External fixation and Kirschner wires in the treatment of paediatric displaced supracondylar femur fractures

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Abstract

Purpose Kirschner-wire fixation (KF) and external fixation (EF) for the treatment of displaced supracondylar femur fractures (SFFs) were demonstrated respectively in previous reports. However, there is no paucity of convincing information on better treatment options for children. The aim of this study was to show results of KF and EF in the treatment of paediatric SFFs according to clinical and radiological outcome.

Methods A retrospective analysis including 22 displaced closed SFFs was performed. A total of 12 patients were treated with KF, other ten patients were treated with EF. All patients were followed up for at least 24 months. Demographic data, surgical outcomes and postoperative knee function using the Knee Society Score (KSS) scale were evaluated in this research.

Results The patients in the KF group were significantly younger than in the EF group (p < 0.001). The KF group had superiority in operative time (p = 0.001), blood loss (p = 0.027) and length of hospital stay (p = 0.001). Clinical healing outcome did not differ between the two groups. The KF group achieved radiological union in a shorter period (p < 0.001), with a better range of movement (ROM) and KSS postoperative score.

Conclusion Both KF and EF can achieve excellent outcomes for paediatric SFFs. KF has many advantages in younger children.

Level of Evidence: IV

Cite this article: Li J, Yue C, Wang H-Q, Guo X, Chen K, Ma J, Wang J, Tang X. External fixation and Kirschner wires in the treatment of paediatric displaced supracondylar femur fractures. J Child Orthop 2020;14:293-298. DOI: 10.1302/1863-2548.14.200050

Keywords: paediatric; displaced supracondylar femur fractures; percutaneous fixation; external fixation

Introduction

Supracondylar femur fractures (SFFs) are rare injuries,¹,² with an overall incidence rate of over 8.7/100 000 per year.³ A population-based epidemiological study identified the peak of SFF frequency as two specific groups of individuals, adolescents and elderly patients > 50 years of age.³ The prevalence of SFFs is reported as 0.4% among all fractures.³ Notably, SFFs still account for 12% of femur fractures in paediatric patients.⁴ Common traumatic aetiology is ascribed to low energy injuries such as falling from a height.³

The optimal surgical treatment options remain unclear for paediatric displaced SFFs. It is well established that multiple factors should be considered, including patients’ age, affected site, fracture types and preoperative complications for successful treatment. Despite Parikh et al⁴ reporting a high complication rate (38%), they advocated that elastic nailing should be a significant option for paediatric SFFs, given its advantages, such as minimally invasive hallmarks with shorter hospital stay and without the necessity of postoperative rigid mobilization or plaster cast. Meanwhile, antegrade and retrograde intramedullary nails have become more and more popular with advantages such as limited tissue exposure and minimal intraoperative bleeding. However, these implants may not be suitable for SFFs in children.⁵,⁶ External fixation (EF) uses less invasive techniques and provides adequate and rapid stability.⁵,⁷,⁸ Another common treatment option is Kirschner wire (K-wire) cross pinning along with closed reduction. A number of studies have reported that the
K-wire can achieve good functional and aesthetic outcomes and consequently is identified as one of the best methods.\(^9\)

Moreover, an increased tendency has been reported for surgical treatment in children’s fractures.\(^10\) This study aims to show the clinical outcomes of EF and K-wire fixation (KF) in the treatment of paediatric displaced SFFs and to analyze any possible complications.

**Patients and methods**

Consecutive paediatric patients aged < 14 years old with SFFs were retrospectively included from the authors’ hospital between 1st June 2015 and 31st August 2017. All patients got EF or KF treatment for SFFs and were followed up for at least 24 months. Their medical charts were reviewed for collecting relevant data. SFF was defined as a femoral fracture spanning a distance no longer than the widest part of the growth plate from the fracture’s centre to the knee joint according to the Arbeitsgemeinschaft für Osteosynthesefragen (AO) Paediatric Comprehensive Classification of Long Bone Fractures.\(^11\) The fracture line should not involve the growth plate and be at least 2 cm far from it. Exclusion criteria were age above 14 years, follow-up time < 24 months, previous fractures of the femur, fracture associated with nerve or vessels injury, open fracture and pathological fracture. The ethics committee of authors’ hospital approved the study. All guardians of these patients signed written informed consent. An experienced surgeon performed all operations.

During the observational period, the baseline details of patients were recorded, including age, sex, height, weight, AO/Orthopaedic Trauma Association (OTA) classification,\(^12\) cause of fracture and the surgical technique. Body mass index (BMI) was then calculated. In addition, operating time, intraoperative blood loss and days in hospital were collected. Clinical outcomes were collected in the follow-up, including radiological and clinical union time, complications, knee range of movement (ROM) and functional scores.

