OPERATIVE TECHNIQUE

Reduction with Pre-Drilling Combined with a Finger Reduction Tool in Difficult-to-Reduce Intertrochanteric Fracture

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Objective: To investigate the feasibility of pre-drilling combined with a finger reduction tool for the reduction of difficult-to-reduce intertrochanteric fractures.

Methods: Patients diagnosed with complicated intertrochanteric fractures during the period from July 2016 to May 2021 at the Affiliated Hospital of our College were enrolled in this study. All patients underwent reduction by pre-drilling combined with a finger reduction tool followed by fixing with proximal femoral nail antirotation. The outcome of reduction was evaluated by intraoperative fluoroscopy. The operation time, intraoperative fluoroscopy frequency, and incidence of postoperative complications (including infection in the incision area, coxa vara, nail withdrawal, nail breakage, blade cut-out, lower limb vein thrombosis, and pulmonary embolism) were recorded to evaluate the speed of the operation, the difficulty of the operation, and the prognosis of the patient, respectively. The Harris hip score at 9 months after surgery was used to evaluate the hip recovery.

Results: A total of 52 patients (17 men and 35 women), 61–88 (77.54 ± 7.40) years of age were included in the study. There were 14 patients with cardiovascular or cerebrovascular disease, ten patients with diabetes, three patients with Parkinson's disease, and three patients with respiratory diseases. The fractures included in the study were classified according to the Orthopedic Trauma Association 31 classification system as type A2.2 ($n = 36$) or type A2.3 ($n = 16$). The time from injury to surgery was 1–11 (3.35 ± 1.78) days, and the operation time ranged 31–101 (65.67 ± 14.17) min. The intraoperative blood loss ranged from 40 to 100 (67.69 ± 18.24) mL, and the number of intraoperative fluoroscopy images obtained was 12 to 32 (20.42 ± 5.27). The Harris hip score at 9 months after surgery ranged from 84 to 94 (90.06 ± 2.15). Patients were followed for 9–16 (10.63 ± 1.61) months. One patient died of acute myocardial infarction at 9 months after surgery. One patient suffered from nail withdrawal 5 months post-operation and thus underwent hemiarthroplasty.

Conclusions: Satisfactory reduction can be achieved using a pre-drilling femoral trochanter combined with a finger reduction tool for the management of difficult-to-reduce complex intertrochanteric fractures. This technique does not increase surgical trauma and also reduces the dose of radiation administered to the patient.

Key words: Difficult-to-reduce; Finger reduction tool; Intertrochanteric fracture; Pre-drilling; Proximal femoral nail anti-rotation

Introduction

Intertrochanteric fractures account for 10%–34% of hip fractures, and nearly half are caused by low-energy injuries.[1] For many patients, such injuries are caused by a simple fall with a direct impact on the lateral upper thigh or buttock. Although the energy of such falls is greater than the

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energy required for intertrochanteric fracture, only a small portion of such incidents lead to fracture.[2] Intertrochanteric fracture often occurs in high-risk populations such as older people, patients with osteoporosis, and individuals with a history of falls (except falls during exercise) or gait abnormality.[2] Patients with a previously sustained osteoporosis-related fracture are more likely to suffer an intertrochanteric proximal femoral fracture. An intertrochanteric fracture can lead to severe dysfunction, socioeconomic burden, and even death.[3,4] The optimal treatment for intertrochanteric femur fracture is surgery, which is often performed with closed reduction followed by internal fixation. The success of surgery depends on the degree of osteoporosis, type of fracture, method used for fixation, and patient's compliance with treatment.[5]

