

Case Report

Self-made adjustable external fixation device with progressive compression for the management of open fracture with bone defects of the distal hallux phalanx: a case report

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Abstract: Open fractures with bone defects of the distal phalanx of the hallux are both rare and complicated, and these conditions pose great clinical challenges to orthopedists, as improper handling can lead to distal tissue necrosis, osteomyelitis, malunion, non-union and even amputation. To ensure blood supply to the distal area of the injured toe, a series of measures, including thorough debridement, timely reduction, axial fixation (K-wire), appropriate suturing and drug administration, can be achieved in the first stage. However, due to the lack of soft tissue and bone and the blocking effect caused by un-disconnected soft tissue, it is relatively difficult to achieve effective reduction and fixation of the fracture by traditional methods. In the current study, we present a patient, diagnosed with open fracture combined with bone defects of the distal segment of the great toe, who was treated using a self-made adjustable external fixation device by complete debridement, effective closed reduction and continuous adjustment. This resulted in effective maintenance of reduction and progressive compression in the fracture ends, finally obtaining optimal fracture healing and satisfactory function of the injured toe.

Keywords: Open fracture, distal phalanx of the hallux, compressive external fixation device, bone defect

Introduction

Open fractures with bone defects of the distal phalanx of the hallux are mainly caused by direct impact, such as crush or chain-saw injury [1]. The latter is relatively less reported in clinical practice [2]. At present, the clinical management of such injuries is primarily based on the classification of open fractures and the degree of bone defects. This involves thorough debridement, reduction and axial fixation (usually by Kirschner wires) that are conducted in one-stage operation [3]. Adjuvant medication is administered to improve blood supply to the distal area postoperatively [3]. The changing of the dressings was generally used on the basis of debridement and suturing in previous studies. Simple axial Kirschner wire fixation cannot fix the broken ends firmly, the anti-rotation ability is poor, and more importantly, there is no continuous pressurization effect. This may in-

crease the risk of delayed healing and nonunion of the fractures, while cross Kirschner wire fixation avoids anatomical reduction due to the narrow section of the distal phalangeal bone, which increases the difficulties and the time of operation, further damaging the distal blood supply [4-7].

This injury accompanied by the deficiency of soft tissue and bone, maybe pose certain challenges to the efficacy of the clinical prognosis, such as distal tissue necrosis, delayed fracture healing, non-union, osteomyelitis and other complications [8-10], which affect the overall aesthetic appearance and load-bearing function of the toe. To some extent, these are combined with the difficulty of receiving proper and effective early treatment of the open fracture [11]. To provide an alternative for these disadvantages, our team designed an adjustable progressive external fixation device on the

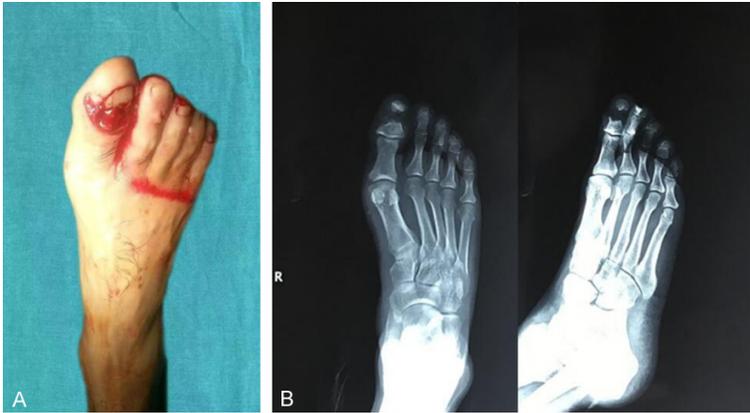


Figure 1. Preoperative wound and X-ray imaging. A. An open wound was noted in the distal phalanx of the right great toe with the majority of the bone disconnected from the proximal part of the toe nail, leaving the inner part exclusively attached to the skin and resulting in a weak peripheral circulation. B. AP radiography indicated that the fracture of the distal hallux phalanx was associated with the separation of broken ends and bone defects.

basis of traditional methods. In the present study, a case of open fracture with bone defects of the right great toe is described. The patient was treated by our self-made external fixation device with a procedure of adjusting the external fixator at different stages. This method aimed to maintain the pressurized state of the fracture ends following the first-stage operation. This surgical technique uses a single Kirschner wire to axially fix the fractured ends, which reduces blood supply damage, and can maintain the continuous pressure state of the fractured ends throughout the treatment. It is the highlight and innovation of our study.

