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# Minimally invasive treatment of old femoral fractures in adults

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ABSTRACT

*Objective:* Extensive incision associated with large-scale callus exfoliation and internal fixation is the common therapeutic approach employed by the majority of orthopaedists in the treatment of old femoral fractures. Inspired by the surgical techniques of intramedullary fixation and reduction by traction, the present study attempted to treat old femoral fractures with minimally invasive methods utilising the principles of biological osteosynthesis (BO).

*Methods:* A retrospective analysis involving 16 patients with old femoral fractures treated with combined traction, small incision, limited callus treatment, reduction by leverage and intramedullary fixation was conducted. The operative effect was evaluated by the operation time, intraoperative blood loss, bone grafting, healing time of fractures during follow-up, VAS score, and Harris hip score.

*Results:* Intraoperative observation revealed an average operation time of $1.53 \pm 0.34$ h and average blood loss of $268.13 \pm 97.29$ ml without bone grafting in all patients. All enrolled patients had outcomes resulting in effective fixation restoration of limb alignment. Of the 16 enrolled patients, 13 patients completed follow-up with an average follow-up time of $7.42 \pm 3.29$ months. The average healing time for proximal femoral fractures was 3 months. The average healing time of femoral shaft fractures was $4 \pm 1.09$ months; two of these cases took 4 months to heal, whereas 1 case demonstrated a delayed healing time of 6 months. The VAS score was $1.15 \pm 1.70$, 1 patient experienced sciatica, and the Harris hip score was $92.92 \pm 5.42$. There were no complications of malunion, nonunion or infection among any of the patients who completed follow-up.

*Conclusions:* Minimally invasive treatment is feasible for most patients with old femoral fractures of the trochanter and femoral shaft. This finding is consistent with BO principles, thereby providing a possible new method for the treatment of old femoral fractures.



## Introduction

With the expansion of urban development, there has been a significant rise in polytraumatic and compound injuries caused by traffic accidents [1] and injury by fall from height. With the primary goal of preserving life, in cases of polytrauma, craniocerebral trauma, chest injury and abdominal injury are given priority [2,3], and limb fractures are typically managed with temporary fixation [4,5]. Multiple trauma is often severe with a relatively longer recovery time. In clinical practice, utilising this procedural treatment strategy based on the theory of damage control operation (DCO) [3] may mean that limb fractures are not able to be managed within the ideal time frame. As a vast developing country with a large population, China, especially in the remote rural areas of the Central and Western regions, is subject to an imbalance of transportation availability, economic opportunity and medical treatment. Due to these circumstances, there are patients who experience missed diagnosis, delayed treatment and unregulated treatment [6] of multiple fractures; consequently, these injuries then develop into old fractures. Also related to the development of old fractures is the frequent association between high-energy multiple trauma and craniocerebral trauma. Prior research has documented that craniocerebral trauma can accelerate the healing of fracture sites [7,8], but it can also make the treatment of old fractures considerably more difficult.

Clinically, the definition of an old fracture is one that has gone without effective treatment for more than 3 weeks. Due to this long period of time without effective medical intervention, primary callus formation has already begun, and a large amount of callus has formed [9], leading to malunion of the fracture and even to the

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formation of pseudo-joints. This process will occur even earlier in cases of combined craniocerebral trauma [7,8].

The femur is one of the major bones of the lower extremity, and old femoral fractures seriously affect the quality of life of patients without effective treatment [10]. There are both advantages and disadvantages to large incision and wide dissection, which is the routine treatment of old femoral fractures. Specifically, reduction and fixation under direct vision is relatively easy, which is an obvious advantage. However, this approach may induce greater trauma and larger amounts of blood loss (Fig. 1). Therefore, it is our pursuit to explore a minimally invasive and effective surgical technique to minimise the shortcomings of the conventional approach. The inspiration behind the minimally invasive surgical technique utilised in this study is femoral intramedullary fixation, implemented with appropriate modification and improvement.