Numerous methods are used for internal fixation, including intramedullary fixation methods such as proximal femoral nail antirotation (PFNA) and use of an InterTan as well as extramedullary fixation methods such as hip arthroplasty and use of a sliding or dynamic hip screw.[6–9] PFNA and InterTan have good biomechanical advantages, including rotational stability, and are associated with less trauma, less blood loss, and shorter length of hospital stay, but may lead to postoperative thigh pain.[10] Treatment of intertrochanteric femur fractures with hip arthroplasty can lead to more severe surgical trauma, excessive bleeding, high risk of blood transfusion requirement, and increased operation time. Hip arthroplasty may be considered when the patient has poor bone quality and the fracture is highly unstable, or in the case of ipsilateral hip arthritis or other complications that may lead to early surgical failure.[8] Dynamic hip screws have shown beneficial stability for simple and nonosteoporosis fractures but not for unstable or osteoporotic intertrochanteric fractures in clinical practice. Although dynamic hip screws have been used for stable intertrochanteric hip fracture fixation for more than 20 years, the failure rate of fixation with unstable fractures is 3%–26%.[11] A recent systematic review and network meta-analysis of randomized controlled trials that compared three techniques (PFNA, dynamic hip screw, and bipolar hemiarthroplasty) concluded that bipolar hemiarthroplasty may be the best technique in terms of risk for operative failure and/or reoperation. The authors of the systematic review reported the highest short- to intermediate-term Harris hip scores (HHS) in patients with unstable intertrochanteric fracture, and PFN was associated with higher long-term HHS than bipolar hemiarthroplasty.[12] Because of its biomechanical advantages, PFNA is currently the preferred intramedullary fixation method for treating intertrochanteric femur fractures.[13,14] However, intramedullary nails cannot be used alone to achieve reduction. Therefore, good reduction is required to prevent surgical failure before fixation.

Fracture reduction may be performed with closed or open strategies, or a combination of the two, depending on the severity of the fracture and other limiting factors.[15] Closed reduction is generally performed through a combination of traction and manipulation without surgical exposure.[15] In almost all cases, closed reduction is usually attempted first. If closed reduction fails to achieve the desired result, open reduction is performed. For unstable intertrochanteric fracture, conventional reduction methods such as rotation and traction often fail to achieve a good reduction.[15,16] Methods involving the use of Kirschner wires, hook leverage, periosteal strippers, or Schanz nails have been proposed to facilitate reduction.[15–17]

Methods based on the use of Kirschner wires are the simplest and most practical because Kirschner wires can be used for temporary fixation to avoid repositioning loss. However, fixation using Kirschner wires may require intramedullary nail insertion, limiting its application. The hook leverage technique can be used to lift and maintain the reduction through a small incision. However, the hook is sharp, which may cause iatrogenic injury. Periosteal strippers can be used to pry and maintain reduction through a small incision. Schanz nails can be placed to pull or select the fracture end in order to control the direction of the fracture. However, because of their large size, Schanz nails may cause iatrogenic fractures and may affect insertion of the intramedullary nail. At present, these techniques for facilitating reduction fail to achieve good outcomes in cases of unstable intertrochanteric fracture.

Here we introduce a new method for reduction that combines pre-drilling with a finger reduction tool (Double Medical, Xiamen, China; Fig. 1) for the management of difficult-to-reduce intertrochanteric fracture. The present study aims to: (i) introduce a novel reduction technique for difficult-to-reduce intertrochanteric femur fracture and investigate its efficacy in clinical application; and (ii) explore how does this technique benefit patients. This approach achieved excellent reduction and fixation efficacy in unstable intertrochanteric fractures.