Case

Basic situation of the patient

A male patient, who was 47 years old, was delivered to the Emergency Department of Orthopedics in the People's Hospital of the Sihong County (Jiangsu Province), due to pain, bleeding and lack of motion of the right great toe for 2 h. His injury was caused by chain-saw trauma. Physical examination indicated that his general condition was optimal and his cardiopulmonary function was normal. The distal segments of the injured toe were mostly disconnected from the proximal side of the toe nail (**Figure 1A**), leaving the fracture ends exposed. Only the inner part was connected with the skin and the poor blood supply of the distal segments. X-ray photos demonstrated that the dis-

tal hallux phalanx was broken with the separation of fracture ends and bone defects (**Figure 1B**). According to the patient's injury history, his symptoms, signs and his auxiliary examination, distal open fractures of the right great toe with bone deficiency were diagnosed. In the emergency department, the affected limb was elevated and temporarily fixed following disinfection and bandaging of the wound. The incidence and severity of various symptoms, including swelling and pain were reduced. Subsequently, the patient was admitted to the department of trauma orthopedics, while ac-

tively finishing preoperative preparations for emergency surgery.

Surgery

Surgery was performed following spinal anesthesia. The patient was placed in the supine position and tourniquets were not used. A preoperative dose of 2 g of cefotiam was intravenously infused. Once satisfactory anesthesia was established, the wound was rinsed and general disinfection pads were used in the operative field. Initially, the wound was thoroughly irrigated and debrided without removing the nail. Subsequently, the self-made adjustable gradually-pressurized external fixation device was made and applied to acquire effective reduction and fixation of the fracture. A diagram showing the technique and the device is illustrated in **Figure 2**.

The specific intraoperative steps were as follows: Following debridement of the wound without tendon rupture, the fracture ends were adjusted in a parallel location and a 1.5 mm Kirschner wire was inserted along the axial direction. The wound was sutured and excellent alignment was acquired using C-arm fluoroscopy. The 1.5 mm Kirschner wire was subsequently inserted from the outside to the inside in the proximal hallux phalanx, taking care to avoid damage to the blood vessels and nerves on both sides of the injured toe. Both ends of

Self-made external device for the management of open fracture

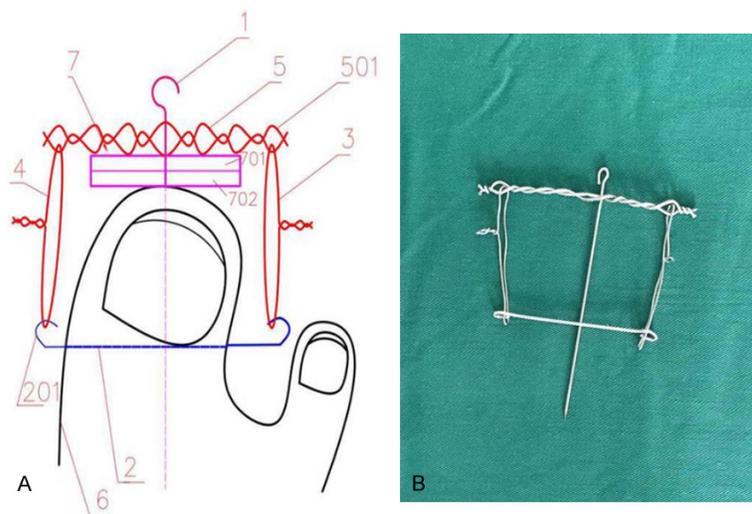


Figure 2. The schematic diagram of the self-made adjustable external fixation device. (1) Axial K-wire, (2) transverse K-wire, (3, 4) pressurized steel wire, (5) cross bar, (6) the distal hallux phalanx, (201, 501) auricular ring, (701) fastener, (702) rubber insert.



