Treatment of nonunion after femoral neck fracture with valgus intertrochanteric osteotomy: a case report with 18-year follow-up

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Abstract
We herein report the long-term effect of valgus intertrochanteric osteotomy for nonunion after femoral neck fracture. In this report, we describe our experience using valgus intertrochanteric osteotomy to treat nonunion after femoral neck fracture in a 20-year-old woman. The patient was discharged from the hospital 10 days after the operation, the internal fixation device was removed 1 year after the operation, and the patient was then followed up for 18 years. Valgus intertrochanteric osteotomy can effectively treat nonunion after adductive femoral neck fracture.

Keywords
Nonunion, femoral neck fracture, valgus, intertrochanteric, osteotomy, case report

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Introduction
Femoral neck nonunion is a relatively uncommon clinical disease. The main risk factors are high-energy injury, fracture displacement, bone resorption of the femoral neck, poor blood supply to the femoral head, alignment after reduction of femoral neck fracture, high degree of limb shortening deformity, osteoporosis, and patient sex and age. Among these risk factors, high-energy injury is common in young and middle-aged patients with femoral neck fracture. Because many high-energy injuries lead to a large degree of fracture.
displacement, soft tissue inhibition and bone destruction, a wide range of periosteal peeling, severe disruption of the blood supply at the fracture ends, and instability of internal fixation caused by the complex factors of local biomechanics, femoral neck fractures caused by high-energy injury readily lead to femoral neck nonunion.⁴,⁵ The occurrence of femoral neck nonunion in middle-aged and young people easily progresses to hip joint dysfunction, which affects the patient’s quality of life and ability to perform activities of daily living. The disability rate associated with femoral neck nonunion is high, and it is a difficult disease to treat in clinical practice.

At present, the treatment of femoral neck fracture nonunion mainly involves bone grafting and internal fixation, joint replacement, and osteotomy. For elderly patients, prosthesis replacement is usually applied, whereas for young patients, preservation of their own hip joint is crucial. Intertrochanteric osteotomy addresses the primary biomechanical cause of the development of nonunion: excessive shear forces across the fracture site. A valgus-producing proximal femoral osteotomy is able to effectively neutralize all or part of the shear forces and convert them into compressive forces at the site of nonunion. Valgus intertrochanteric osteotomy alters the biomechanical environment of the nonunion site and restores limb length; however, few reports have focused on the results of this procedure in the management of femoral neck nonunion. We herein present a case of valgus intertrochanteric osteotomy for nonunion after femoral neck fracture.

**Case report**

A 20-year-old woman presented to our hospital with a 9-month history of pain in her right hip and a 3-month history of limping. Nine months previously, the patient had developed pain in her right hip after a fall from riding a bicycle. After 6 months of conservative treatment while bedridden, she gradually progressed to weight-bearing walking; however, her pain was not relieved and she exhibited obvious lameness. Before the injury, the patient had free movement and normal function of the right hip, and she had no history of abnormal bone morphology. A plain radiograph of the lower limb showed that the edges of the fracture ends were sclerotic, and obvious fracture lines were present. The proximal fracture end was hyperostogenic relative to the distal fracture end, but the two fracture ends were not connected to each other (Figure 1). At the time of admission, the patient had no spinal deformity and no obvious tenderness or percussion pain of any spinous process. The right leg was 2 cm shorter than the left leg. The right hip exhibited tenderness and joint movement disorder. Right hip flexion (passive activity) was 100°, back extension was 10°, and internal and external rotation movement disorder.

![Figure 1. Preoperative anteroposterior X-ray film. The fracture line was clear, the inner downward fragment was oblique to the outer upward fragment, the Pauwels angle was 63°, the fracture ends were unstable, and the local shearing force was large.](image-url)
was found (the patient was unable to cooperate with the examination of internal and external rotation because of pain). The pain was aggravated during passive activity, and the skin sensation and blood circulation of the lower limb were normal. No abnormality was found in the preoperative examination. X-ray examination showed no obvious collapse or deformation of the femoral head, change in the hip joint space, limitation of joint range of motion, or obvious signs of osteoarthritis.

Considering that the patient was young and her condition did not conform to the indications for hip replacement surgery, hip preservation therapy was the first choice. A plain radiograph showed that the fracture of the right femoral neck was an old non-union, and the Pauwels angle at the fracture line was >50°/C14, indicating an adduction fracture. The main cause of fracture nonunion was high shear stress and poor stability of the fracture ends, and the secondary factor was destruction of the blood supply to the femoral head. Therefore, the focus of treatment was to reduce the Pauwels angle at the fracture line through surgical osteotomy and create an abduction fracture, reduce the shear force after internal fixation of the fracture ends, and create an ideal mechanical environment for fracture healing. We considered whether to perform a vascularized fibular graft at the same time; however, the predicted postoperative effect was unclear because of the large degree of surgical trauma, and the patient would not have been able to tolerate the graft procedure. Therefore, we decided to treat the right femoral neck fracture with nonunion of the greater tuberosity by interval valgus osteotomy and internal fixation. We recommend valgus intertrochanteric osteotomy for nonunion after the femoral neck fracture.

