European Journal of Trauma and Emergency Surgery (2019) 45:995–1002
https://doi.org/10.1007/s00068-018-0972-1

ORIGINAL PAPER

Anteromedial femoral neck plate with cannulated screws for the treatment of irreducible displaced femoral neck fracture in young patients: a preliminary study

Linbo Zhuang[1] · Lisheng Wang[1] · Dongming Xu[1] · Zhiyong Wang[1]

Received: 24 December 2017 / Accepted: 12 June 2018 / Published online: 16 June 2018

Abstract

Backgrounds Although most displaced femoral neck fractures of young patients can be repositioned successfully by closed reduction, there are still some can not repositioned successfully by this way and open reductions are required. This type of fracture was defined as irreducible displaced femoral neck fracture in this study. The purpose of this study was to introduce a new technique using anteromedial femoral neck plate with cannulated screws fixation by open reduction for the treatment of irreducible displaced femoral neck fractures in young patients.

Methods Totally 26 patients with irreducible displaced femoral neck fracture treated by this technique were retrospectively reviewed. This technique included three major steps: open reduction of femoral neck fracture was performed via the modified anterior approach of hip joint, anteromedial femoral neck plate was fixed to the femoral neck, and two cannulated compression screws were inserted in the femoral neck inside.

Results All patients were followed up with an average of 18months (range 12–30 months). Radiological and clinical outcomes were evaluated. The fracture union was achieved in 24 patients (92.3%) with an average duration of 4.5 months (range 3.8–10 months). Nonunion was not observed in all cases. Avascular necrosis of femoral head was identified in two patients (7.7%). Clinical outcomes of 24 hips with satisfactory union were evaluated by the Harris Hip Scores (HHS), excellent outcomes were achieved in 20 cases (HHS $\geqq$ 90), fair outcomes in 3 cases (80 $\leqq$ HHS < 90), and poor outcome in 1 case (HHS < 80).

Conclusions Anteromedial femoral neck plate with cannulated screws fixation by open reduction is an alternative therapeutic method for the irreducible displaced femoral neck fracture in young patients, with low incidence of complications including nonunion and avascular necrosis.

Keyword Femoral neck fracture · Anteromedial femoral neck plate · Cannulated screws · Open reduction · Avascular necrosis · Nonunion

Introduction

Although arthroplasty has been widely used for displaced femoral neck fractures in elderly patients [1, 2], it is not the best choice for young patients [3, 4]. Internal fixation is still the better choice than arthroplasty for displaced femoral neck fracture in young patients [5, 6]. Internal fixation by closed reduction is the most commonly used therapeutic method for displaced femoral neck fracture of young patients [7, 8], because this treatment does less damage to the blood supply of the femoral head. However, there are still some cannot be repositioned successfully by closed reduction and open reduction are required [9, 10]. This type of fracture was called irreducible displaced femoral neck fracture in this study. Based on our clinical experiences, the common reason

✉ Linbo Zhuang
zhuanglinbo@163.com

Lisheng Wang
Lishengw@yeah.net

Dongming Xu
xdm10@126.com

Zhiyong Wang
wzy7562@163.com

[1] Department of Orthopedics, Baoan Central Hospital of Shenzhen, the 5th Affiliated Hospital of Shenzhen University Health Science Center, Shenzhen 518102, Guangdong, China

why irreducible displaced femoral neck fracture could not be repositioned successfully by closed reduction was soft tissue embedded in the fracture gaps. There were few literatures which reported how to treat this special femoral neck fracture.

Although there have been many kinds of implants to fix the femoral neck fracture, such as multiple parallel cannulated screws, dynamic hip screws, dynamic locking blade plate and so on, none of them can perfectly avoid the complications [5, 8–13]. Avascular necrosis of femoral head and nonunion is a major complication after the treatment of femoral neck fracture in young patients [14, 15]. The rate of avascular necrosis was reported to be 6–42%, and the rate of nonunion was in the range of 0–45% (with an average age of 38 ranging from 22 to 50 years old) [15–18]. One of the important causes of the complication was inadequate stabilization provided by the conventional implants which only provided intramedullary fixation [9, 10]. Consequently, we invented this technique using anteromedial femoral neck plate with cannulated compression screws fixation by open reduction for the treatment of this rare irreducible displaced femoral neck fracture. Anteromedial femoral neck plate provided extramedullary fixation, cannulated screws provided intramedullary fixation, both extramedullary fixation and intramedullary fixation worked together to make the fracture more stable.

