

Research Article

External fixation in the treatment of displaced supracondylar femoral fracture in children: A retrospective case series

Jin Li^{1*} , Kailei Chen^{2*} , Jiewen Ma² , Xikai Guo² , Changjie Yue² , Saroj Rai³ , Xin Tang¹ ¹Department of Orthopaedic Surgery, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China²Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China³Department of Orthopaedics and Trauma Surgery, National Academy of Medical Sciences, Mahankal, Kathmandu, Nepal

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ORCID iDs of the authors:

J.L. 0000-0003-0610-2991;

K.C. 0000-0001-8086-1449;

J.M. 0000-0003-2234-478X;

X.G. 0000-0001-5776-910X;

C.Y. 0000-0003-0665-5721;

S.R. 0000-0001-6896-3928;

X.T. 0000-0002-6860-6530.

ABSTRACT

Objective: The aim of this study was to evaluate the clinical and radiological outcomes and complications of external fixation use in the treatment of children with displaced supracondylar femoral fractures..**Methods:** In this retrospective study, 14 children (6 boys, 8 girls; mean age = 7.3 years; age range = 3.9 – 10.3 years) who underwent external fixation for the treatment of a displaced supracondylar femoral fracture from 2010 to 2017 were included. Their medical records were reviewed for general information and surgery details. Postoperative information, such as time to radiographic union, time to regain walking ability, Knee Society Scores (KSS) postoperative score, and KSS functional score were collected. Radiographic images were examined for the measurement of leg length discrepancy and valgus deformity.**Results:** The mean follow up was 34 (range = 24–50) months. The mean time to radiographic union was 12.3 (range = 10–16) weeks, and the mean time to regain walking ability was 11.8 (range = 11–13) weeks. Leg length discrepancies were all less than 0.8 cm, and valgus deformity was all limited in 10°. The mean KSS postoperative score was 97.5 (range = 93–100), and the mean KSS functional score was 97.1 (range = 90–100). None of the patients exhibited functional deficiency. Neither deep infection nor refracture was detected postoperatively.**Conclusion:** External fixation seems to be an acceptable alternative modality for treating displaced supracondylar femoral fractures in children, with favorable clinical and radiological outcomes as well as a low complication rate.**Level of Evidence:** Level IV, Therapeutic Study

Introduction

Supracondylar Fracture of the Femur (SFF) is uncommon in children; however, it is usually associated with complications, such as limb length discrepancy and severe angular deformity.^{1,2} Smith et al. reported that supracondylar femoral fracture accounts for 12% of femur fracture in children, and half of them are displaced.² Treatment of undisplaced SFF is not complex.³ However, there is still no consensus regarding the management of displaced SFF in children.⁴ Some unique characteristics make this type of fracture unstable.^{1,4} Nonsurgical treatment was considered the standard treatment method for pediatric fractures traditionally, but the excellent bone remodeling even in children does not always correct residual deformity. The short distal metaphyseal fragment and continuous pull of the fragments by the gastrocnemius and adductor muscles make the fragment displaced, making nonsurgical treatment failure. Surgical techniques, including plate fixation, percutaneous pinning, and elastic nailing, are described in the literature. But, they have limitations such as injuring physis, insufficient stability for obese children, and complex procedure requiring experienced surgeons.^{5–10}

External fixation is a widely used treatment for femoral fracture in adult.¹¹ The advantages of external fixation lie in a relatively easy procedure and short learning curves.¹² It is also practical for older children with higher weight,^{10,12} but there was no consensus on the utilization of external fixation for SFF in children. This retrospective study aims to figure out the surgical outcomes, including union rates, complication incidence, recovery score, limb length discrepancy, and deformity degree of external fixation in the treatment of supracondylar fracture of the femur in children.

Materials and Methods

From June 2010 to August 2017, pediatric patients with supracondylar femoral fractures treated in the authors' institution were reviewed in this study. The inclusion criteria were: 1) supracondylar femoral fracture confirmed on AP and lateral radiographic images, 2) treated with external fixation, and 3) followed up for 2 years or more. Supracondylar femoral fracture is defined as the fracture located at the square area where side length equals the widest part of the distal physis, extending from the epiphysis to proximal metaphysis.¹³ The exclusion criteria were: 1) patients with congenital diseases, 2) pathological fracture, 3) incomplete medical records, and 4) follow-up of less than 2 years.