The scheme of the osteotomy was designed before the operation. First, the angle between the fracture line and a horizontal line (Pauwels angle) was measured. Next, we determined the angle after osteotomy (in principle, <30°). The angle of osteotomy was equal to the Pauwels angle of the fracture minus the designed Pauwels angle after the operation. We selected a side steel plate with an angle of 135° to 155°. A larger angle of the side steel plate resulted in a larger angle of insertion of the fixing needle. The angle of insertion of the fixation pin refers to the angle between the fixation pin and the lateral cortex of the femur. This angle is equal to the angle of the side plate minus the angle of the osteotomy.

The patient underwent epidural anesthesia. She was then positioned on her back on the fracture table, with her feet fixed on the pedals and her right hip padded at 30°. The operation was carried out under the fluoroscopic control of a C-arm X-ray machine. A 20-cm lateral straight incision was performed over the right hip. After the skin and subcutaneous fascia were incised, the posterior margin of the lateral femoral muscle was cut, a femoral neck compression nail was introduced, and the bone canal of the abduction osteotomy was designed 3 cm below the greater trochanter. After the osteotomy, a goose head nail plate (Ideal Medical Industries, Ningbo, China) was fixed. Before the goose head nail was inserted, a guide needle was inserted into the femoral head from under the greater tuberosity of the proximal femur through the neck of the femur. In the anterior and posterior positions, the goose neck screw insertion point was located between the greater tuberosity and the osteotomy line and screwed into the femoral head along the axis of the femoral neck; the goose head screw in the lateral position was located in the middle of the longitudinal axis of the femoral neck. The success of abduction osteotomy and the location of the goose head nail were confirmed by C-arm X-ray examination. The incision was washed and
sutured. No skin traction was needed after the operation to encourage activities while bedridden. If self-control of the affected limb was possible (i.e., straight leg elevation) about 1 week after the operation, the patient was allowed to get out of bed with double crutches and walk without bearing weight until the fracture healed.

For 3 months after the operation, the patient rested in bed and stood without weight-bearing. After this 3-month period, she stood on the unaffected foot with the assistance of crutches, and the affected leg was partially weight-bearing within the tolerance of the lower limbs (Figure 2(a)). After 6 months, she finally abandoned the crutches and was able to walk, and X-ray examination showed that the fracture had healed (Figure 2(b)). Periodic X-ray reexaminations were performed at 1, 2, 3, 6, 9, and 12 months postoperatively to dynamically observe the fracture healing. X-ray reexamination 1 year after the operation indicated that the fracture line had disappeared and that the fracture had healed. The right hip active flexion was 120°, and back extension and internal and external rotation movement were 20°. The right Harris hip score was 78, and the visual analog scale score was 1. The internal fixation device was removed within 1 year after the operation (Figure 3). At the time of this writing (18 years following surgery), good bone union was observed (Figure 4), and the Harris hip score had increased to 92. Extension of the affected hip was 10°, active flexion was 120°, adduction movement was 20°, abduction movement was 40°, internal rotation movement was 20°, and external rotation movement was 30°. The patient has engaged in hard labor with no difficulties, and no signs of osteoarthritis or osteonecrosis have been found (Figure 5).

**Figure 2.** X-ray examinations were performed 3 and 6 months after internal fixation with valgus intertrochanteric osteotomy using a goose head nail. The anteroposterior view showed that the internal fixation device was well positioned. The Pauwels angle was 45°. (a) Three months after the operation, the fracture at the osteotomy site had healed well, the fracture line was blurred, and the fracture line at the femoral neck fracture site was still visible. (b) Six months after the operation, the fracture line at the osteotomy site had disappeared, and the fracture line at the femoral neck fracture site was blurred.
Discussion

Femoral neck fractures are rare in young patients and usually occur after high-energy trauma. Nonunion or delayed union is more likely to occur after internal fixation. According to statistical data, the rate of nonunion in young patients with femoral neck fracture is 13.2% after internal fixation in our hospital. There are different diagnostic criteria for nonunion of femoral neck fracture. In terms of the duration of time since injury, we believe that nonunion should be defined as >3 months in patients with an untreated displaced fracture and >1 year in those who have been treated with internal fixation. Our patient had obvious symptoms and signs, and her main complaints were pain, local tenderness, shortness and extroversion deformity, and the inability to walk with weight-bearing. Radiographic examinations showed that the varus deformity gradually increased in severity and that the femoral neck bone resorbed and hardened. Therefore, nonunion of femoral neck fractures should be diagnosed according to the type of fracture, time after injury, clinical manifestations, function, and X-ray manifestations. In this case, the main complaints, symptoms, and related examination findings at the time of admission basically met the above criteria. Thus, the patient was diagnosed with nonunion after femoral neck fracture.