## Patients and methods

The present retrospective analysis was conducted in the Department of Orthopaedics, First Affiliated Hospital of Chongqing Medical University. Inclusion criteria for patients in this study were as follows: 1. patients who had proximal femur and femoral shaft fractures more than three weeks old (patients with femoral condylar fractures were excluded), with imaging examination revealing displaced fracture with callus growth; 2. patients with fractures caused by trauma and without organic lesions (e.g., tumour, tuberculosis, and infection) at the end of the fracture. All patients (n = 16) underwent surgery between 2015 and 2017. There were 10 patients with proximal femur fractures (intertrochanteric and subtrochanteric) and 6 patients with femoral shaft fractures. Of the 16 patients, there were 11 males and 5 females with an average age of 46.63 ± 16.14 years and a maximum age of 81 years. Regarding laterality, there were 7 patients with fractures on the right side and 9 patients with fractures on the left side. The average length of time-after-fracture was 5.51 ± 4.38 w, with the longest duration reaching 21.4 w (Table 1). All patients signed a written informed consent prior to surgery, and the Ethics Committee of Chongqing Medical University approved the study protocol.

**Table 1**
Sex (S), Age (A), Affected Limb (AL), Fracture Time (week, FT), AO Classification (AO), Length of Incision (cm, Calculate by the longest incision, LI), Intraoperative blood loss (ml, Only the femur is counted, BL), Bone Graft (BG), Operation time (hour, OT).

| No | S | A | AL | FT (w) | AO | LI (cm) | BL (ml) | BG | OT (h) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | M | 28 | L | 4.3 | 32A3 | 5 | 100 | N | 1 |
| 2 | F | 29 | R | 4.5 | 32C3 | 5.5 | 200 | N | 1.5 |
| 3 | M | 76 | L | 5 | 31A3 | 8 | 350 | N | 1.3 |
| 4 | M | 48 | R | 10 | 31A2 | 10 | 260 | N | 2.1 |
| 5 | M | 28 | R | 3.3 | 32B1 | 7 | 200 | N | 1.5 |
| 6 | M | 47 | R | 21.4 | 31A2 | 6.5 | 440 | N | 2.3 |
| 7 | M | 44 | L | 3.8 | 31A3 | 5 | 200 | N | 1.5 |
| 8 | F | 81 | L | 4.3 | 31A2 | 6 | 200 | N | 1 |
| 9 | F | 66 | L | 3.3 | 31A2 | 5.5 | 230 | N | 1.3 |
| 10 | M | 43 | L | 4.4 | 32A2 | 4 | 150 | N | 1.5 |
| 11 | F | 52 | R | 3.4 | 31A3 | 8.5 | 300 | N | 2 |
| 12 | M | 38 | R | 4.8 | 31A1 | 6 | 450 | N | 1.5 |
| 13 | M | 32 | L | 4.1 | 32C1 | 6 | 250 | N | 1.4 |
| 14 | F | 56 | L | 3.6 | 31A2 | 7 | 400 | N | 1.4 |
| 15 | M | 29 | L | 3.4 | 32B1 | 5 | 260 | N | 1.7 |
| 16 | M | 49 | R | 4.6 | 31A3 | 8 | 300 | N | 1.5 |

The X-ray and CT of the fracture site for each patient was reexamined preoperatively to visualise the fracture displacement and callus formation (Fig. 2A, Fig. 3A). Careful examination of the skin [11] and soft tissue at the surgical site were also carried out in accordance with basic surgical protocol. Antibiotics were delivered 30 min prior to surgery in order to prevent infection. Patients were routinely instructed to lie on the fracture table (Fig. 2B, Fig. 3B), and the affected limb was placed under appropriate preoperative traction, as to slightly increase the skin and muscle tension at the fracture site. Next, under the guidance of C-arm fluoroscopy and according to the type and site of the fracture, a small incision was made. C-arm fluoroscopy revealed a large amount of fibrous callus