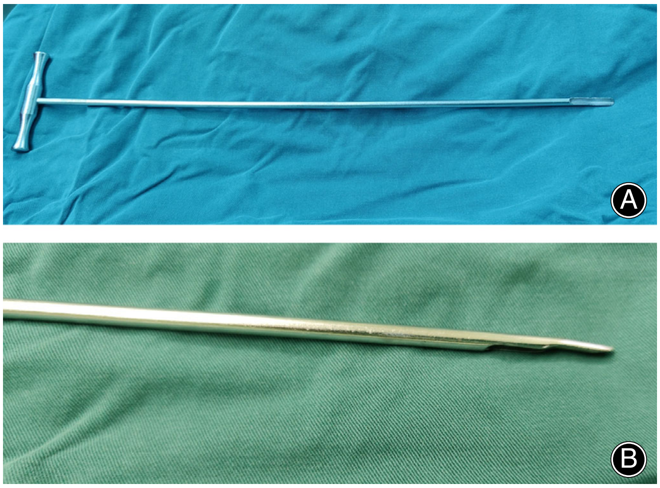

Fig. 1 The finger reduction tool used in the present study. (A), whole view of the finger reduction tool (Double Medical, Xiamen, China). It has a distal end with an arc shape, which is similar to the auricular finger for picking the ear, for controlling the direction of the guide needle; (B), distal end of the finger reduction tool.

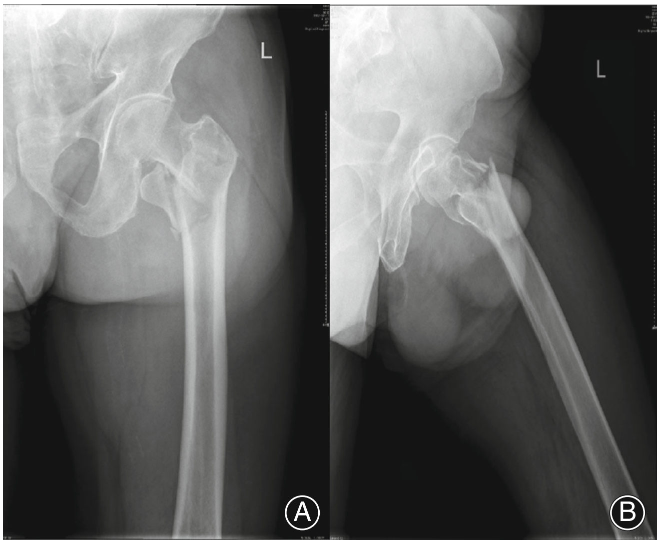

Fig. 2 Intertrochanteric fracture (AO/OTA 31 type A2.2). (A), anteroposterior view; (B), lateral view.

Patients and Methods

Patients

This retrospective case series enrolled patients with intertrochanteric fracture who underwent reduction with pre-drilling combined with a finger reduction tool and fixation with PFNA during the period from July 2016 to May 2021 in the Orthopedics Department of the Affiliated Hospital of our University. Femoral intertrochanteric fracture (Fig. 2) was classified according to the Orthopedic Trauma Association (AO/OTA) 31 classification system.[18] Difficult-to-reduce intertrochanteric fractures are unstable intertrochanteric fractures such as lesser trochanteric fracture, reverse intertrochanteric fracture, intertrochanteric comminuted fracture with posterior medial wall fractures, greater trochanteric fractures, and lateral wall fracture.[19] The criteria for inclusion in this study were as follows: (i) patients were diagnosed with intertrochanteric fracture of AO/OTA 31 types A2; (ii) patients had received unsatisfactory reduction with anteroposterior and lateral fluoroscopy after traction and rotation, adduction, or abduction using the traction bed; (iii) patients would receive internal fixation with PFNA; (iv) the reduction was evaluated using intraoperative fluoroscopy; and (v) hip recovery was evaluated using HHS at 9 months after surgery. The exclusion criteria were as follows: (i) pathological fracture; and (ii) fixation with a nail plate system. The study was performed in accordance with the Declaration of Helsinki and its amendments. The protocol was approved by the Ethics Committee at our hospital. Written informed consent was obtained from individual participants.

