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Treatment of distal metaphyseal tibia fractures using an external fixator in children

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Abstract

Introduction: Current treatment of pediatric distal metaphyseal tibial/fibular fractures is challenging due to poor skin and soft tissue coverage and limited blood supply to the distal tibia area in children. It remains unknown whether the SK combined external fixator (made by Double Medical Technology Inc., China) is effective for the treatment of distal metaphyseal tibia/fibula fractures in children.

Hypothesis: We hypothesized that SK combined external fixator could achieve satisfying outcomes for pediatric distal metaphyseal tibia/fibula fractures.

Patients and methods: A total of 19 pediatric patients with a median age of 6 years (range: 3.8–12.0 years), who had distal tibia/fibula metaphyseal fractures and attended our hospital between January 2017 and November 2017, were evaluated. All patients with tibia fracture had closed reduction and percutaneously fixed SK combined external fixators. Radiographs were taken at an average of every 4 weeks to evaluate the healing of the fracture. Complications were recorded, and the stability of the pin clamp and rod were also checked. Follow-up was conducted for up to 13 months. All patients provided informed consent for publication of the case.

Results: All patients achieved a satisfactory clinical outcome at the final follow-up. Weight-bearing exercises were started at post-operative 2 weeks. Bone union was obtained at 8 weeks post-operation on average. No delayed healing or nonunion was observed, although one case of pin site infection and three cases of pin clamp loosening occurred.

Discussion: Three-dimensional SK combined external fixators are light, easy to apply, minimally invasive, and result in low rates of complications. They provide excellent stability for pediatric distal tibia/fibula metaphyseal fractures.

Level of evidence: IV.

Abbreviations: CEF = combined external fixator, MUDEF = method for the unified designation of external fixation, SK = Stryker.

Keywords: combined external fixator, fracture, metaphysis, pediatric, tibia/Fibula

1. Introduction

Skeletal development in children is rapid with strong plasticity. Most pediatric tibia/fibula fractures can be treated with a long-leg cast, which achieves good outcomes after 6 to 8 weeks.[1] However, distal tibia skin and soft tissue coverage is relatively poor in children, and the blood supply to the bone is not abundant. Furthermore, fractures at this area of the bone are usually complicated with distal fibula fractures, which significantly affects the stability of the ankle joint on that side.[2] Traditional treatment options for distal metaphyseal tibia fractures are antegrade insertion of elastic intramedullary nails, open reduction plate fixation, and external fixator fixation.[3–5] Recently, percutaneous minimally invasive compression locking plates have been gradually popularized, but these have been mostly applied for older children. The elastic intramedullary nail fixation of metaphyseal fixation provides limited strength to maintain the longitudinal axis of the fracture.[6,7] Elastic stable intramedullary nails are mostly used for lower leg fractures, but are rarely used in metaphyseal fractures, and the insertion of an intramedullary nail into the cancellous bone cannot help control the rotation and angulation, which needs the support of a cylinder cast, post-operatively.[8]

The SK combined external fixator is a three-dimensional external fixator system, with individual parts that can be built into multiple configurations, as needed. Furthermore, the procedure is simple to use. The rod is made of carbon fibers, and the clamps are made of aluminum, making the whole external fixator more radiolucent and light to handle. This external fixator is recommended when performing a closed reduction. We hypothesize that external fixation alleviates post-operative discomfort and pain, shortens hospital stay, allows early weight bearing, and secondary anesthesia for hardware removal can be avoided. SK combined external fixators have become an potential choice in the management of pediatric complete distal tibial fractures.

However, it remains unknown whether the SK combined external fixator is effective for the treatment of distal metaphyseal lower leg fractures. The aim of the present study was to evaluate the clinical outcomes of the use of this combined external fixator for treating distal metaphyseal lower leg fractures.

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Table 1

Patient characteristics (n = 19).

	Median (range)
Age	6 (3.8–12.0)
Gender	
Male (n, %)	15, 79%
Female (n, %)	4, 21%
Mechanism of injury	
Falling injuries	2
Sports injuries	5
Motor vehicle accident	12

Table 2

Radiographic classification.

