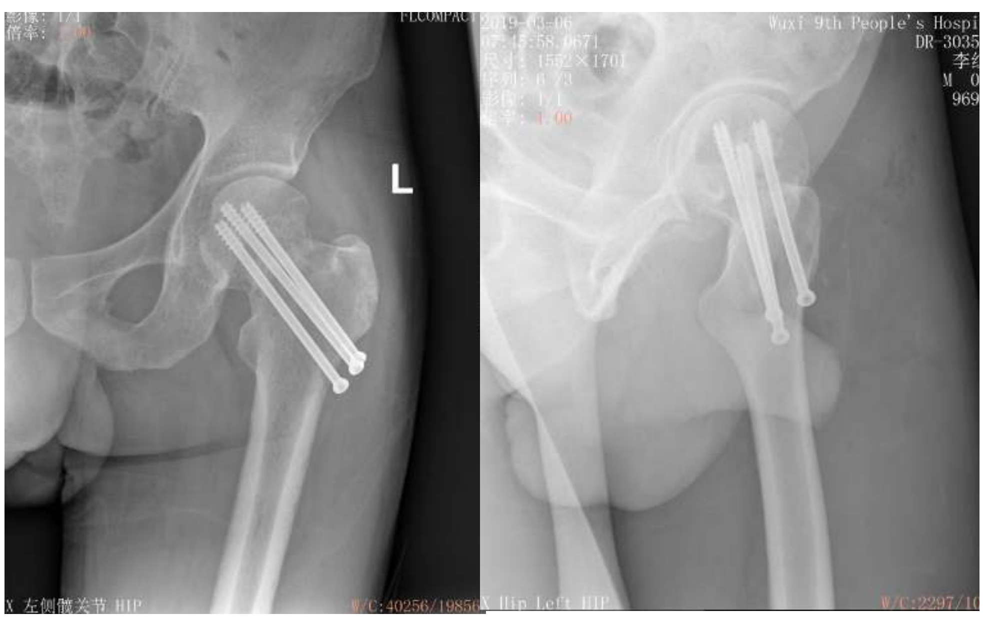


Fig. 1a.



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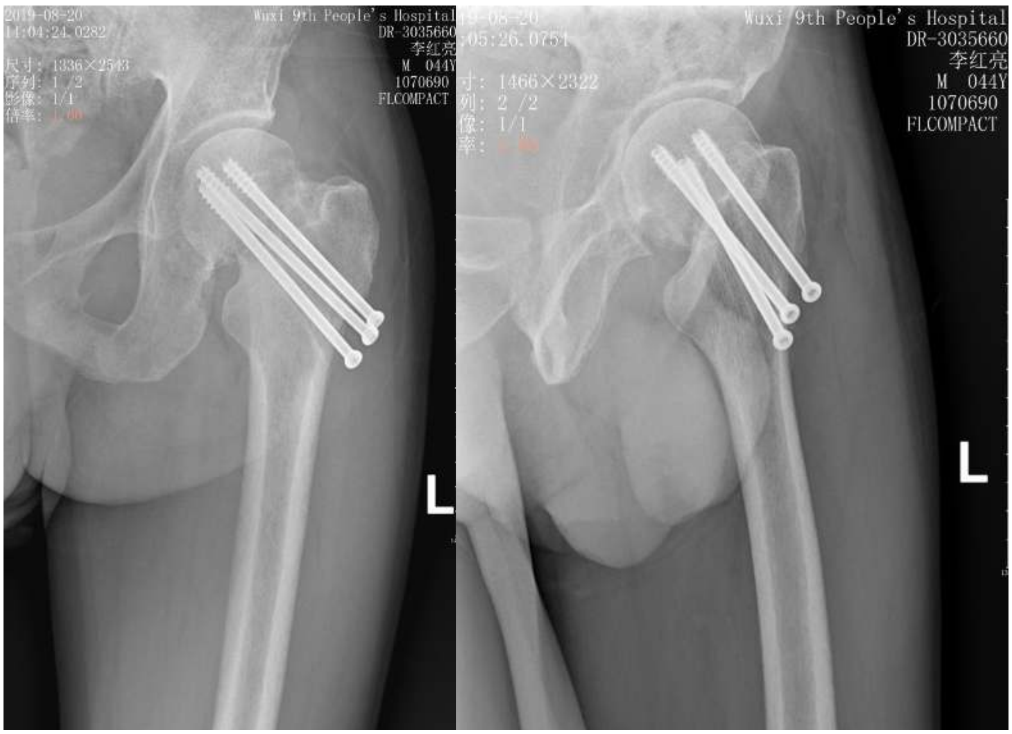
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Fig. 1c.