SFFs were diagnosed and defined by the AO/OTA classification according to anteroposterior and lateral radiograph or CT scan. The presence of periosteal incorporation and remodelling on medical imaging was the radiological standard of fracture healing. Clinical union were identified when patients are able to walk without pain, stiffness or other discomforts at the fracture site. No progression of healing within six months from surgery was regarded as nonunion.\(^13\) Delayed union was defined as healing that was still occurring but exceeded six months.\(^14\) Malunion was considered as the situation where healing occurs but the healed bone has angular deformity, translation or rotational alignment that requires surgical correction.\(^15\) Complications including infection, nerve and vascular injury, delayed union or nonunion, physeal arrest and angular deformity degree were also recorded. The postoperative ROM was evaluated with a manual goniometer and knee function was assessed using the postoperative Knee Society Score (KSS) scale.\(^16\)

**Surgical technique**

The patient was usually placed in the supine position after general anaesthesia with muscle relaxation. Reduction was performed by manual traction when flexion in anteriorly displaced fractures and extension in posteriorly displaced fractures had been prepared. In the K-wire group, smooth K-wires with a diameter of 1.5 mm or 2.0 mm were then applied in percutaneous cross-pinning via the epicondyles under image intensifier control (Fig. 1). In the EF group, fracture surfaces were set as close or minimal open incision if needed and fixed using pins in 4.5 mm to 6.5mm. One half or three-quarter ring with two pins was used at the femoral condylar area distal to fracture site while another half or three-quarter ring with two pins was applied at the area proximal to fracture site (Fig. 2). The pins should not be placed in the tibia or the distal femoral

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**Fig. 1** a) Radiological findings of a 2.7-year-old girl with a displaced supracondylar femur fracture; b) anteroposterior radiographs postoperatively show fracture treated with K-wire fixation and closed reduction; c) anteroposterior radiographs obtained three months after surgery; d) anteroposterior radiographs obtained 12 months after surgery.
epiphysis. The two rings were assembled with two connecting rods across the area of fracture after reduction.

After fixation, knee joint flexibility from full extension to full flexion and stability of fracture site were carefully checked. Patients were discharged if their body temperature and wound condition allowed. Patients’ caregivers learned how to perform pin care daily. Standing anteroposterior and lateral radiographs of the operated side were taken at four or six weeks, 12 weeks, 24 weeks, 12 months and 24 months postoperatively. When the fracture gap was not visible in three of the four cortices, the fracture stability was assessed. Full-term functional exercise was then allowed and weight-bearing followed.

Statistical analysis

Appropriate statistical methods were used for descriptive statistics. Continuous data were compared using an independent sample t-test and categorical variables were tested by Fisher’s exact test except for sex, which was evaluated using the Pearson Chi-squared test. All statistical tests were two-tailed. Statistical analysis was performed using the IBM SPSS statistics version 20 software (SPSS Inc., Chicago, Illinois).

Results

In all, 32 patients with this injury were treated during the observational period, but two fractures were associated with nerve or vessel injury, there was one pathological fracture, two were lost to follow-up and five were open fractures; all of these were excluded. A total of 22 patients were enrolled in the study. According to the AO/OTA classification, 14 patients were classified as type 33A1 and eight patients as type 33A2. Ten patients in EF group were stabilized with EF, and 12 patients in KF group were treated with K-wire after close reduction. There were no significant differences in sex, AO/OTA classification or cause of fracture (Table 1). All fractures got closed reduction. No patient had
infection, nerve or vascular injury after surgery. All K-wires and external fixations were removed after radiological evaluation at four to six weeks postoperatively. There was no delayed union or nonunion but malunion and growth disturbance were observed during the follow-up.

There was a significant difference in age, operating time, intraoperative bleeding and length of hospital stay (Tables 1 and 2). Patients of the KF group were younger than patients of the EF group (2.5 years versus 7.5 years; \( p < 0.001 \)). In the follow-up results, the KF group achieved radiological union earlier than the EF group (8.3 weeks versus 11.8 weeks; \( p < 0.001 \)) (Table 2), and knee flexion angle was also larger than in the EF group (134.4° versus 125.0°; \( p < 0.001 \)) (Table 2). As for the mean KSS score, the KF group all got full scores while the scores of the EF group were slightly lower (98.7 ± 1.8) (Table 2). In addition, there is no significant difference in the perioperative stay, clinical union time, length discrepancy of the lower limbs, the angle of knee extension and the valgus deformity degrees between two groups.