Details of the radiographic measurements and treatment	Number of patients
Type of soft tissue injury (according to Tscherne)	
Grade 0	6
Grade 1	8
Grade 2	1
Grade 3	4
Type of fracture (AO)	
M/3	19
Method of fixation	
A	9
B	10

Table 3

Clinical outcomes and complications of the 19 patients after the external fixation treatment.

Clinical outcome measurements	Median (range)
Surgical time (min)	32 (25–60)
Intraoperative blood loss (mL)	9 (5–30)
Hospital stay (day)	7 (5–16)
Weight training time (day)	17 (7–30)
Fracture healing time (day)	84 (60–90)
Functional score of joint (LKS)	98 (95–100)
Fixation removal time (day)	45 (45–60)
Complication	
Pin site infection	1
Secondary bone shift	1

2. Patients and methods

2.1. General characteristics

A total of 19 pediatric patients (15 male and 4 female patients) with an median age of 6 years (range: 3.8–12.0 years) (Table 1), who had sustained complete metaphyseal fractures of the distal lower leg between January 2017 and November 2017, were evaluated. The median weight of patients was 31 kg (range: 20.0–58.5 kg). All patients had sustained closed fractures classified grade 0–3 according to Tscherne,[1] according to the AO metaphyseal fracture type M/3 complete fracture[9] (Table 2). Failed closed reduction was indicated by a fracture alignment of $<60\%$, a valgus or varus of $>5°$, anterior or posterior angulation of $>10°$.

All surgeries were performed by the same group of surgeons at Suzhou University Affiliated Children's Hospital. Follow-ups were conducted for up to 13 months. The clinical healing of the fracture was evaluated, and the complications were recorded (Table 3). Ethical committee approval. (Date: December 1, 2016. Number: 2016029.)

2.2. Preoperative planning

Based on the patient's age, body weight, and distance between the fracture line and distal tibial growth plate, different combinations of external fixator constructs were simulated using the same configuration based on the principles of Ilizarov. As illustrated in Figure 1A, the tibia plane was divided into eight equal parts from the level of the tibial tubercle (level I) to the level of the tibiofibular syndesmosis distal end (level VIII).[10] The methods for the construction of the model were as follows: Method A: The bi-planar parallel pin was placed in the proximal fracture fragment, and the multi-directional and single-plane pins were

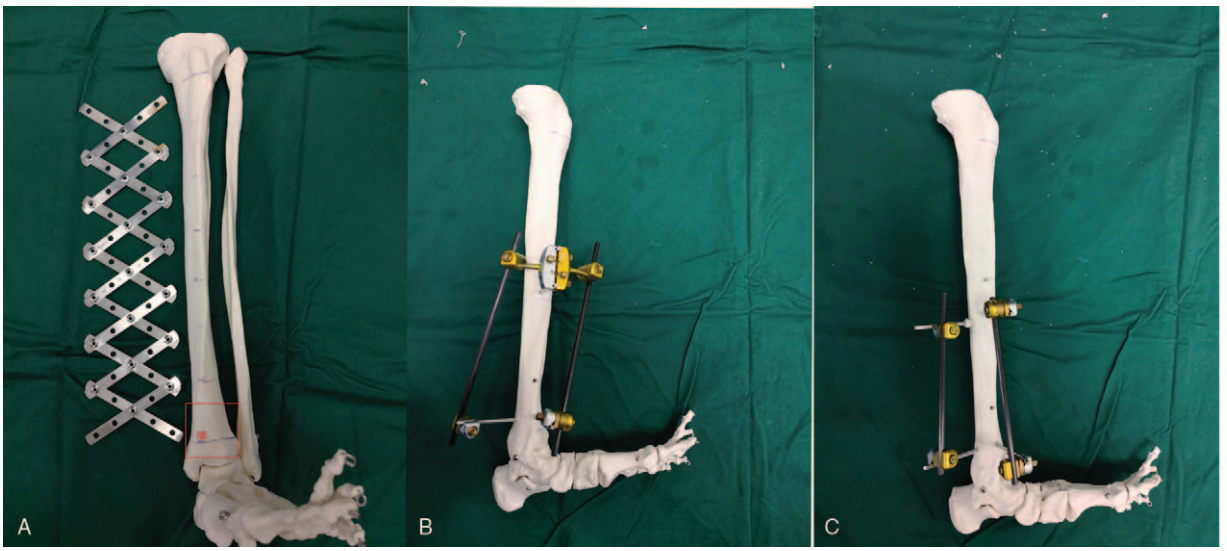

Figure 1. (A) The tibia shaft bone can be divided into eight segments. (B) Method A: The double plane parallel pin used for the proximal bone, and single plane multi-channel individual pin for the distal bone. (C) Method B: The single-plane multi-channel individual pins used for both the distal and proximal bone.