Methods

Patients

Between January 2014 and January 2017, 26 patients with femoral neck fracture from a teaching hospital were enrolled for this study and accepted the treatment of anteromedial femoral neck plate with cannulated screws fixation by open reduction. All patients included Garden grades III ($n=12$) and IV ($n=14$). Our inclusion criteria were the irreducible displaced fracture of femoral neck which could not be repositioned successfully by closed reduction. All the patients accepted closed reduction first, only those who could not be repositioned successfully by closed reduction were included. Patients with other associated injuries such as femoral shaft fracture were excluded. All the patients consisted of 18 males and 8 females with an average age of 36.5 years (range 19–44 years old) at the time of surgery. The average duration between injury and operation was 22.8 h (duration range 4–47 h). More details of the patients were summarized in Fig. 1 and Table 1.

Implant

The compression titanium plate was shaped to curve shape which was similar to the anteromedial surface of the femoral neck, and the shaped compression titanium plate was called anteromedial femoral neck plate in this study. The cannulated screws were made of titanium alloy too, with diameter of 7.3 mm and length of 80–120 cm.

Surgical technique

Spinal epidural anesthesia or general anesthesia was used for the patient. All surgeries were performed by a senior surgeon. The patient lay down on the traction bed for lower limbs, closed reduction including internal rotation, adduction and traction of the injured lower limb were first performed. Fluoroscopy was used to monitor the fracture. If the anatomic reduction could not be achieved in the patient, the patient was included in this study.

The modified anterior approach of hip joint was used for the surgery. The No. 1 incision was started from the position where was 5 cm below the anterior superior iliac spine (ASIS), and extended 8–10 cm along the line which connecting ASIS and the lateral margin of patella. It was important to identify the intermuscular space between sartorius and tensor fascia lata. Femoral nerve and femoral artery should be protected carefully. The rectus femoris was situated deep in the sartorius and tensor fascia lata. The anterior part of hip joint capsule would be seen after the rectus femoris was released. The anterior part of joint capsule was incised in T-shape, and the femoral neck fracture was exposed. Soft tissue such as joint capsule might be seen in the gaps between the fracture ends. Soft tissue and blood clot existed in the fracture gaps must be removed carefully. Thus, the femoral neck fracture could be repositioned under direct vision. A compression titanium plate was shaped to curve shape which was similar to the anteromedial surface of the femoral neck, and this plate was called the anteromedial femoral neck plate in this study. The anteromedial femoral neck plate was fixed to the anteromedial surface of the femoral neck, 4–6 screws were inserted into the bone to fix the plate.

The No. 2 incision with length of about 2 cm was made at the position where was 5 cm distal to the greater trochanter of femur. Two guide pins were drilled into the femoral neck from this incision, and two cannulated compression screws were inserted into the femoral neck with the guide of the pins. The two cannulated screws should be in the centre of the femoral neck as close as possible, and the tips of the screws should be at the position where was 5 mm below the articular surface of the femoral head.