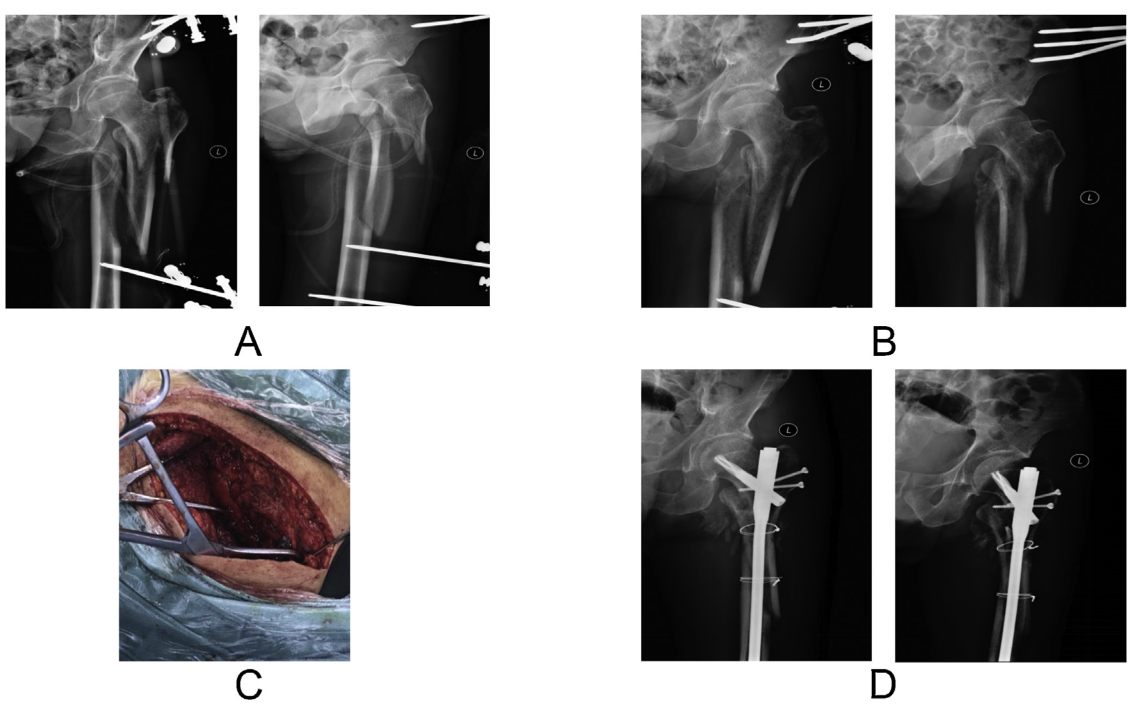


**Fig. 1.** Conventional surgical intervention for the treatment of a 48-year-old patient with an old femoral fracture (31A3), incision (20 cm), bleeding (4000 ml), operation time (4 h). (A) X-ray after external fixator treatment in the Emergency Department; (B) X-ray 83 days after external fixator treatment, with the treatment planning of removing the external fixator and replacing it with an internal fixator; (C) Intraoperative surgical incision, with the appearance of a large amount of callus and scar tissue, showing the long incision and significant bleeding, operation time; (D) Anterior-posterior and lateral X-ray 5 days postoperatively.