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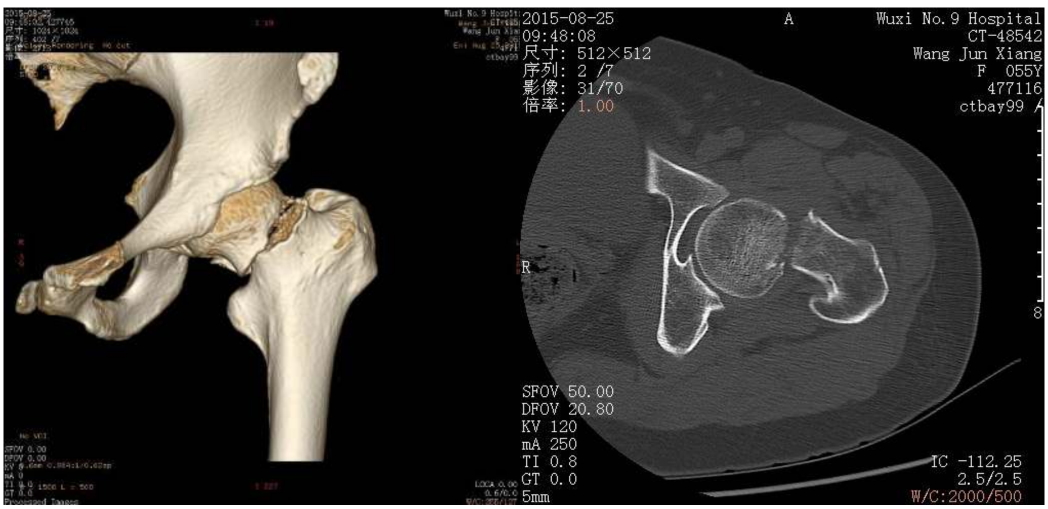
Fig. 1d.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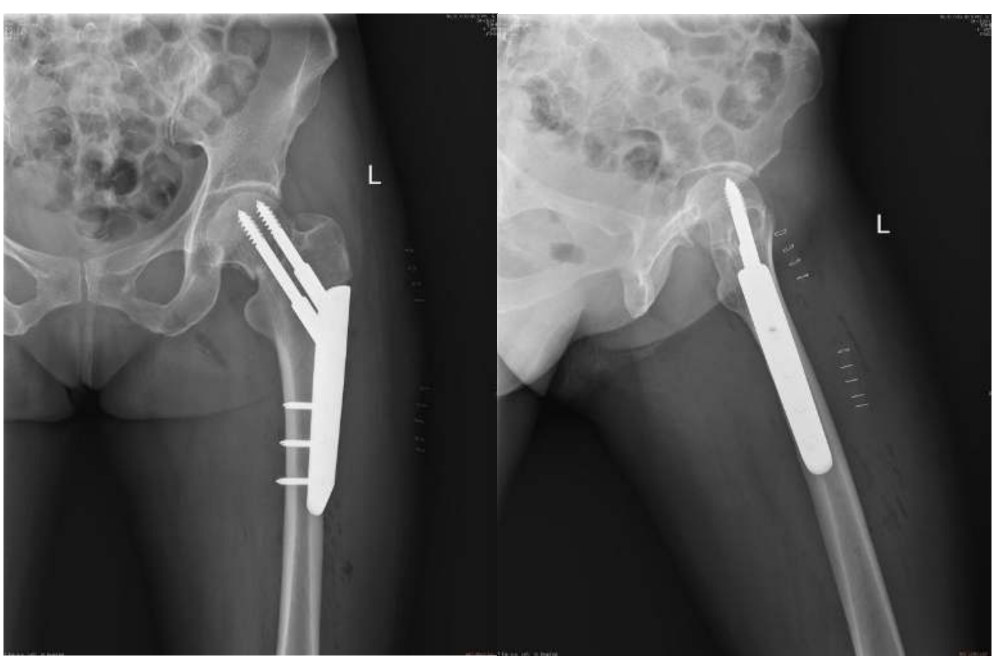
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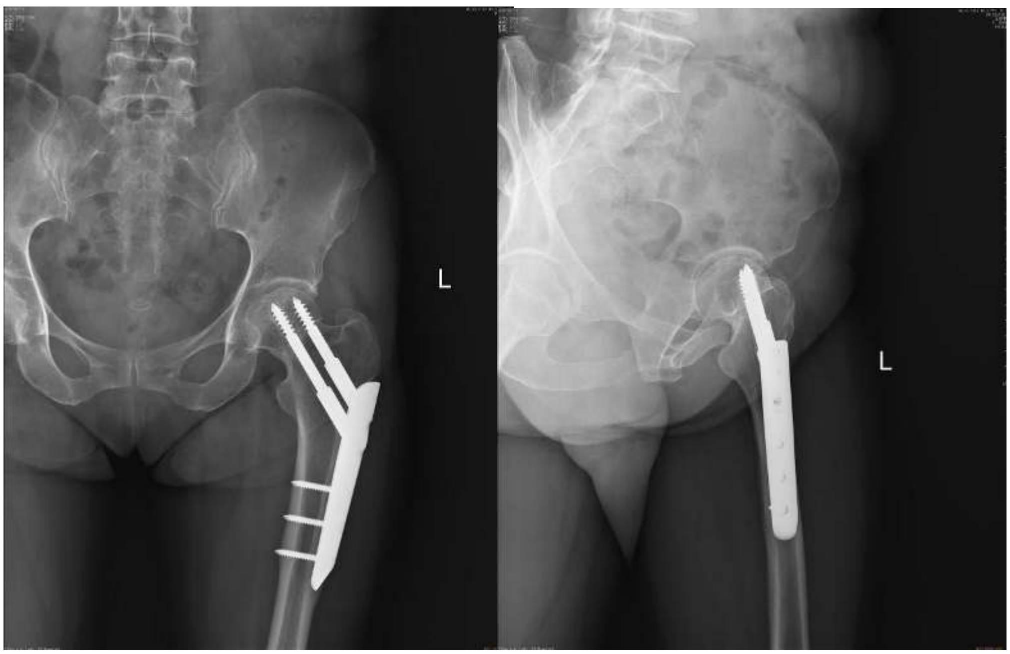
Fig. 2b.