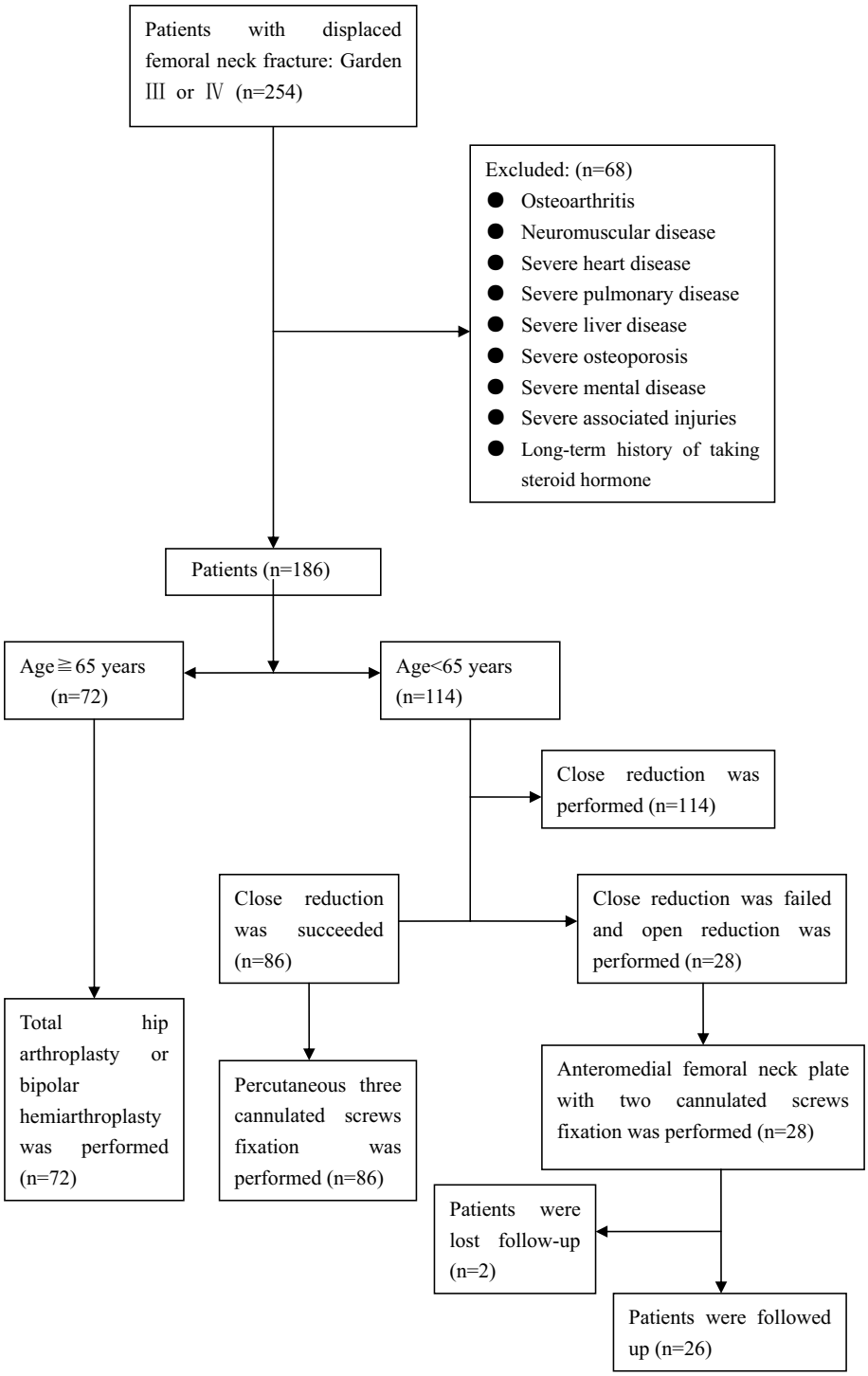

Fig. 1 Flow diagram of the study

The positions of the screws must be confirmed by fluoroscopy. Isometric contraction exercise of the quadriceps should be initiated postoperative 24 h. Non-weight bearing mobilization was started 3 days after the surgery. Toe-touch weight-bearing mobilization was initiated 3 weeks postoperatively (Figs. 2, 3).

Evaluation standard

Postoperative radiographs were used to evaluate the fracture healing. Union was defined as an absence of visible margins of the fracture. Nonunion was defined as either displacement of the fracture or clearly visible margins of the fracture 1

Table 1 Summary of clinical characteristic of 26 patients with irreducible displaced femoral neck fractures ($n=26$)

Patients (number)	26
Sex	
Men, number (%)	18/26 (69.2%)
Women, number (%)	8/26 (30.8%)
Ages (years), range	36.5 ± 6.5 (19–44)
Body mass index (Kg/m^2), range	20.0 ± 3.2 (16.1–23.6)
Cause of injury	
Traffic accident, number (%)	10/26 (38.5%)
Falling from high place, number (%)	11/26 (42.3%)
Falling from stairs, number (%)	3/26 (11.5%)
Other, number (%)	2/26 (7.7%)
Close fracture, number (%)	26/26 (100%)
Open fracture, number (%)	0
Fracture site	
Right femoral neck fracture, number (%)	15/26 (57.7%)
Left femoral neck fracture, number (%)	11/26 (42.3%)
Bilateral fracture	0
Garden grade	
III, number (%)	12/26 (46.2%)
IV, number (%)	14/26 (53.8%)
Long-term history of alcoholism, number (%)	0
Long-term history of taking steroid hormone, number (%)	0
History of hip surgery, number (%)	0
History of severe hip injury, number (%)	0
Dysplasia of the hip, number (%)	0
Long-term history of smoking, number (%)	3/26 (11.5%)
Diabetes mellitus, number (%)	2/26 (7.7%)
Duration between injury and surgery (h), range	22.8 ± 5.6 (4–47)