Surgical Technique

All patients were subjected to combined spinal-epidural anesthesia. The patient was placed in a supine position on a traction bed with the healthy side abducted. The affected side was placed on a traction frame for reduction with appropriate rotation or traction. The results of C-arm fluoroscopy showed unsatisfactory intertrochanteric reduction after closed reduction (Fig. 3). A 3 cm incision was made from the upper posterior of the femoral trochanter to the deep fascia. The gluteal muscle was bluntly dissected with curved forceps until the surgeon's index finger made contact with the greater trochanter. The point of insertion was identified under anteroposterior-view fluoroscopy as 0.5 cm lateral to the femoral greater trochanter and under lateral-view fluoroscopy as the point separating the anterior 1/3 from the posterior 2/3 of the lateral greater trochanter. A small hole was first made through the cortex for insertion of the finger reduction tool using an 11.0 mm drill at the correct opening position of the femoral trochanter. The surgeon then inserted the finger reduction tool into the femoral trochanter for reduction. By prying or pressing, the direction of the finger reduction tool distal arc was changed to insert the guide needle. After reduction was confirmed as satisfactory by fluoroscopy, a guidewire was inserted in the medullary cavity, and the pre-drilling hole was enlarged to 16.5 mm. An intramedullary nail was positioned in the guide-wire and rotationally inserted using the aiming arm until contact was made with the femoral head.

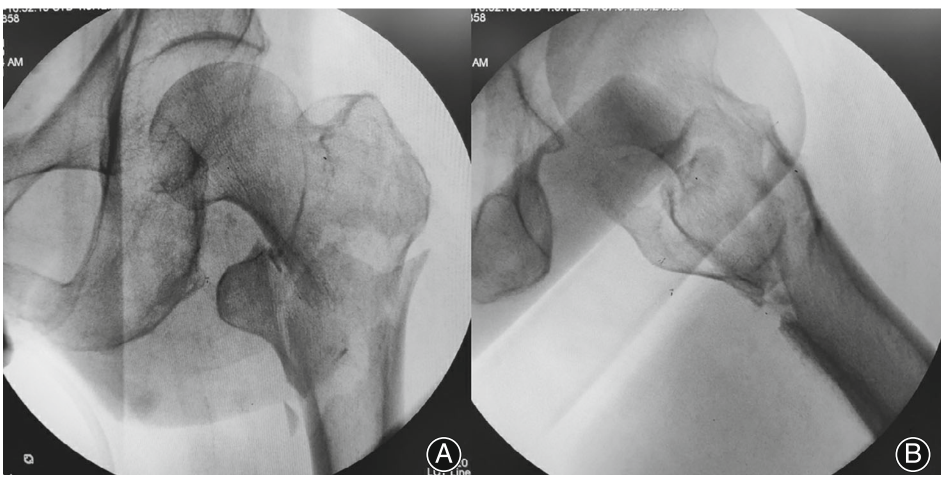

Fig. 3 Unsatisfactory reduction during surgery under C-arm fluoroscopy. (A), anteroposterior view, para position of the lateral wall; (B), lateral view, para position of the posterior wall.

The results of fluoroscopy showed that the nail was positioned well. The length of the PFNA blade was measured, and the blade was positioned through a hole in the proximal lateral cortex of the femur with a hollow drill. With the aid of the aiming arm, a static locking nail was positioned at the distal end. Once the PFNA was satisfactorily positioned at the femoral head, the aiming arm was removed, and the end cap was inserted (Fig. 4; it should be noted that to visualize this procedure in detail, the patient in Fig. 4 received some unnecessary fluoroscopy). The flowchart of this technique is shown in Fig. 5. After the operation, the incision was irrigated, sutured, and bandaged with a sterile dressing under pressure.

Methods of Assessment

Routine blood tests were performed on the 1st and 3rd days after surgery to evaluate the patient's hemoglobin levels. Conventional anticoagulation low-molecular-weight heparin was administered from 12 h after surgery until discharge to prevent deep vein thrombosis. Color Doppler ultrasonography of the lower extremity veins was reviewed 1 week after surgery to detect thrombosis. Patients commenced with ankle-pump and quadriceps-contraction exercises on the 1st day after surgery, and x-ray examination was performed on the 3rd day after surgery (Fig. 6). Patients performed partial weight-bearing exercises with the aid of a walker.

