# Application of a Custom-designed External Fixation Restorer for Pediatric Femoral Fractures

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**Research Article**

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# Abstract

**Background:** Closed reduction of pediatric femoral shaft fractures is one of the most difficult types of partial fracture reductions. Open reduction increases the harm to children. Although smaller invasive open reduction is mostly used at present, it has an impact on the microenvironment around the fracture and results in increased intraoperative bleeding, an increased risk of postoperative infection and surgical scarring, which has a great psychological impact on children.

**Methods:** Given the above challenges, we propose another intraoperative reduction method. The technique described involves closed reduction and internal fixation for pediatric femoral shaft fractures using a new type of intraoperative fixator.

**Result:** This technique brings hope that the success rate of closed reduction for pediatric femoral shaft fractures can reach 100%.

**Conclution:** The method is demonstrated in a patient.

# 1. Introduction

Femoral fracture is a common fracture in children, accounting for approximately 4% of traumatic fractures in children [1]. There are two peak periods of femoral fracture occurrence in children: toddlerhood and adolescence, and most patients are boys [2]. The treatment approach for femoral fractures in children has changed over the years, but the use of surgical treatment for unstable femoral fractures has been widely recognized by orthopedic surgeons [3]. At present, the common treatment methods for pediatric femoral fracture include lower limb traction, plaster and bracing fixation, internal fixation with steel plates, internal fixation with elastic intramedullary nails, external fixators, and internal fixation with retrograde or retrograde reamed interlocking intramedullary nails [4].

In 1982, Metaizeau and Nancy invented the elastic intramedullary nail in France and used it for the treatment of femur fractures in children. At present, elastic intramedullary nails are a routine treatment for femoral shaft fracture in young children due to their advantages of a minimally invasive surgical incision, shorter hospital stay, less soft tissue injury, quick recovery, less bleeding and fewer postoperative complications [5]. A number of international studies have found that flexible intramedullary nailing has unique advantages over other treatment methods in the treatment of femoral fracture in children. Jonden et al. found that flexible intramedullary nailing had less impact on families than other treatments [6].

Elastic intramedullary nails are used to treat femoral fractures in children with closed reduction and internal fixation under direct visualization. For a minority of older children with femoral fracture, an orthopedic traction bed can be used. Even if closed reduction is unable to achieve effective resetting of the bone, repeated resetting not only increases the harm to children and workload of the operation personnel but also leads to a prolonged operation and recovery time and causes local soft tissue injury of the fracture end, ultimately requiring open reduction. In addition, a long time period of time is required to maintain traction in a traction bed, and there will be related soft tissue injury. Kelly et al. [7] reported 8 cases of nerve palsy in children with femoral shaft fracture treated using a traction bed (3.1%), and the occurrence of nerve palsy was related to the patient's weight and the length of the operation. For the majority of pediatric femoral fractures, an intraoperative traction bed cannot be used, and only manual traction can be used for reduction. The strength of manual traction is due to cross-joint traction, the traction efficiency is low, and it is difficult to maintain limited traction by manual traction. Open reduction has to be used for some fractures.

For the above reasons, we designed an external fixation reductor for pediatric femoral fractures to facilitate the insertion of elastic intramedullary nails in femoral fractures in children. The purpose of this article is to introduce the new type of reductor for pediatric femoral shaft fractures.

## 2. Methods And Results

# 2.1 Technical description

The reset device is composed of two parts (FIG. 1):

# 2.1.1 Axial tension reset device

The axial tensile reset device includes connection of a proximal and distal link connecting rod along the horizontal axis, a proximal connecting rod needle holder with two 3-mm diameter fixation needles, a needle holder with a remote connection rod clamp and one Schanze nail for distal fracture fixation that is 5 mm in diameter. A stretching reset device is used to restore fracture length. The horizontal axis of rotation is used to correct the fracture length to obtain a residual lateral angle for the fracture after recovery.