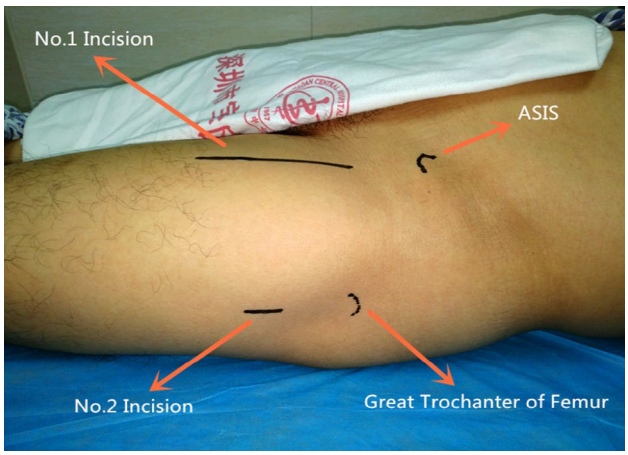

Fig. 2 Picture of the two incisions for the surgery. No. 1 incision is used for open reduction of femoral neck fracture and anteromedial compression plate fixation. No. 2 incision is used for inserting the two cannulated screws. ASIS is the anterior superior iliac spine

year after operation. Avascular necrosis was identified by the Steinberg classification from stage 2 and upward [19]. Failure of fixation was identified by the need of revision surgery due to nonunion, avascular necrosis or cut out of the implant. The clinical outcomes were evaluated by Harris Hip Scores (HHS). The HHS higher than 90 was defined as the excellent outcomes, HHS in the range of 80–90 as the fair outcomes, and HHS less than 80 as the poor outcomes. Consequently, the incidence of excellent and good outcomes were set up as HHS higher than 80.

Results

Anatomic reduction was achieved in all patients. All patients were followed up with an average duration of 18 months (range 12–30 months). Radiological and clinical results were evaluated. Totally, fracture unions were achieved in 24 patients (92.3%) with an average duration of 4.5 months (range 3.8–10 months). Nonunion was not observed in all cases. Avascular necrosis was identified in 2 patients (7.7%). Clinical outcomes of 24 hips with

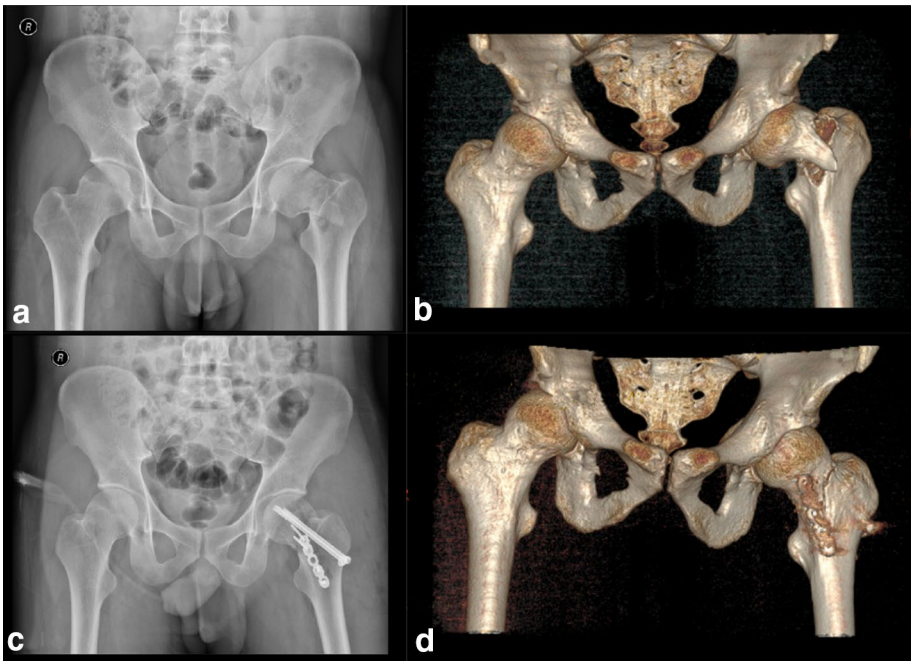

Fig. 3 X-ray films and CT 3D-reconstructions of a 27-years-old male patient with left femoral neck fracture. **a** preoperative X-ray film showing the displaced femoral neck fracture, **b** preoperative CT 3D-reconstruction showing the oblique fracture line between the femoral head and distal part of the femoral neck, **c** postoperative X-ray film showing the femoral neck fracture was fixed by the anteromedial femoral neck plate with two cannulated screws, **d** postoperative CT 3D-reconstruction showing the anatomic reduction of the femoral neck fracture and the anteromedial femoral neck compression plate