The operation time (from the skin incision to the wound closure), intraoperative blood loss (from the gauze and suction), frequency of intraoperative imaging, and postoperative complications were recorded. HHS at 9 months after surgery was calculated to evaluate therapeutic efficacy.

Results

General Information

A total of 52 patients (17 men and 35 women) with ages ranging from 61–88 (77.54 ± 7.40) years were included in the study. There were 17 cases on the left side and 35 cases on the right side. The study included 14 patients with cardiovascular or cerebrovascular disease, ten patients with diabetes, three patients with Parkinson's disease, and three patients with respiratory disease. There were 36 cases of type A2.2 intertrochanteric fracture and 16 cases of type A2.3. The duration from injury to surgery was 1–11 (3.35 ± 1.78) days.

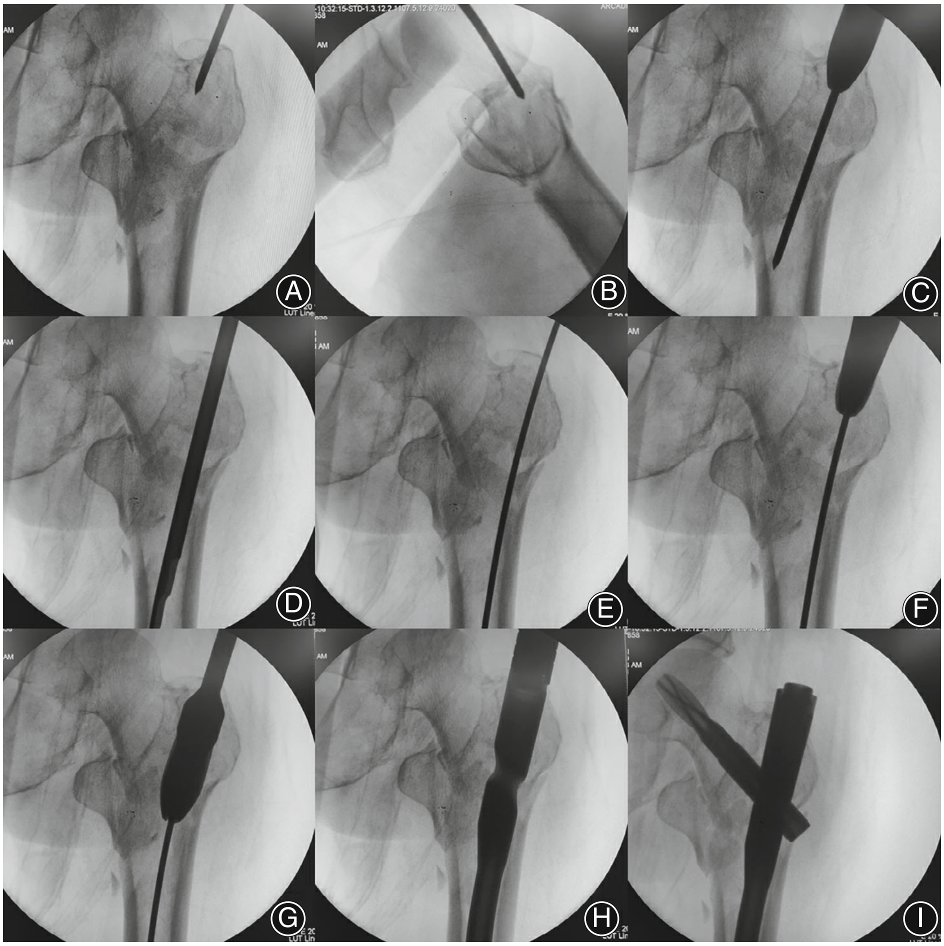

Fig. 4 Surgical procedure for reduction with pre-drilling combined with finger reduction tool followed by proximal femoral nail antirotation (PFNA) fixation. (A), anteroposterior-view fluoroscopy