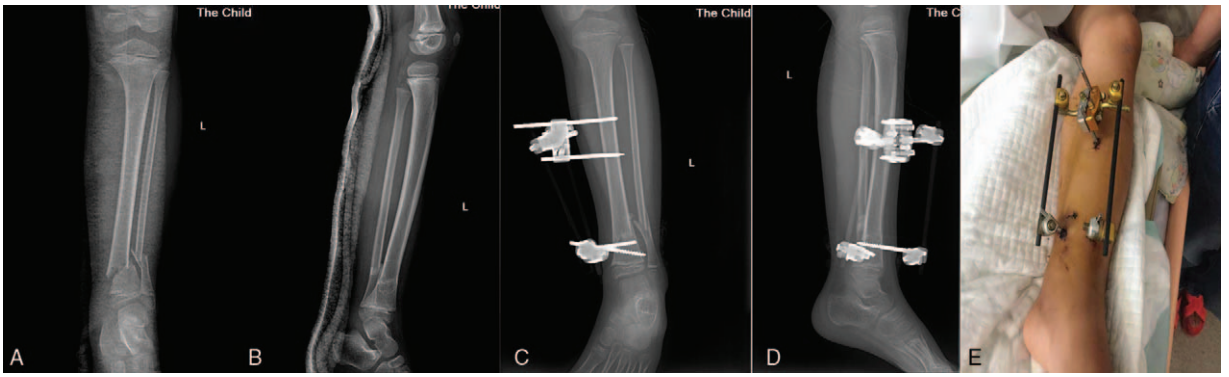

Figure 2. Typical Case 1. Method A was applied in a 6-year-old boy, in which the pins were placed in proximal parallel planes and single-plane dual tunnels in the distal tibia. The pre-operative X-ray film from the lateral view of both sides (A and B) during surgery. The post-operative X-ray film from the lateral view of both sides (C and D). The appearance of the leg after the operation (E).

placed in the distal fracture fragment (Fig. 1B). Method B: Both single-plane multi-channel single pins were placed for both the proximal and distal fracture fragments (Fig. 1C).

2.3. Closed reduction and internal fixation

Closed reduction was performed for all patients under general anesthesia, and malrotation and shortening were corrected. The SK combined external fixator was purchased from Double Medical Technology Inc., China.

If the fracture line was located at the junction of the tibial shaft and metaphyseal bone, the distance between the fracture line, and epiphyseal line of the distal tibia was sufficient. However, since most of the metaphyseal fractures had a relatively shorter distance between the fracture line and distal tibial plateau, parallel pins could not be placed. Therefore, method B was adopted. Method A was applied when the fracture line was transverse, or short oblique. Method B was used for cases with long oblique fracture line. According to the age and weight of the patient, 4.0-mm or 5.0-mm half-pins were used, and a 2.5-mm Kirschner wire was used instead of a drill-bit in the tibia, in order to penetrate through the cortical bone. The self-tapping half-pin was used to follow the path of the Kirschner wire to penetrate through both cortices of the tibia.

In most of the cases, double pin fixation of the proximal and distal modules was used, and several half-pins were added in older children who had larger body weight. The half-pin was placed as close as possible to the plane of fracture, and pin clamps and carbon rods were placed as close as possible to the skin, in order to improve the rigidity of external fixation. However, a certain distance (~1.5–2.0 cm) was maintained to avoid soft tissue compression due to swelling.