Fig. 4 X-ray film of the patient 1 year after surgery showing the fracture line disappeared and avascular necrosis of the femoral head was not observed, and union was achieved

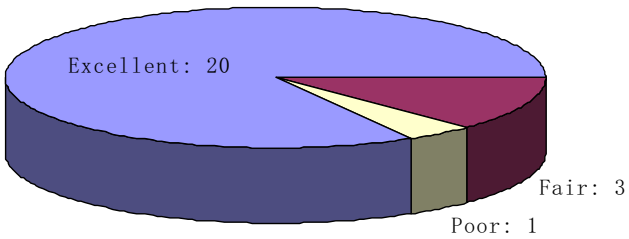

Fig. 5 Clinical outcomes of 24 hips with satisfactory union

satisfactory union were evaluated by HHS, the excellent outcomes were achieved in 20 cases (HHS ≧ 90), fair outcomes in 3 cases (80 ≦ HHS < 90), and poor outcomes in 1 case (HHS < 80). The rate of excellent and good outcomes was up to 95.8%. The average HHS was 94.5 (range 72–100) at the final follow-up. The average length of the limb was shortened by 0.8 cm (range 0–2.2 cm). No serious intra-operative complications occurred in all cases. Only one patient suffered from unilateral femoral vein thrombosis postoperatively (Figs. 4, 5; Table 2).

Discussion

In the present study, we found out that the irreducible displaced femoral neck fracture was characterized by the oblique fracture line between the femoral head and the distal part of the femoral neck. This type of femoral neck fracture generally occurred in young adults with high energy trauma. According to our clinical experience, the main reason why the irreducible displaced femoral neck fracture could not be repositioned successfully by closed reduction was soft tissue such as joint capsule embedded in the gaps between the fracture ends, other possible reasons consisted of massive blood accumulation in the hip joint cavity, higher body mass index (BMI) of the patient, poor skills of the surgeon, severe displacement of femoral neck fracture, and so on.

Unlike diaphyseal fracture, the femoral neck fracture cannot heal by periosteal (external) callus formation. The bone healing is dependent on primary osteonal

Table 2 Peri-operative and post-operative outcomes of 26 patients ($n=26$)

Patients (number)	26
Duration of surgery (minutes), range	100 ± 20.5 (70–145)
Peri-operative blood loss (ml), range	205 ± 45.8 (120–650)
Severe intra-operative complication, number (%)	0
Fracture reduction	
Anatomic reduction, number (%)	26/26 (100%)
Poor reduction, number (%)	0
Duration of fracture union (months), range	4.5 ± 1.6 (3.8–10)
Duration of fracture union	
3–6 months, number (%)	19/26 (73.1%)
6–9 months, number (%)	5/26 (19.2%)
9–12 months, number (%)	2/26 (7.7%)
Duration of follow-up (months), range	18 ± 5.3 (12–30)
Radiological outcome	
Union, number (%)	24/26 (92.3%)
Nonunion, number (%)	0
Avascular necrosis of femoral head, number (%)	2/26 (7.7%)
Cut out of the implant, number (%)	0
Clinical outcomes of 24 hips with satisfactory union (HHS)	
Excellent: HHS ≧ 90, number (%)	20/24 (83.3%)
Fair: 80 ≦ HHS < 90, number (%)	3/24 (12.5%)
Poor: HHS < 80, number (%)	1/24 (4.2%)
The rate of excellent and good outcomes of 24 hips with satisfactory union (HHS ≧ 80), number (%)	23/24 (95.8%)
Length of the limb was shortened (cm), range	0.8 ± 0.2 (0–2.2)

HHS Harris Hip Score

reconstruction which requires anatomic reduction and absolute stability [20–25]. In the present study, although open reduction might cause more damage to the blood supply of femoral head, open reduction provided direct vision, which meant surgeons could see the fracture site with naked eyes directly, and anatomic reduction could be achieved more easily. In contrary, closed reduction merely provided indirect vision of the fracture site by fluoroscopy. The direct vision of the fracture site in operation was very helpful for the surgeons to make the anatomic reduction become reality. Besides, radiation exposure was also decreased for both the patients and the surgeons.