showed the insertion point located at the apex of the femoral greater trochanter; (B), lateral-view fluoroscopy showed the insertion point located where the anterior 1/3 of the greater trochanter met the posterior 2/3; (C), pre-drilling in the greater trochanter; (D), satisfactory reduction with finger reduction tool; (E), guide-wire for insertion; (F,G), re-reaming; (H), insertion of the intramedullary nail; (I), anteroposterior-view fluoroscopy after insertion of the intramedullary nail.

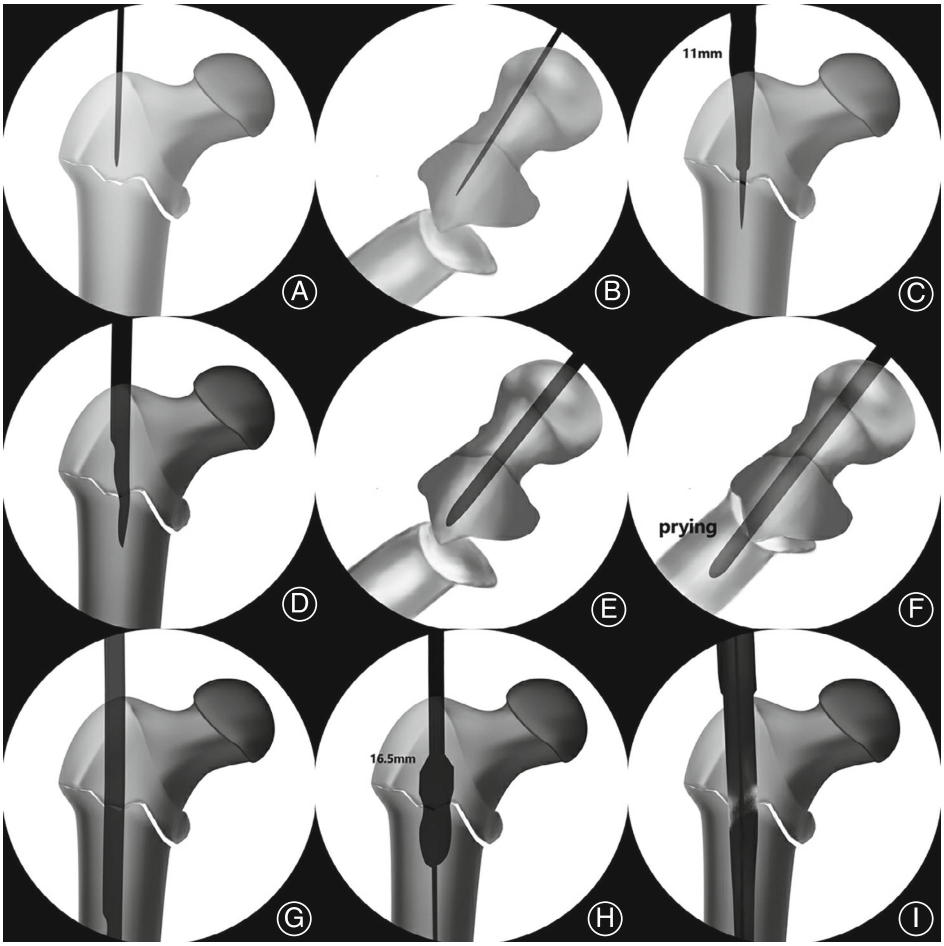

Fig. 5 The diagram of this technique. (A), anteroposterior view of the insertion point located at the apex of the femoral greater trochanter; (B), lateral view of the insertion point located where the anterior 1/3 of the greater trochanter met the posterior 2/3; (C), pre-drilling in the greater trochanter; (D), anteroposterior view of finger reduction tool insertion; (E), lateral view of finger reduction tool insertion; (F), prying using finger reduction tool; (G), lateral view after prying; (H), re-reaming; (I), insertion of the intramedullary nail.