# 2.1.2 Radial pressure reset device

The radial pressure reduction device consists of a pressure screw and a U-shaped connecting rod, and the pressure screw is connected to the axial reduction device through the U-shaped connecting rod. The pressure screw is smooth in front and threaded in the back. For angular displacement of the fracture to the left after reduction by an axial reduction device, the tip of the compression screw is fixed to the surface of the forward-displaced fracture end. The direction of the compression screw is consistent with the direction of fracture displacement, which may be forward, anterolateral, or anterolateral.

# 2.2 Clinical application

After general anesthesia, the child was placed in the supine position, and a 1-2 cm incision was made near the epiphyseal line of the distal femur (the insertion point of the elastic nail). A longitudinal incision of approximately 1.5 cm in length was made in the lateral thigh, and a 5-mm diameter Schanze nail was inserted horizontally (Fig. 2a). Two 3-mm diameter Kirschner needles were inserted in the proximal end of the femur fracture (Fig. 2b), and an axial stretching device was installed. Other nut and pin holders were locked, except the fastening nut of the axial tension reset device (Fig. 2c). For stretching, the stretching reset device was inserted through the distal end into the far end of the needle holder to stretch the femoral fracture (Fig. 2d). To correct the femur fracture overlap after achieving the proper femoral length (Fig. 2e), the axial tensile repositioning fastening nut was tightened. At this time, depending on the type of femur fracture, such as fracture-angle abnormality, the horizontal axis of rotation was loosened, giving correcting and shifting the fracture-angle abnormality. Then, the horizontal rotating shaft nut was tightened.

Lateral fluoroscopy of the femur showed that the first elastic intramedullary nail was inserted through the medullary cavity if the end of the remaining fracture was rotated (FIG. 2k-l). If the angle at the femoral fracture is enough to break an elastic intramedullary nail, a U-shaped connecting rod is placed in the forward displaced portion of the fracture end (FIG. 2f - g), and the proximal connecting rod should be fixed. The radial pressure should be reduced, and the percutaneous screw cap should be placed at the front of the fracture end. The pressure of the reset screw nails should be slowly adjusted before and after a reset. This screw also corrects residual lateral displacement (FIG. 2h-i).

For fracture reduction, an elastic intramedullary nail was inserted into the far end of the lateral thigh through a longitudinal incision that was approximately 1.5 cm long near the distal femoral growth plates, approximately 1~2 cm to the side, with the opening into the elastic pin partially exposed (Fig. 2j). An elastic nail was inserted into the proximal end of the fracture (Fig. 2k), the reset device was dismantled. Another elastic intramedullary nail of the same diameter was inserted into the Schanze nail hole. Generally, after the first elastic intramedullary nail passes through the fracture, the second elastic intramedullary nail passes easily. The elastic screw was advanced so that the lateral screw head was located at the prominences of the greater trochanter and the medial screw head was located in the area between the talus, femur and distal side of the growth plate of the proximal femur body (approximately 1 cm from the growth plate) (Fig. 2l).

Finally, the flexion, extension and rotation function of the affected limb and the stability of fracture fixation were assessed. If no errors were found, the nail tail was cut off with 1.5 cm was left exposed outside the bone cortex; it was then slightly bent and buried under the skin (Fig. 2m - n).

# 3. Discussion

Surgical treatment of children's fractures is developing toward minimally invasive treatment. The premise of minimally invasive treatment of fractures is closed reduction and needling for pediatric long bone fractures. Because of long bone growth characteristics, the use of elastic intramedullary nails has become the gold standard treatment for pediatric long bone fractures. Open reduction was used for femoral shaft fracture in children because of the difficulty of manipulative reduction. In a single-center study by Zenon Pogorelic et al. [8], the incision rate associated with elastic intramedullary nail placement for femoral shaft fracture in children was 13.6% (14/103). In addition, to avoid repeated fluoroscopy and shorten the operation time, some scholars directly adopt open reduction for some femur fractures, resulting in a higher incision rate. Although a limited number of incisions and small incisions were adopted as much as possible, the periosteum around the femur is removed in open reduction, which affects the microenvironment around the fracture, increases intraoperative bleeding, increases the risk of postoperative infection, and leaves surgical scarring, which has a great psychological impact on children.