One of the sources of the revascularization of femoral head is the vascular ingrowth across the uniting fracture line, and these ingrowing tender vascular buds could be torn repeatedly if there is persistent motion at the fracture site due to inadequate fracture stabilization [26–28]. Therefore, stabilization of the femoral neck fracture was significant for the revascularization of femoral head, and played an important role in bone healing and avascular necrosis. In this technique, the anteromedial femoral neck plate was very close to the calcar femorale which played an important role in the stabilization of the femoral neck, thus the anteromedial femoral neck plate could provide adequate stabilization for the fracture. The conventional implants for femoral neck fracture such as multiple parallel screws or sliding hip screw devices only provided intramedullary fixation. However, in this technique, extramedullary fixation was provided by anteromedial femoral neck plate, intramedullary fixation was provided by the two cannulated screws, both extramedullary fixation and intramedullary fixation worked together to make the fracture more stable.

The bigger volume of the implant in the femoral head may disturb the revascularization of the femoral head, so the incidence of avascular necrosis of the femoral head may increase [25, 29, 30]. In this technique, only two cannulated screws were inserted in the femoral head, which meant the volume of the implant in the femoral head was smaller than the three cannulated screws fixation.

There were two limitations of this study. First, the study was a retrospective study with a small number of subjects. Second, the follow-up period was short. The biomechanical study of this technique has not been carried out yet. This study is a preliminary research, researches with big number of subjects and long-term follow-up are needed to confirm the therapeutic effects of this technique.

Conclusions

In summary, the advantages of this technique consist of anatomic reduction under direct vision, adequate stabilization for the femoral neck fracture, relative low volume of implant in the femoral head, and so on. Consequently, anteromedial femoral neck plate with cannulated screws fixation by open reduction is an alternative therapeutic method for the irreducible displaced femoral neck fractures in young patients, with low incidence of complications including avascular necrosis of femoral head and nonunion.