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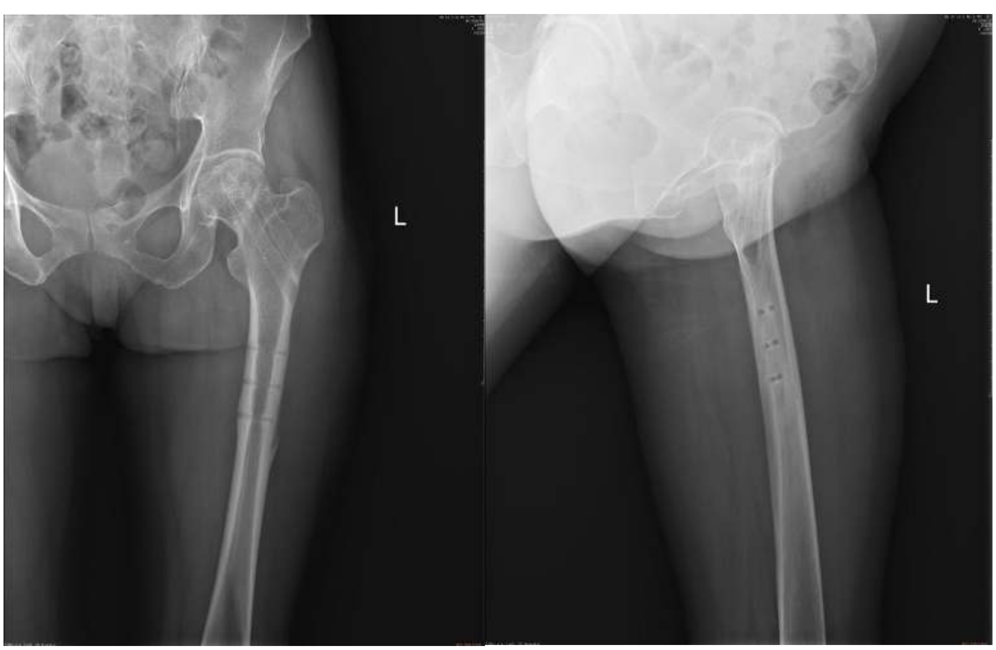

Fig. 2d.