At present, how to achieve high-quality minimally invasive fracture reduction is still a difficult problem for orthopedic surgeons. Homeopathic fracture reduction theory has been successfully applied in adult orthopedic trauma cases in recent years [9]. The theory includes five essential elements: ① the traction force is consistent with the axis of the limb; (2) the tractive force conforms to the trajectory of soft tissue and bone; (3) using the muscle, ligament, joint capsule and other soft tissue around the fracture envelope effects the traction, causing extrusion and aggravation of the fracture; (4) bone-to-bone bidirectional traction, mutual reactions, and direct action on the bone result in large and balanced forces; and ⑤ irritation and iatrogenic injury to soft tissue are reduced, contributing to minimally invasive treatment.

By combining the theory of homeopathic fracture reduction with the characteristics of elastic intramedullary nailing in the treatment of pediatric femoral fracture, we designed a flexible intramedullary nailing assistive reduction device for pediatric femoral shaft fracture. This restorer of axial tensile force can stretch the femur to normal length, while restoring the lateral angle, and the horizontal axis of rotation is able to obtain a lateral angular deformity correction. The radial compression pressure provided by the reset device can be adjusted via the pin and moving the device relative to the fracture end. This reductor can achieve comprehensive reduction of femoral fractures in terms of fracture length, angle and displacement. It provides three-dimensional reduction and can achieve a satisfactory reduction effect, creating good conditions for the insertion of elastic intramedullary nails.

Application of a traction bed for the reduction of femoral shaft fractures has low reduction efficiency, and some patients need assisted reduction through a small incision. Additionally, the relatively fixed position of the traction bed and affected limb affects c-arm fluoroscopy and the placement of internal fixators, thus prolonging the operation time and increasing the amount of X-ray exposure. After the fracture is reduced, the reductor temporarily fixes the fracture and can arbitrarily move the femur without fracture displacement. Moreover, due to the temporary fixation of the fracture end, it is particularly easy to introduce the elastic intramedullary nail.

Application of the reductor directly addresses the difficulty of partial reduction of femoral shaft fractures in children, which requires incisions, especially in hospitals with poor medical conditions and no pediatric traction bed that can be used intraoperatively.

Although this technique has been demonstrated for closed reduction of pediatric femoral shaft fractures, it has limitations. Biomechanical experiments using reset devices are not included in this report but may be a direction of future research. At the same time, whether the reset device can be widely used remains to be verified.

# 4. Conclution

The intraoperative reduction device for pediatric femoral shaft fractures described in this paper brings hope that the success rate of closed reduction for pediatric femoral shaft fractures can reach 100%. Meanwhile, the simplicity of the operation and apparatus also provide the possibility for further popularization.

# Declarations

Ethics approval and consent to participate

The studies involving human participants were reviewed and approved by the Ethics Committee of Hebei Medical University Third Affiliated Hospital(2019-03H). Written informed consent to participate in this study was provided by the participants'legal guardian/next of kin. Written informed consent was obtained from the minor(s)'legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Y-ZL and Y-CL designed the whole study scheme.  X-JP, C-FL and J-YY recruited the case and performed the clinical evaluation. J-YY and C-FL wrote the original version of this manuscript, and all co-authors have read it and proved the submission.

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# Figures

### Figure 1

The reset device consists of an axial tension reset device and a radial pressure device.