Funding There is no funding source.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Bensen AS, Jakobsen T, Krarup N. Dual mobility cup reduces dislocation and re-operation when used to treat displaced femoral neck fractures. Int Orthop. 2014;38(6):1241–5.
2. Liu Y, Tao X, Wang P, Zhang Z, Zhang W, Qi Q. Meta-analysis of randomised controlled trials comparing unipolar with bipolar hemiarthroplasty for displaced femoral-neck fractures. Int Orthop. 2014;38(8):1691–6.
3. Gierer P, Mittlmeier T. Femoral neck fracture. Unfallchirurg. 2015;118(3):259–69.
4. Davidovitch RI, Jordan CJ, Egol KA, Vrahas MS. Challenges in the treatment of femoral neck fractures in the nonelderly adult. J Trauma. 2010;68(1):236–42.
5. Elgeidi A, El Negery A, Abdellatif MS, El Moghazy N. Dynamic hip screws and fibular strut graft for fixation of fresh femoral neck fracture with posterior comminution. Arch Orthop Trauma Surg. 2017;137(10):1363–9.
6. Yu XB, Zhao DW, Zhong SZ, Liu BY, Wang BJ, Liu YP, Zhang Y, Cui DP, Fu DP, Xie H. Prospective and comparative analysis of internal fixation of femoral neck fractures with or without vascularized iliac graft in young adults. Orthopedics. 2013;36(2):132–8.
7. Souder CD, Brennan ML, Brennan KL, Song J, Williams J, Chaput C. The rate of contralateral proximal femoral fracture following closed reduction and percutaneous pinning compared with arthroplasty for the treatment of femoral neck fractures. J Bone Joint Surg Am. 2012;94(5):418–25.
8. Araujo TP, Guimaraes TM, Andrade-Silva FB, Kojima KE, Silva Jdos S. Influence of time to surgery on the incidence of complications in femoral neck fracture treated with cannulated screws. Injury. 2014;5:S36–S39.
9. Lin D, Lian K, Ding Z, Zhai W, Hong J. Proximal femoral locking plate with cannulated screws for the treatment of femoral neck fractures. Orthopedics. 2012;35(1):e1–e5.
10. Samsami S, Saberi S, Sadighi S, Rouhi G. Comparison of three fixation methods for femoral neck fracture in young adults: experimental and numerial investigations. J Med Biol Eng. 2015;35(5):566–79.
11. Yu X, Zhao D, Huang S, Wang B, Zhang X, Wang W, Wei X. Biodegradable magnesium screws and vascularized iliac grafting for displaced femoral neck fracture in young adults. BMC Musculoskelet Disord. 2015;16:329.
12. Chammout GK, Mukka SS, Carisson T, Neander GF, Stark AW, Skoldenberg OG. Total hip replacement versus open reduction and internal fixation of displaced femoral neck fractures: a randomized long-term follow-up study. J Bong Joint Surg Am. 2012;94(21):1921–8.
13. Kapoor A, Deety LV, John VZ, Devadoss S, Devadoss A. Management of neglected femoral neck fractures and nonunion using a novel triple surgery combination: an Indian experience. Int J Low Extrem Wounds. 2012;11(1):49–58.
14. Xie X, zhang C, Jin D, Chen S, Gao Y. Free vascularised fibular graft for neglected femoral neck fractures in young adults. Hip Int. 2012;22(3):319–23.
15. Mathews V, Cabanela ME. Femoral neck nonunion treatment. Clin Orthop Relat Res. 2004;419:57–64.
16. Kalra M, Anand S. Valgus intertrochanteric osteotomy for neglected femoral neck fractures in young adults. Int Orthop. 2001;25(6):363–6.
17. Sen RK, Tripathy SK, Goyal T, Aggarwal S, Tahasildar N, Singh D, Singh AK. Osteosynthesis of femoral-neck nonunion with angle blade plate and autogenous fibular graft. Int Orthop. 2012;36(4):827–32.
18. LeCroy CM, Rizzo M, Gunneson EE, Urbaniak JR. Free vascularized fibular bone grafting in the management of femoral neck nonunion in patients younger than fifty years. J Orthop Trauma. 2002;16(7):464–72.
19. Steinberg ME, Hayken GD, Steinberg DR. A quantitative system for staging avascular necrosis. J Bone Joint Surg Br. 1995;77(1):34–41.
20. Perren SM. Physical and biological aspects of fracture healing with special reference to internal fixation. Clin Orthop Relat Res. 1979;138:175–96.
21. Claes LE, Heigele CA. Magnitudes of local stress and strain along bony surfaces predict the course and type of facture healing. J Biomech. 1999;32(3):255–66.
22. Siavashi B, Aalirezaei A, Moosavi M, Golbakhsh MR, Savadkoohi D, Zehtab MJ. A comparative study between multiple cannulated screws and dynamic hip screw for fixation of femoral neck fracture in adults. Int Orthop. 2015;39(10):2069–71.
23. Panteli M, Rodham P, Giannoudis PV. Biomechanical rationale for implant choice in femoral neck fracture fixation in the nonelderly. Injury. 2015;46(3):445–52.
24. Su Y, Chen W, Zhang Q, Li B, Li Z, Guo M, Pan J, Zhang Y. An irreducible variant of femoral neck fracture: a minimally traumatic reduction technique. Injury. 2011;42(2):140–5.
25. Van Walsum ADP, Vroemen J, Janzing HMJ, Winkelhorst T, Kalsbeek J, Roerdink WH. Low failure rate by means of DLBP fixation of undisplaced femoral neck fractures. Eur J Trauma Emerg Surg. 2017;43(4):475–80.
26. Sevitt S. Avascular necrosis and revascularisation of the femoral head after intracapsular fractures: a combined arteriographic and histological necropsy study. J Bone Joint Surg Br. 1964;46:270–96.

27. Dargan DP, Callachand F, Diamond OJ, Connolly CK. Three-year outcomes of intracapsular femoral neck fractures fixed with sliding hip screws in adults aged under sixty-five years. Injury. 2016;47(11):2495–500.
28. Roerdink WH, Aalsma AM, Nijenbanning G, van Walsum AD. Initial promising results of the dynamic locking blade plate, a new implant for the fixation of intracapsular hip fractures: results of a pilot study. Arch Orthop Trauma Surg. 2011;131(4):519–24.
29. Stromqvist B, Hansson LI, Palmer J, Ceder L, Thorngren KG. Scintimetric evaluation of nailed femoral neck fractures with special reference to type of osteosynthesis. Acta Orthop Scand. 1983;54(3):340–7.
30. Linde F, Andersen E, Hvass I, Madsen F, Pallesen R. Avascular femoral head necrosis following fracture fixation. Injury. 1986;17(3):159–63.