In patients with a viable femoral head, it is desirable to salvage the native hip joint and delay total hip arthroplasty as long as possible. The main operative methods for femoral neck nonunion include repeat internal fixation, bone grafting and replacement of internal fixation, fibular transplantation with vascular anastomosis, and valgus osteotomy. Vertically oriented fractures have a higher risk of nonunion because of the increased shear forces across the fracture. The intertrochanteric osteotomy alters the anatomy of the proximal femur and converts shear forces at the nonunion site to compressive forces, thereby

Figure 3. X-ray examination was performed 1 year after surgery. Both the osteotomy site and the fracture line had disappeared, the fracture had healed well, the internal fixation device was removed, the femoral head showed no obvious cystic change or collapse, and the joint space was visible.

Figure 4. X-ray examination performed 18 years after surgery showed that the fracture had healed well, and no symptoms of osteoarthritis or necrosis of the femoral head were observed.
promoting osseous union.\textsuperscript{12–14} Pauwels\textsuperscript{15} proved that the biomechanical factor that is not conducive to healing of femoral neck fractures is an increase in the Pauwels angle after the fracture. The author used the valgus osteotomy under the rotor to move the fracture line to the horizontal direction, successfully treating femoral neck nonunion without affecting the blood flow of the fracture ends.\textsuperscript{15} Mueller\textsuperscript{10} advocated the use of intertrochanteric osteotomy in the treatment of femoral neck nonunion, which can reduce the Pauwels angle by $25^\circ$.\textsuperscript{14} Valgus-producing intertrochanteric osteotomy with a smaller degree of correction than has been traditionally described leads to an excellent rate of radiographic union while preserving more of the native proximal femoral anatomy.\textsuperscript{16} Excess valgisation offers no advantage with regard to fracture union and should be avoided to prevent poor function, avascular necrosis of the femoral head, and joint degeneration.\textsuperscript{17} In the present study, the Pauwels angle decreased by $18^\circ$ after intertrochanteric osteotomy. Some scholars have stated that an angled plate should be used for fixation after valgus intertrochanteric osteotomy.\textsuperscript{11,12} Angle plate fixation can effectively control the rotation of the proximal end of the fracture and shift the femoral shaft displacement to the side, thus reducing the varus angle of the knee joint. Anglen\textsuperscript{11} reported 13 cases of nonunion healing, including 1 case of necrosis of the femoral head and 2 cases of final artificial joint replacement. Sixteen of the 41 patients reported by Zehi et al.\textsuperscript{12} had necrosis of the femoral head. The above reports show that the application of angle plate fixation requires high surgical skills. Placement of the femoral neck screw requires that the anterior and posterior positions are closer to the cortex of the lower edge of the femoral neck while ensuring a suitable apex of the femoral head, and joint degeneration.\textsuperscript{17} Figure 5. Follow-up at 18 years after surgery. The Harris hip score had increased to 92. Extension of the affected hip was $10^\circ$, active flexion was $120^\circ$, adduction movement was $20^\circ$, abduction movement was $40^\circ$, internal rotation movement was $20^\circ$, and external rotation movement was $30^\circ$. (a) Both lower limbs were of equal length, and the patient was able to walk without limping. (b) The patient was also able to squat completely.
distance, and the screw head should be fixed to the subchondral bone as much as possible. Furthermore, to ensure that the above requirements are met as closely as possible after valgus intertrochanteric osteotomy, the vertex of the lateral femoral cortex should be located above the osteotomy line. Therefore, the position of the screw here is different from the position of the screw for intertrochanteric fractures, which is relatively high and maintains the shortest possible tip distance. After valgus intertrochanteric osteotomy, the shearing force at the fracture ends is reduced and the fracture ends are relatively stable, which significantly reduces the occurrence of complications such as femoral neck shortening and screw cutting. We believe that this is the optimal position of the lag screw in the femoral head when intertrochanteric osteotomy is used to treat nonunion of the femoral neck. In the present case, satisfactory fixation was achieved after intertrochanteric osteotomy.

Many techniques are available for the treatment of femoral neck fracture, but the optimal technique is to let the femoral head and neck heal automatically after the fracture is stabilized; the treatment of femoral neck nonunion is no exception. Valgus intertrochanteric osteotomy follows this basic principle.

We recognize that there are some limitations of valgus intertrochanteric osteotomy for nonunion after femoral neck fracture. Although this alteration of the proximal femoral anatomy neutralizes the shear forces across the nonunion, it also reduces femoral offset, medializes the femoral shaft, translates the greater trochanter caudally, and lateralizes the mechanical axis of the limb at the knee. Furthermore, after osteotomy, the trochanter moves down, increasing the tension of the hip abductor muscle and thus increasing the pressure of the femoral head joint; this may promote the occurrence of aseptic necrosis of the femoral head. However, no necrosis of the femoral head was found during 18-year follow-up in the present case.

In conclusion, despite the risk of necrosis of the femoral head, valgus intertrochanteric osteotomy is a method worth exploring for the treatment of femoral neck fracture nonunion in young and middle-aged patients. However, large-sample prospective studies are still needed.

Declaration of conflicting interest
The authors declare that there is no conflict of interest.

Ethics
The patient provided written informed consent for treatment and publication of this report. The study protocol was approved by the Ethics Committee of Funing People’s Hospital, Funing County.

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