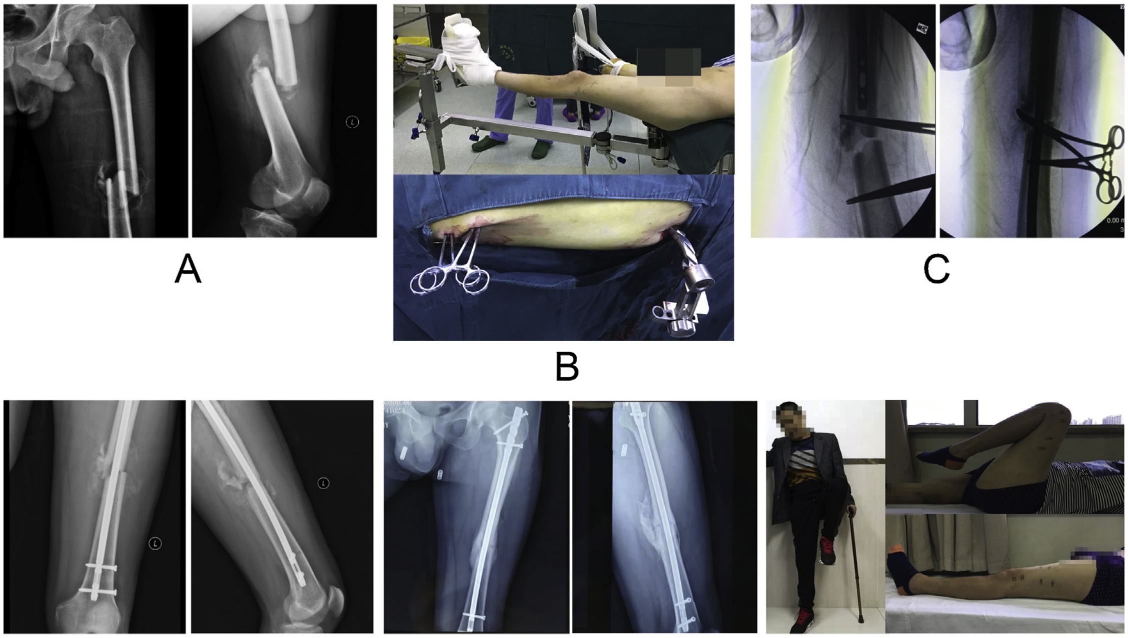


**Fig. 2.** Minimally invasive surgery for the treatment of a 43-year-old patient with an old femoral shaft fracture (32 A2), incision (4 cm), bleeding (150 ml), operation time (1.5 h). (A) X-ray 4.4 weeks after injury, a large amount of callus formation found at the end of the fracture with obvious displacement; (B) Traction, surgical incision, blunt release, reduction by leverage and elevating-pull via long haemostatic forceps; (C) X-ray of intraoperative reduction and insertion of intramedullary nail; (D) Anterior-posterior and lateral X-ray 1 day postoperatively; (E) Anterior-posterior and lateral X-ray 4 months postoperatively; (F) Postoperative function(The left lower limb was the operative side, and the right lower limb stood up with prosthesis after amputation.).