2.4. Intraoperative and post-operative treatment and evaluation

The half-pin tunnels were covered with sterile dressings during the surgery. If there was no obvious exudation after the operation, the dressing was changed weekly. Patients were encouraged to perform flexion and extension of the knee and ankle joints from post-operative second day, and weight-bearing exercises were encouraged from post-operative 2 weeks. Radiographs were reviewed every 4 weeks on average, in order to evaluate the fracture healing, and check the stability of the pin clamp and rods. After fracture union, external fixation was removed and replaced with a brace, and ambulation with full weight bearing was allowed.

Patients were evaluated using the following indexes: surgical time, intraoperative blood loss, hospital stay, weight training time, bone healing time, joint function assessment, and time interval until removal of external fixation.

3. Results

The demographic characteristics of all patients are summarized in Table 1. All tibia fractures were manually reduced under general anesthesia and percutaneously stabilized with the SK external fixator. Method A was used in 9 patients (some representative patients are presented in Fig. 2), and Method B was used in 10 patients (these typical patients are presented in Fig. 3). The average operation time was 32 min, the average blood loss during surgery was 9 mL, and the mean length of hospital stay was 7 days.

The post-operative X-ray results suggested that the axial tibial shaft alignment was >85%, and both valgus and varus angulation were <5°. Furthermore, the anterior and posterior angulation angles were <5°, the median weight training time was 17 days, and the median fracture healing time was 84 days.

A case of pin site infection occurred within post-operative 2 weeks. The wound was disinfected with a nonalcoholic disinfectant, and the infection healed. In addition, in three children loose clamps were noted, but no shortening, angulation, or malrotation occurred. The external fixator was removed median 45 days after the operation, and the lower leg was supported with a brace. Lower limb function recovery was satisfactory when the functional score of the joint was >97.

4. Discussion

At present, there is no consensus on the management of instable lower leg fracture in children.[11] Most pediatric tibia fractures can be treated with closed reduction and long-leg cast for 6 to 8 weeks to achieve satisfactory clinical outcomes. Severely unstable fractures, progressive varus or valgus deformities, open fractures, severe soft tissue injuries, including degloving injuries, osteofascial compartment syndrome, and fractures in polytraumatized children require surgical stabilization.[11] In the present study, we included 19 pediatric patients with distal tibia/fibula metaphyseal

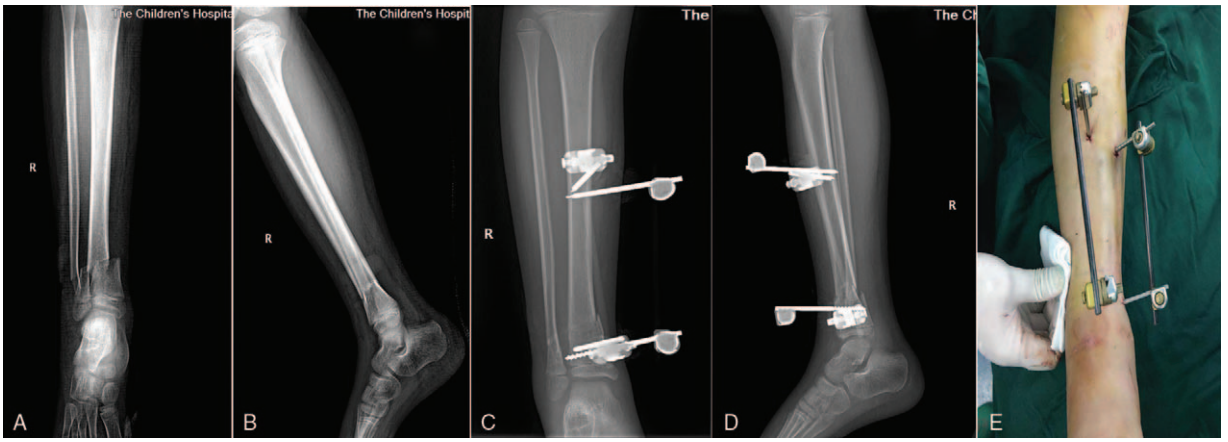

Figure 3. Typical Case 2. Method B was performed in a 8-year-old boy. Single-plane dual channel individual pins were placed both in the distal and proximal ends. The pre-operative X-ray film from lateral view of both sides (A and B) during surgery. The post-operative X-ray film from the lateral view of both sides (C and D). The appearance of the leg after the operation (E).

fractures treated with closed reduction. We stabilized the fractures with SK combined external fixators. We retrospectively reviewed medical charts of patients. All patients obtained satisfactory clinical outcomes, and no delayed healing or nonunion was observed.