Figure 3. Postoperative wound and X-ray films (day 5). A. The wound was well healed postoperatively with no infection and necrosis, and the fracture ends were effectively fixed by the device with the exception of the slight shortening of the finger. B. AP and lateral radiographs of the right hallux following fixation demonstrating that the fracture was well-aligned.

the Kirschner wire were folded into the shape of the auricular ring. The rubber pad, button and the self-made twisted crossbar were sequentially inserted through the axial K-wire. The crossbar was established by 1.2 mm K-wires with both ends were prefabricated in the shape of an "ear", opposite to the ear ring of the proximal K-wire. A series of 0.8 mm steel wires were used to penetrate the four auricular rings. The rings were tightened moderately to form an external fixation device, while allowing the mon-

itoring of the blood supply of the distal great toe and their retention in case of compression.

Postoperative management

The affected limb was raised following operation and treated with the anti-inflammatory drug cefotiam that was administered at 2 g intravenously on day 2. Moreover, the anticoagulative drug enoxaparin (40 mg) was subcutaneously injected on day 1. In addition, the vasodilatory drug papaverine (30 mg) was injected intramuscularly on day 3. The dressing change of the wound was strengthened and the device was adjusted to increase pressure once every 3 days. The wound was well healed postoperatively with no infection and necrosis and the fracture ends were effectively fixed by the device with the exception of the slight shortening of the digit (**Figure 3A**). The fracture was well-aligned as determined by a postoperative X-ray examination (**Figure 3B**). The swelling and the peripheral circulation of the broken toe were closely observed and the patient was discharged from the hospital on the 7th day following operation. After discharge, the dressings were changed as required and the stitches were removed 2 weeks post-surgery without soft-tissue complications, such as infection and necrosis. The steel wires were initially tightened using the auricular structure and the rubber band was subsequently used to maintain a pressurized state by simultaneous observation of the blood supply of the injured toe and by launching of functional exercises of the other toes. The rehabilitation exercises were performed by encouraging the patient to take the initiative to exercise the flexion and the extension of the other toes. Subsequently, he was able to walk with

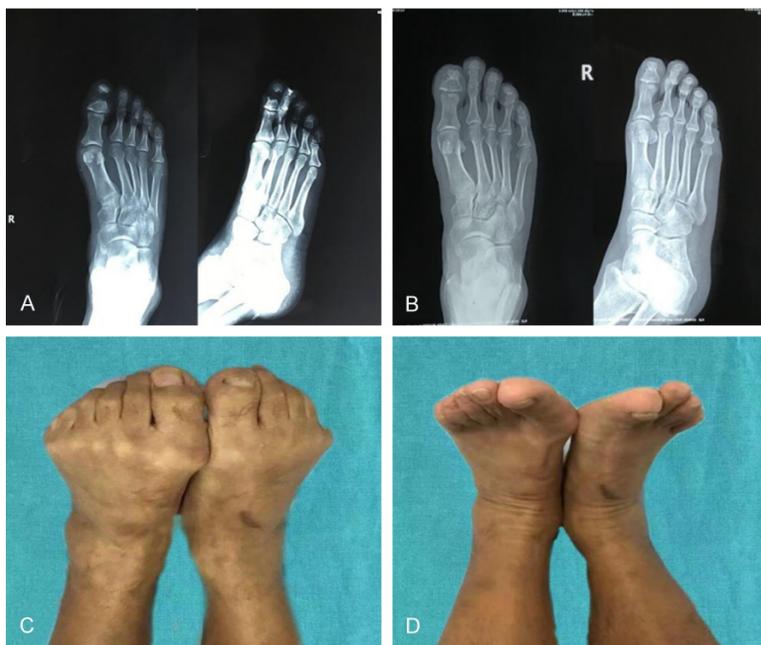


Figure 4. Postoperative recovery and follow-up results (all photos were from the same patient at 24 months postoperatively). A. AP radiography indicating that the fracture of the distal hallux phalanx with the separation of broken ends and bone defects. B. AP and lateral films indicating that the fracture was well healed without nonunion. C. The extension function between the uninjured side and the injured side. D. The flexion function between the un-healthy side and the healthy side.

crutches without any weight bearing on the affected toe when both swelling and pain of the affected limb were obviously subsided. The external fixation device and axial K-wire were routinely removed 6 weeks postoperatively. Subsequently, the flexion and extension function of the right great toe was strengthened and weight bearing was gradually increased. Finally, the correction of his limping gait was achieved and the patient returned to his normal daily activities. During follow-up, the complications delayed union, nonunion and re-fracture of the injured toe did not occur, while the appearance of the injured toe was slightly shorter (**Figure 3A**). The fracture was well healed without obvious angular and rotating malformations as determined by the 24-month postoperative X-ray examination (**Figure 4B**). The affected toe was functioning well, with fine appearance although it was shortened considerably. The recoveries of the extension and flexion of the injured toe were optimal (**Figure 4C, 4D**).