*These authors contributed equally to this work.

Corresponding Author:

Xin Tang

dr_xintang@hust.edu.cn



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We applied the AO hybrid frame biplanar external fixators in all the patients. All the surgeries were performed under general anesthesia and muscle relaxation without the use of a pneumatic tourniquet. The patient was positioned in the supine position, and the surgical site was painted and draped. Fractures were reduced by manual traction under the guidance of an image intensifier. Posteriorly displaced fracture was reduced by extension, and anteriorly displaced fracture was reduced by flexion. Shortening was reduced first, followed by angular and lateral displacements, and rotation was corrected at last. In case of open fractures, thorough debridement was performed initially.

Under fluoroscopy guidance, Schanz pins (3.5-5.0 mm) were applied from the anterolateral aspect of the femur along the safe zone, avoiding injury to the neurovascular structure. The first proximal-inferior pin was inserted 2-3 cm proximal to the fracture line, while the second proximal-superior pin was inserted to the shaft of the femur proximally along the same plane. The distal-proximal pin was inserted close to the fracture fragment, while the distal-inferior pin was inserted about 2-3 cm to the epiphysis. Insertion of the pins too posterolaterally or too proximally should be avoided. After the insertion of the pins, a rod was held with the clamp when the fracture was acceptably reduced without affecting knee Range of Motion (ROM).

Patients or patient's caregivers were taught about pin care. Physiotherapy, including quadriceps strengthening exercise, started the next day, and knee ROM was started after 3-5 days postoperatively. Patients were encouraged to stand without extra aid at 6-8 weeks. When radiographic evidence of union was observed, and patients could walk by themselves without any pain, the external fixators would be removed. After the removal of external fixators, children were encouraged to go to school.

The general information of the patients, including age, gender, height, weight, injured limb, Arbeitsgemeinschaft für Osteosynthesefragen (AO)/Orthopaedic Trauma Association (OTA) classification,¹³ fracture type (transverse, oblique, comminution), time to union, limb length discrepancy and valgus deformity, were collected through the medical record system of authors' institution. Radiographic union was symbolized by the disappearance of fracture line and bone callus formation. Limb length discrepancy and valgus deformity were measured on radiographic images. Knee Society Score (KSS) postoperative score and KSS functional score were evaluated at the last follow-up.¹⁴ This retrospective research was approved by the author's IRB institution (IORG No: IORG0003571). Each patient's parents were informed about the treatment protocol and signed consents.

Results

Fourteen patients diagnosed with supracondylar femoral fractures and treated with external fixators, including 6 males and 8 females,

were included in the study. Their general information is shown in Table 1. The age of the patients ranged from 3.9 to 10.3 years (average 7.3). There were 7 fractures in the left limb and the other 7 in the right. Five of them had open and 9 had closed fractures. The causes of injury included motor vehicle accidents for 7, falls from elevated height for 6 and other reasons for 1. According to AO/OTA classification of fracture type, 7 patients had type 33A1, 3 patients had type 33A2, 4 patients had type 33A3.¹³

The average operation duration was 48.9 minutes. Average intraoperative blood loss was 17.9 mL on average, most having less than 30 mL and none of them needed open reduction. However, one patient with an open fracture caused by a motor vehicle accident lost 90 mL of blood (Table 2). The average hospital stay was 9.9 days due to many complex comminuted open fractures. None of the patients had neurovascular injury neither had deep infection postoperatively. However, 2 patients had a pin site infection but entirely resolved with oral antibiotics and regular dressing change.

The average time to radiographic union was 12.3 weeks (10-16 weeks), while time to regain walking ability ranged from 11 to 13 weeks (average 11.8 weeks). There was no case of delayed union. Most fractures (12 of 14) achieved clinical and radiographic union at 13 weeks. (Figure 1) In the average of 34 months follow-up, no physeal injury or refracture was detected. No patients developed a valgus deformity of more than 10 degrees. The leg length discrepancies of all 14 patients were less than 0.8 cm (Table 2). No patient exhibited functional deficiency. Nine of 14 patients regained full ROM. The average postoperative KSS and functional score at the latest follow up were 97.5 points and 97.1 points, respectively (Table 2).