**Discussion**

The incidence of supracondylar fractures of the femur is relatively low, making up only 12% of paediatric femur fractures. Paediatric displaced SFFs are a challenge for treatment, due to displacement and instability of the metaphyseal fragments caused by the unbalanced pull of the gastrocnemius or adductor muscle. Additionally, the actively growing ossification centre of the distal femur makes recovery more difficult without complications in children. Traditional open surgery with suprphyseal plating could not be performed on all these paediatric patients with displaced SFFs, considering that damage to the physs may lead to early closure and other deformities. The fracture pattern may play a role in the treatment choice in some way, but multiple factors including patient age, BMI etc., should be considered. The optimal approach ought to ensure anatomical normality such as alignment and ROM, be affordable for patients and their family and get satisfactory to excellent functional outcomes with minimal complications and invasive operation. The patient could be positioned on the operative table in a prone position with the ipsilateral hip overextended and a radiolucent bag under the lifted knee to facilitate either traction or image intensifier control or percutaneous K-wiring of the fracture (this depends on the surgeon’s preference). A traction table also may be used to obtain an easier and better fracture reduction if needed.

Owing to their ease of use and the versatility, EF and percutaneous pinning play a more and more important role in the management of paediatric injuries. Arazi et al suggested that EF has considerable advantages such as short operating time, low blood loss, minimal surgical exposure and greater mechanical stability. There have been case series that have reported good to excellent outcomes following this form of treatment in SFFs. However, prolonged hospital stay, loss of ROM and infections in the EF have been highlighted by advocates of other alternative treatments. The result of this research showed more blood loss, longer operating time and longer hospital stay in the EF group compared with the KF group.

Percutaneous cross pinning using K-wires was recommended by some researchers as a less invasive method of securing reduction that ensures good functional and radiological results in SFFs. But Smith et al argued that K-wires must cross the growth plate or pass intra-articular to achieve stable fixation, risking damage to the femoral vessels medially and the growth plate as well as septic arthritis. In this research, the extra-articular epicondyles were used as penetration points and only K-wires of 1.5 mm to 2.0 mm in diameter were used. These pins only cross approximately 1% of the growth plate, thus the destruction is incapable of causing permanent growth dis-
turbulence according to an experimental study.\textsuperscript{19} Although epiphyseal injury was controlled, loss of ROM for flexion and valgus deformity have been reported in KF.\textsuperscript{17} In this study, excellent results were reported in the KF group and the EF group. The EF group had a mean ROM for flexion of 10° less compared with the KF group. As to the union time, our study demonstrated no difference in the time of clinical union between the EF and KF groups, however, the radiological union time of the KF group was 3.9 weeks less compared with the EF group. But it should be noticed that this superiority may be partly attributed to the younger population of the KF group and their greater healing potential. With a shorter healing process, patients in the KF group passed the radiograph evaluation earlier than those in the EF group and then had their pins removed to start functional rehabilitation. Full-term functional exercise in the early stage allowed patients to get better knee function without stiffness and deformity.\textsuperscript{21}

Lack of randomization is a limitation of this retrospective study. The crossed K-wires were more acceptable for younger children, while an external fixator was better for the elder fractures in this research. The baseline level between the two groups was insufficiently controlled.\textsuperscript{21} However, the data and outcome in this research were still worth collecting and gave many valuable insights for these two surgical techniques.

**Conclusion**

This study demonstrated that paediatric displaced SFFS can be treated with KF and EF, both of which had good outcomes in function and radiography. Compared with EF, KF has advantages in younger children less than four years old.

Received 14 March 2020; accepted after revision 5 June 2020.

**COMPLIANCE WITH ETHICAL STANDARDS**

**FUNDING STATEMENT**

This study was supported by the National Natural Science Foundation of China in data collection and cases follow-up. (NNSFC grant 81470100 to X.T. and 81572182 to HQ.W).

**OA LICENCE TEXT**

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**ETHICAL STATEMENT**

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology (IORG No: IORG0003571) gave a final approval for this study.

**Informed consent:** Although the data were collected anonymized and centrally, all guardians of patients signed written informed consent for participation.

**ICMJE CONFLICT OF INTEREST STATEMENT**

None declared.

**ACKNOWLEDGEMENTS**

Yiqiang Li from Guangzhou Women and Children’s Medical Center performed statistical analysis.

**AUTHOR CONTRIBUTIONS**

JL: Responsible for literature search, Study design, Drafting the manuscript.
CY: Drafting the manuscript, Finalized the manuscript.
H-QW: Finalized the manuscript.
XG: Involved in data collection and follow-up assessments.
KC: Involved in data collection and follow-up assessments
JM: Involved in data collection and follow-up assessments
JW: Involved in data collection and follow-up assessments
XT: Involved in data collection and follow-up assessments, Responsible for literature search, Study design, Finalized the manuscript.

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