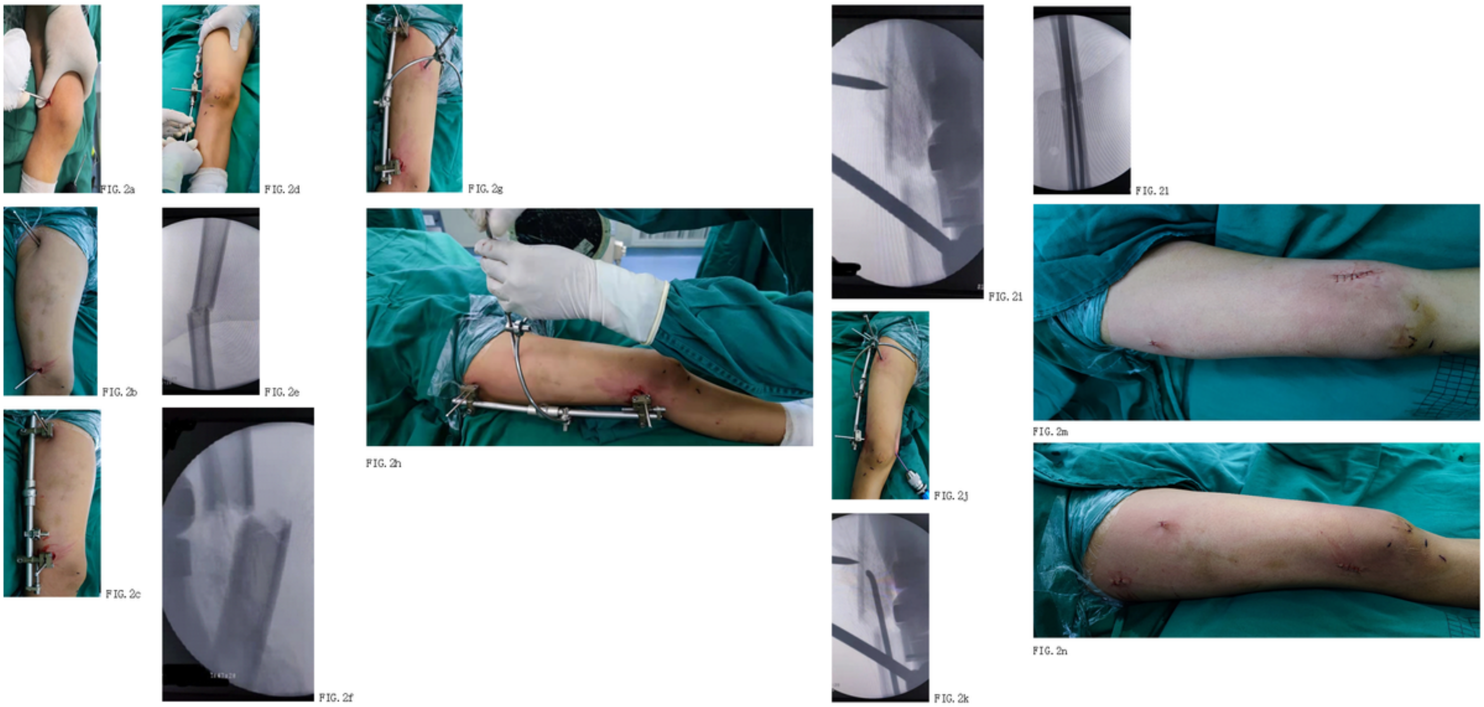

**Figure 2**

A 12-year-old boy with a transverse fracture of the right femoral shaft.

Figure 2a Schanze nail was inserted lateral to the distal femur.

Figure 2b Two Kirschner wires were inserted lateral to the proximal femur.

Figure 2c Installation of axial tension reset device.

Figure 2d Stretching reset device for stretching.

Figure 2e Fluoroscopic reconstruction of orthotopic femoral fracture length was achieved by inserting an elastic intramedullary nail.

Figure 2f Fluoroscopic view of the lateral femoral fracture length was restored. The fracture end was obviously displaced, and an elastic intramedullary nail could not be inserted.

Figure 2g An axial compression device was installed to apply pressure to the fractured end.

Figure 2i The fracture was reduced, and an elastic intramedullary nail was inserted.

Figure 2j The first elastic intramedullary nail was inserted in the distal medial side of the femur.

Figure 2k Elastic intramedullary nail through the fracture.

Figure 2l The reducer was removed, the second elastic intramedullary nail was successfully inserted, and the fracture was successfully reduced

Figure 2m, n Postoperative appearance.