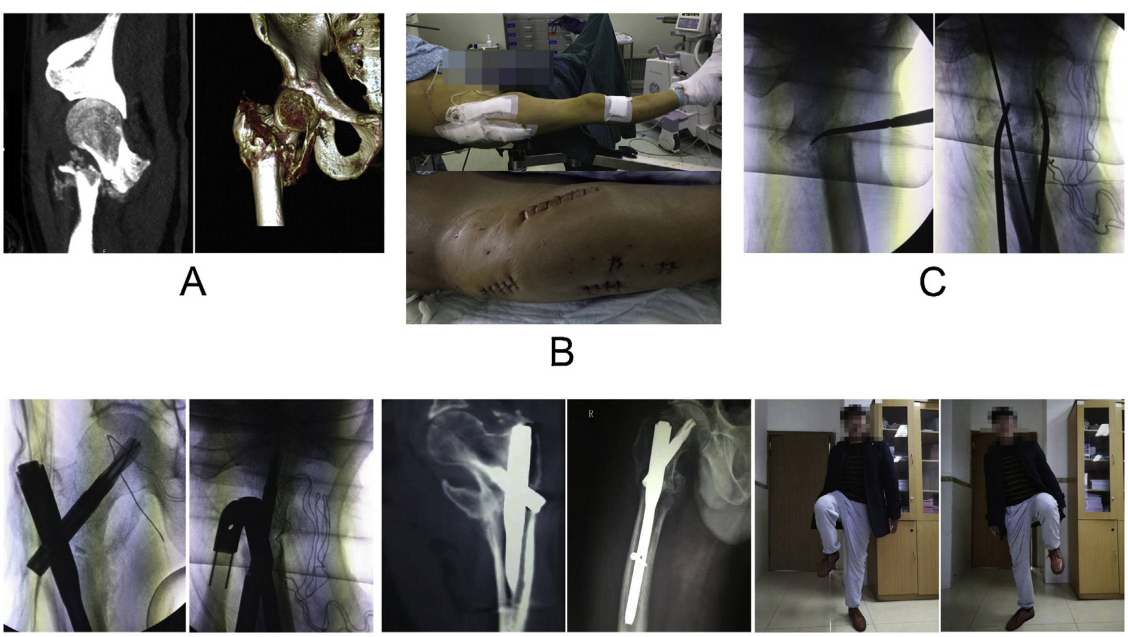


**Fig. 3.** Minimally invasive surgery for the treatment of a 48-year-old patient with an old proximal femoral fracture (31A2) combined with craniocerebral trauma, incision (10 cm), bleeding (260 ml), operation time (2.1 h); (A) Three-dimensional CT reconstruction 10 weeks after injury, with the presence of a large amount of callus formation at the fracture end; (B) Traction, surgical incision; (C) Combined traction, and intraoperative sharp separation of callus via periosteal detacher; (D) Intraoperative anterior-posterior and lateral X-ray; (E) CT coronal scan and lateral X-ray 3 months postoperatively; (F) Postoperative function.

and scar tissue formation at the broken ends of the fracture. After the incision was made,the surgical assistant was then instructed to gradually increase the traction force to the affected limb. Simultaneously, the broken ends of the fracture were loosened utilising such instruments as long haemostatic forceps, osteotome, periosteal detacher until the degree of traction was sufficient for of reduction of the fracture. Early calluses can be released bluntly (Fig. 2C), while older calluses can be cut sharply with an osteotome or periosteal detacher (Fig. 3C). The traction was maintained at this level. The rotational angle of the lower limb was adjusted with traction, and the broken ends of the fracture were reset utilising a combination of reduction by both leverage and elevating-pull (Fig. 2C, Fig. 3C). Proximal femoral fractures required the restoration of the collodiaphyseal angle and anteversion angle, while restoration of alignment was required in fractures of the femoral shaft. An incision was made at the apex of the greater trochanter followed by insertion of a lead wire through the broken ends of the fracture and reaming. After placement of the appropriate intramedullary nail, the screw or screw blade was inserted into the distal and proximal end, as required. C-arm fluoroscopy showed good fracture reduction, and the incision was closed after rinsing.

On the second day after operation, patients were instructed to perform CPM-assisted passive function exercises of the affected limb. Patients who were capable of out-of-bed activity were encouraged to gradually implement weight-bearing exercise utilising an assistive device 1 week after the operation.

## Results

### *Surgical outcomes*

The average operation time for all patients was $1.53 \pm 0.34$ h (only considering duration of the femur operation), with the longest time being measured at 2.3 h. The average incision length was $6.44 \pm 1.52$ cm. The intraoperative blood loss was 100–450 ml, and the average blood loss was $268.13 \pm 97.29$ ml without blood transfusion or bone grafting. Sciatica occurred in 1 patient, and no infection was found (Tables 1 and 2).

### *Follow-up finding*

Of the 16 patients, 13 patients successfully completed follow-up through fracture healing. The longest follow-up period was 16 months with an average follow-up time of $7.42 \pm 3.29$ months. The average healing time for proximal femoral fractures was 3 months. The average healing time of femoral shaft fractures was $4 \pm 1.09$ months, among which 2 patients took 4 months, and 1 patient (32C3) experienced delayed healing of 6 months before meeting the established standard of healing. The VAS score [12] was $1.15 \pm 1.70$, 1 patient had sciatica, and the Harris hip score [13] was $92.92 \pm 5.42$, One patient was unable to participate in the harris score due to amputation of the contralateral lower extremity, but the limb function of the operative side was satisfied (Fig. 2F). All patients exhibited recovery of limb alignment and satisfactory recovery of the collodiaphyseal angle and anteversion angle. There were no complications of malunion, nonunion or infection among any of the patients who completed follow-up. Hip joint function recovered satisfactorily.