Operation Time, Intraoperative Blood Loss, and Frequency of Intraoperative Imaging

The operation time ranged from 31 to 101 (65.67 ± 14.17) min, the intraoperative blood loss ranged from 40 to 100 (67.69 ± 18.24) mL, and the number of intraoperative fluoroscopy images captured ranged from 12 to 32 (20.42 ± 5.27). Patients were followed for 9–16 (10.63 ± 1.61) months after surgery.

HHS and Postoperative Complications

HHS at 9 months after surgery ranged 84–94 (90.06 ± 2.15). One patient died of acute myocardial infarction at 9 months

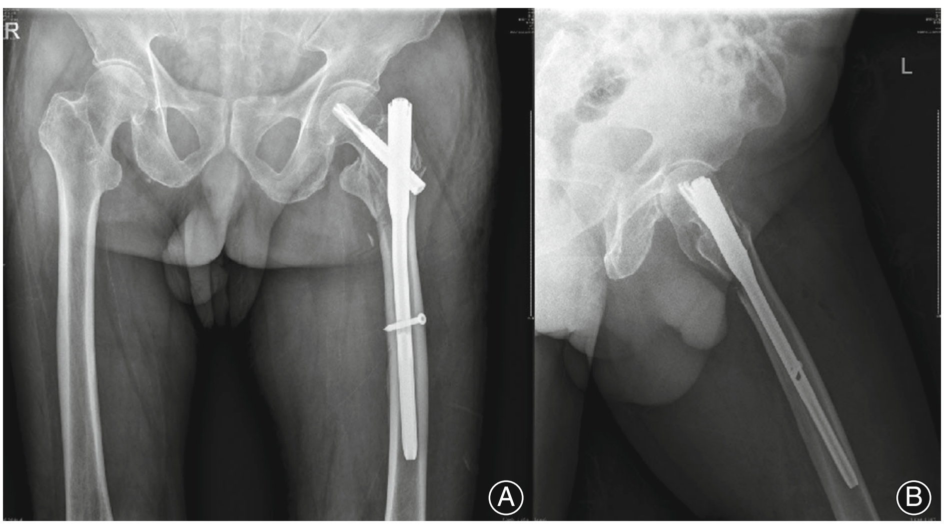

Fig. 6 Postoperative X-ray. (A), anteroposterior film obtained 3 days after surgery; (B), lateral film obtained 3 days after surgery.

after surgery. One patient suffered from nail withdrawal 5 months post-operation and thus underwent hemiarthroplasty.

Discussion

In the study, we applied a new reduction strategy that combines pre-drilling with a finger reduction tool for the reduction of complex intertrochanteric fracture after unsuccessful closed reduction. Using this reduction method with subsequent PFNA fixation, 52 patients with complex intertrochanteric fracture recovered well.

Importance of Anatomical Reduction for Difficult-to-reduce Intertrochanteric Femur Fracture

Femoral intertrochanteric fracture is a common hip fracture in older individuals. The condition is associated with high levels of mortality and significant functional disability. Intramedullary fixation is the strategy used most commonly to manage intertrochanteric fracture. This approach often results in early functional recovery and minimizes the risk of complications.[7,20] However, intramedullary nails do not have a reduction effect when used alone. The postoperative quality of fracture reduction can be defined as good, acceptable, or poor.[17] Good reduction must be achieved before intramedullary fixation to prevent surgical failure. Due to differences in fracture types and the quality of surgical reduction, complications such as fracture nonunion, coxa vara, breakage of screw nails, withdrawal of nails, and cutting-out may occur.[21] It has previously been reported that unstable femoral intertrochanteric fractures have a higher failure rate than stable fractures. Therefore, unstable fractures should be treated more carefully.[5] One study reported that the failure of intramedullary fixation may be attributed to the integrity of the proximal lateral cortex of the femur, defective posteromedial cortical bone, failure to protect the external lateral cortex during surgery, and failure to achieve good reduction. Support from the posterior medial cortex is the main contributing factor in the stability of intertrochanteric fractures. Poor fracture reduction is associated with postoperative complications.[21] Ye *et al.*[22] suggested that the posterior medial cortex is a key factor for the success of surgery; hence, reduction of the posterior medial cortex is important. Baumgaertner *et al.*[23] noted that the risk of spiral blade cutting was three times higher in patients with poor reduction than in those with good reduction. Therefore, achieving good reduction before fixation is important.