The most commonly used external fixators was the monolateral fixator. The single-arm external fixator is simple, lightweight, and easy to use. However, due to the single-channel pin placement, its ability to control rotation and angulation is poor.

Re-fractures and leg-length discrepancies are the major complications observed in patients treated with external fixators.[12,13] However, this is not the case for the present study, and this could be attributed to the advantages of the application of the SK combined external fixator. This fixator is a three-dimensional external stabilization system, which can be assembled in a variety of configurations through a modular assembly. Through multi-faceted multi-channel pin insertion, the ability of the Ilizarov ringed fixator to control rotation and angulation can be achieved. Due to the use of carbon fiber rods and aluminum components, the X-ray imaging of the fracture site is improved, and the weight of the fixator is reduced, which is as simple and light as a monolateral fixator. Closed-reduction techniques were used during the operation, and four half-pins were inserted for fixation.

The present study has limitations. First, this was a retrospective case study with a relatively small sample size. All patients were treated by the same group of surgeons using a consistent surgical technique. Second, some patients had relatively short follow-up periods due to various reasons, such as loss of contact. Prospective studies with a large sample size and control group are warranted to confirm these findings.

5. Conclusion

In summary, the SK external fixator has advantages of convenient operation, minimally invasive stabilization, minimal blood loss, low rate of complications, light weight, and avoidance of secondary surgery. Furthermore, it is effective and safe for the treatment of distal tibial metaphyseal fractures in children.

Author contributions

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References

[1] Xu YL, Shen KY. Minimally invasive treatment in border region severe fracture between diaphysis and metaphysic of distal tibia in children. China J Surg 2016;37:69–72.
[2] Zuo YM, Zhang HL. Minimally invasive percutaneous locking compression plate internal fixation in the treatment of metaphyseal fracture of distal tibia in children. China J Pediatr Surg 2010;31:357–60.
[3] Masquijo JJ. Percutaneous plating of distal tibial fractures in children and adolescents. J Pediatr Orthop B 2014;23:207–11.
[4] Perren SM. Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: choosing a new balance between stability and biology. J Bone Joint Surg Br 2002;84:1093–110.
[5] Zuo YM, Zhang HL, Wang YG. Minimally invasive percutaneous locking compression plate fixation for the treatment of school-age children of metaphyseal fracture of distal tibial. Chin J Pediatric Surg 2010;31:357–60.
[6] Labronici PJ, Franco JS, Silva AFD, et al. Treatment of distal fractures of the tibia. Acta Ortopédica Brasileira 2009;17:40–5.
[7] Vallier HA, Le TT, Bedi A. Radiographic and clinical comparisons of distal tibia shaft fractures (4 to 11 cm proximal to the plafond): plating versus intramedullary nailing. J Orthop Trauma 2008;22:307–11.
[8] Moran. AO principles of fracture management.Rüedi TP, Buckley RE, and Moran (Eds). Thieme (Stuttgart); 2007. ISSN: 9781588905567.
[9] Solomin LN. The basic principles of external skeletal fixation using the Ilizarov device. Solomin LN (Ed). Springer Science & Business Media; September 2008.
[10] Ramasubbu RA, Ramasubbu BM. Surgical stabilization for open tibial fractures in children: external fixation or elastic stable intramedullary nail—which method is optimal? Indian J Orthop 2016;50:455–63.
[11] Tolo VT. External skeletal fixation in children's fractures. J Pediatr Orthop 1983;3:435–42.
[12] Evanoff M, Strong ML, MacIntosh R. External fixation maintained until fracture consolidation in the skeletally immature. J Pediatr Orthop 1993;13:98–101.
[13] Gordon JE, Schoenecker PL, Oda JE, et al. A comparison of monolateral and circular external fixation of unstable diaphyseal tibial fractures in children. J Pediatr Orthop B 2003;12:338–45.