Discussion

Toe phalangeal fractures, caused by various trauma mechanisms, are common and account

for approximately 3.6-8% of injuries of the lower extremities [12, 13]. Among children, 5-13% of fractures occur in the foot and of these, fractures of the toes are the most common [14, 15]. The majority of fractures of the hallux occur at the distal phalanx and are a result of a direct crushing type of injury. Fractures between the 2nd and the 5th toe are generally of little consequence and can typically be treated successfully with conservative measures, whereas fractures of the hallux can lead to significant long-term pain and disability [14]. Unfortunately, the hallux is the most common toe that is injured, representing the greatest proportion of all toe phalangeal fractures (38-56%) [16, 17]. Open fractures without the hallux are mostly caused by high-energy injuries, whereas chain-saw damage exhibits low incidence

and causes major destruction, which is often accompanied by surrounding soft tissue injury and bone defects.

The injury, often involves the absence of soft tissue and bone and the blocking effect of the mutilated soft tissue and of the irregular section of the distal phalangeal bone. This inhibits the effective reshaping and placement of the fracture ends. According to previous studies [1, 18], it has been shown that fracture healing requires good mechanical environment, separation and rotation. Shear stress and other forces are not conducive to the stability and healing of the fractures, which require control. The debridement, reduction, axial K-wire fixation and progressive compression of our self-made external fixation as well as the contact area and the friction of the fracture ends were effectively increased, reducing the impact of the forces, such as separation, rotation and shear stress. Concomitantly, normal toes can continue to exercise under the broken toe, which is fixed by pressure application. This increases the blood circulation of the broken toe, which is beneficial to fracture healing. This method can potentially reduce the iatrogenic

injury of the distal segments under the premise of minimally invasive treatments, including primary debridement, reduction, axial fixation and suturing. Moreover, an auxiliary drug therapy is applied to increase the blood supply of the distal area as much as possible. Following observation of the optimal blood supply of the injured toe, the fracture ends were progressively subjected to axial compression by the self-made external device by gradually adjusting the steel wires on both sides. This maintained the compression effect of the fracture ends by the transverse Kirschner wires. The present case indicated that the self-made adjustable external fixation device could achieve progressive axial compression, maintain high stability of the fracture ends and lower the interference of the blood supply, which was beneficial to fracture healing and improved the early functional exercise of the toes. Finally it increased the recovery of load bearing function, thus rendering it an alternative approach for the complex injury.

The following advantages of the self-made adjustable external fixation device were generally analyzed and concluded: First of all, the device exhibited potent plasticity with reasonable design, simple construction, instant generation in the operation, and high practicability and ease of operation. Moreover, the device exhibited low cost and reduced learning curve. High stability could be efficiently acquired by the process of axial fixation and progressive compression, which could maintain the fracture ends in a stable, gradually-stressed state, thereby promoting fracture healing. In addition, the technique was a relatively minimally invasive operation with low trauma incidence and maximum blood supply protection. Its application can reduce the financial burden of patients as low costs of materials are used, and a simple removal of the device can be accomplished in the absence of anesthesia and hospitalization. This type of external fixation device exhibits certain shortcomings, mainly manifested in the following aspects: First of all, it is inconvenient to carry and secondly potential nail canal infection may be caused. In addition to this application, transarticular fixation of this method is detrimental to joint movement, notably in the early stage of functional exercises. Therefore, comminuted fractures and fractures involving joint surface are not highly recommended when using this device.

Conclusion

The self-made adjustable external fixation device of progressive compression is an alternative for the management of open fracture associated with bone absence of the distal phalanx of the hallux. The device is simple to manufacture with a low cost and practicality and is reliable in maintaining reduction and fixation. Moreover, it exhibits lower interference with distal blood supply and it can be further developed for future applications in the clinic.

Disclosure of conflict of interest

None.

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