**Table 2**
Follow-up time (month, FUT), Fracture healing time (month, FHT), visual analogous scale (point, Vas), Harris score (point, harris).

| No | AO | FUT (M) | FHT(M) | vas (p) | harris (p) |
|---|---|---|---|---|---|
| 1 | 32A3 | 6 | 3 | 0 | 97 |
| 2 | 32C3 | 16 | 6 | 2 | 91 |
| 3 | 31A3 | 6 | 3 | 1 | 91 |
| 4 | 31A2 | 12 | 3 | 0 | 98 |
| 5 | 32B1 | 7 | 4 | 1 | 96 |
| 6 | 31A2 | 6 | 3 | 0 | 96 |
| 7 | 31A3 | 6 | 3 | 0 | 95 |
| 8 | 31A2 | 5 | 3 | 2 | 85 |
| 9 | 31A2 | 6 | 3 | 6 | 81 |
| 10 | 32A2 | 11 | 4 | 0 | – |
| 11 | 31A3 | 6 | 3 | 3 | 89 |
| 12 | 31A1 | 5.5 | 3 | 0 | 100 |
| 13 | 32C1 | 4 | 3 | 0 | 96 |
| 14 | 31A2 | – | – | – | – |
| 15 | 32B1 | – | – | – | – |
| 16 | 31A3 | – | – | – | – |

## Discussion

It is difficult to achieve functional reduction for old femoral fractures utilising manual reduction. In these cases, surgical treatment is required to restore limb alignment, correct deformities [14], and establish optimal conditions to promote fracture healing.

There is massive amount of bleeding at the broken ends of a femoral fracture, and haematoma at these broken ends plays an essential role in the formation of callus [15]. Consequently, massive callus and scar tissue formation frequently occurs at the broken ends of old femoral fractures, resulting in the loss of the original anatomical structure. This phenomenon becomes a significant obstacle to fracture reduction and fixation [16]. Traditional surgical procedures have adopted a full-exposure approach, utilising an extensive incision and large-scale callus exfoliation to facilitate reduction and create a favourable position for the placement of an internal fixator. Despite the realisation of temporary results during the operation, the destruction of blood supply greatly inhibits fracture healing [17,18]. Furthermore, in order to prevent the occurrence of complications, such as long-term nonunion, autogenous or allogeneic bone grafting [19,20] at the broken ends of fractures becomes necessary. This situation increases both the pain and economic burden of the patient. Additionally, extensive incision and wide dissection may substantially increase the risk of injury to surrounding tissues. This risk of tissue damage combined with long exposure time and increased blood loss, which may lead to an increased risk of infection, even endanger the lives of elderly patients in serious cases. The traditional surgical approach also requires longer periods of intraoperative and postoperative life support.