Good reduction allows for early functional recovery, prevents complications, and is pivotal for a successful surgery. The quality of a reduction depends on the skill level of the doctor performing the procedure.[15,17] Good reduction provides compressive stress stimulation to the fracture, which promotes healing. For unstable intertrochanteric fracture, conventional methods of rotation and traction often fail to achieve a good reduction. While alternative methods for reduction, such as Kirschner wires, hook leverage, periosteal strippers, and Schanz nails have been developed, the use of these devices requires additional surgical procedures.[15–17]

Advantages of this Technique and Precautions for Application

In the present study, pre-drilling of the femoral trochanter was combined with a finger reduction tool to assist with reduction. The results showed that this approach can be used as an effective method to reduce difficult-to-reduce intertrochanteric fractures. The operation time ranged from 31 to 101 min with a mean of 65.67 $\pm$ 14.17 min, which was comparable to the time reported by Chen *et al.* (61 min) and Kim *et al.* (71 min).[24,25] The key point is that when the reduction during fixation surgery is suboptimal, an insertion site on the medial femoral trochanter can be selected, and pre-drilling can be performed first at this location. The finger reduction tool is then inserted into the femoral medullary cavity. After prying and reduction, the guide-wire is inserted, the medulla is re-reamed, and the intramedullary nail is inserted. This method has the following advantages: (i) no need to add a new incision; (ii) use of a finger reduction tool for prying; (iii) the curvature of the front end of the finger reduction tool facilitates the insertion of a guide-wire at the distal or proximal ends with slight sinking and upturning; (iv) pre-drilling does not reduce the volume of the proximal femur; (v) the finger reduction tool has no sharp tips, which prevents iatrogenic damage; (vi) no effect on the lateral wall of the femur; and (vii) decreased frequency of intraoperative fluoroscopy. However, there are also some disadvantages. First, for distal and proximal fractures with obvious sinking and upturning, alternative methods are required to assist with reduction, and a small incision may be necessary. Second, other reduction methods are needed to maintain the reduction when reduction cannot be maintained after application of the method described above. Third, pressing the finger reduction tool too hard may result in fracture of the greater trochanter vertex.

This study has some limitations. First, this is a retrospective study and bias is inevitable. Second, this study is of low-level evidence because no control patients were included. Prospective, multi-center studies are needed to further verify the efficacy of this technique. Third, the sample size was small and the follow-up time was not long enough. Longer follow-up is needed to verify the long-term effect.

Conclusion

Pre-drilling of the femoral trochanter combined with the use of a finger reduction tool to assist with the reduction of difficult-to-reduce intertrochanteric femur fractures is an effective approach to improve the efficacy of reduction without increasing surgical trauma. This approach also reduces the dose of radiation administered to the patient. However, this method should be applied with caution. The technique described above should only be used when irreversible intertrochanteric femur fracture is difficult to reduce intraoperatively and successful reduction cannot be achieved in any other way.

Author Contributions

Guoli Chen designed and planned the experiments. Xianwei Wu and Mei Lin carried out the operation. Hongxin Hu wrote the manuscript. Haibin Lin critical revision of the manuscript.

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Ethics Statement

Ethical approval was obtained from Affiliated Hospital of Putian University Ethics Committee. (Approval No: 202021).

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