In contrast to the traditional surgical approach, the minimally invasive surgical technique that we proposed relies on the guidance of C-arm fluoroscopy, and the incision is made after a comprehensive judgement regarding fracture location. The incision, in this case, is only an operative channel specifically placed utilising C-arm fluoroscopy, to facilitate the release of partial callus and scar tissue affecting the reduction. Even if the incision needs to be slightly elongated (Fig. 3B), the approach avoids the traditional large incision required to expose the broken ends of the fracture. Moreover, with respect to the origination of most of the blood supply to the callus [9,21], small incisions also protect muscles and extraperiosteal tissues around the broken ends as much as possible. The fracture table (Figs. 2B and 3 B) is essential in the proposed minimally invasive technique to provide continuous and controllable traction to the affected limb. The traction should be guided by C-arm fluoroscopy and coordinated with the releasing of tissue through the small incision and providing of leverage at the broken ends of the fracture to assist in reduction. Early calluses can be released bluntly (Fig. 2C), while older calluses can be cut sharply with an osteotome or periosteal detacher (Fig. 3C), thereby minimising the disturbance to the reduction without removing callus. Traditionally, long plates and screws in combination with extensive stripping of the callus to place the plates and promote good adherence to the bone surface are used to fix fracture fragments. In the present study, intramedullary nails,which is a part of the procedure inspired by central fixation, were used to fix the fractures.There was only a need to restore femoral length, rotation and limb alignment, and the long-term union would not be affected, even if there was displacement of some fragments of the fracture. In the proposed new technique, the process of reaming and inserting nails established freshness of the broken ends of the fracture and was associated with re-canalisation of the medullary cavity which, in turn, can stimulate the broken ends of the fracture directly and is beneficial to fracture healing [22,23]. Furthermore, the placement of intramedullary nails exhibited no significant interference with the periosteum, which is crucial for osteogenesis in most old fractures in the primary callus formation stage [24]. Intramedullary nails were also relatively stable, placed utilising a type of elastic fixation that can also stimulate callus growth [25,26]. Reduction was achieved with the leverage and elevating pull of traction (Figs. 2C and 3 C), resulting in a more simple and practical operation. In the traditional surgical approach, callus presence at the broken ends of the old femoral fracture increase the complexity of the surgery and need to be removed as much as possible, which necessitates back-fill with autogenous or allogeneic bone. Minimally invasive surgery emphasises protection of the callus and the minimisation of interference, not only protecting the blood supply of the callus but also maintaining the original callus. Therefore, no additional bone grafting is required to compensate for the deficiency of bone mass or to induce bone formation; the importance of bone grafting becomes considerably less prominent. The minimally invasive surgery with low-intensity intervention created favourable conditions for accelerating postoperative rehabilitation. Studies regarding old fractures were retrieved through PubMed for this study, and no similar research has been reported.

Minimally invasive treatment of old femoral fractures has prominent advantages, but the dependence of this technique on intramedullary nails also exhibits some deficiencies. Therefore, during the process of screening for eligible patients, cases with old femoral supracondylar and intercondylar fractures were not included in the present study. Traditional surgery is still the desired approach for patients with fractures adjacent to and involving the articular surface. Similarly, there is no need for bone grafting in the course of minimally invasive surgery, partly because the original callus can continue to function effectively; therefore, the minimally invasive approach is not applicable for old fractures accompanied by atrophic nonunion with a small or no callus formation. In the cases of complete malunion requiring osteotomy, reduction depending on traction and small incision-based leverage only may become difficult to achieve; minimally invasive surgery may not be applicable in these cases, as well. Although traction is a notably important component of the minimally invasive technique, the strength and timing of traction need to be controlled effectively and implemented by someone with practical experience. In this study, one patient experienced sciatica, which could have been the result of traction injury [27]. Therefore, the proposed minimally invasive surgery requires surgeons and assistants with higher operative skills and proficiency.

In conclusion, our attempt to treat old femoral fractures with minimally invasive surgery has the advantages of a small incision, less bleeding and no bone grafting, rendering the technique more amenable to the biological characteristics of bone repair. Despite the discussed shortcomings, minimally invasive surgery provides a feasible model for the treatment of old fractures of the extremities, especially those of the long bones of the extremities. The minimally invasive surgical technique warrants further research and exploration.

## Conflict of interest

The authors declare no conflict of interest.

## Author contributions

Xiang Zhang: Writing the manuscript, Collecting the data, Statistical analysis, Assisted in the surgeries.

Wei Shui: Writing the manuscript, Collecting the data, Statistical analysis, Assisted in the surgeries.

Weidong Ni: Supervising the study, Editing the manuscript.

Zhenming Hu: Editing the manuscript.

Wei Huang: Editing the manuscript.

Gang Luo: Reviewing the literature.

Bo Qiao: Reviewing the literature.

Shuquan Guo: Chief surgeon, Designing the study, Editing the manuscript.

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