Discussion

Among all the displaced femoral fractures in children, supracondylar fracture accounts for 6.9%.² Smith et al. reported that the most common cause of this type of fracture was fall.² In this study, both fall from height and motor vehicle accidents were the most common causes of pediatric SFF. Undisplaced supracondylar femoral fractures are easy to manage with the application of brace or cast immobilization, while displaced fractures have a relatively high failure rate by closed reduction and immobilization.^{6,8,9,12,13,15} So, operative treatment is indicated for the optimum outcome for such injuries. However, it is a challenging job as surgery can damage the physeal growth plate. According to literature reports, the use of external fixation in pediatric femur fractures is largely limited by its complications. Common complications include soft-tissue injury, knee stiffness, malalignment, refracture, and pin-tract fracture.^{12,16,17} Some patients refused to attend school with the external fixator and go back to society later may partly because of psychological impact, which is currently unexplored.^{16,17} In an average follow-up of 34 months, neither refracture nor deep infection occurred in our study, indicating that most reported complications could be avoided with careful surgery and nursing care. Muscular pull or high pressure on pins during the early healing process may lead to micro-movement of pins,¹⁸ imposing negative influence on stability and the union of the fracture. However, early postoperative exercises, including quadriceps strengthening exercise and passive knee ROM exercise, are still considered critical in preventing knee stiffness. To avoid malunion and malalignment, weight-bearing is allowed only after gaining clinical evidence of union. The clinical and radiographic union rates of 100% (14 of 14) in this study indicate that an external fixation is an alternative option for managing supracondylar femoral fractures in children. Both the postoperative KSS score and functional score showed satisfactory results. The average KSS postoperative score was 97.5 points, with a minimum

HIGHLIGHTS

- Fourteen patients with supracondylar fracture of the femur were treated with AO external fixator and followed up for 2 years.
- Time to the radiographic union, time to regain walking ability, the postoperative Knee Society Scores (KSS) and KSS functional score were collected.
- Radiographic images were reviewed for the measurement of leg length discrepancy and valgus deformity.
- The results showed that external fixation is a reliable alternative treatment for displaced supracondylar femoral fracture in children, achieving a good outcome.

Table 1. Characteristics of pediatric patients with supracondylar femoral fracture treated by external fixators

No.	Gender	Age, y	Side	AO/OTA Classification	Fracture type	Open fracture	Other fractures	Cause
1	Female	4.7	L	33A3	Comminuted	+	-	Vehicle accident
2	Female	3.9	L	33A1	Transverse	-	-	Vehicle accident
3	Female	5.8	R	33A1	Transverse	-	-	Vehicle accident
4	Female	7.1	L	33A3	Comminuted	+	-	Others
5	Male	7.3	R	33A1	Transverse	-	Opposite femur	Vehicle accident
6	Female	9.4	R	33A3	Comminuted	+	-	Fall
7	Female	9.4	L	33A3	Comminuted	+	-	Fall
8	Female	4.0	L	33A1	Transverse	-	-	Vehicle accident
9	Male	10.3	L	33A2	Oblique/spiral	-	-	Fall
10	Male	6.8	R	33A2	Oblique/spiral	-	-	Vehicle accident
11	Male	7.4	L	33A1	Transverse	-	-	Fall
12	Male	8.5	R	33A1	Transverse	-	-	Fall
13	Male	9.1	R	33A2	Oblique/spiral	+	-	Vehicle accident
14	Female	8.7	R	33A1	Transverse	-	-	Fall

Table 2. Surgery related information and postoperative information

No.	Operating time (min)	Intraoperative blood loss (mL)	Stay in hospital (day)	Time to radiographic union (week)	Time to regain walking ability (week)	KSS* post-operative Score	KSS* functional score	Leg length discrepancy (cm)	Valgus deformity degree
1	115	90	25	16	12	93	90	0.7	2-10°
2	32	10	5	10	11	100	100	0.5	<2°
3	38	15	5	11	11	99	100	0.6	<2°
4	68	30	12	12	12	98	100	0.5	<2°
5	37	10	7	10	12	98	100	0.7	2-10°
6	36	15	10	12	13	94	90	0.5	2-10°
7	41	15	10	12	13	93	90	0.3	2-10°
8	34	10	18	11	11	99	100	0.4	<2°
9	40	10	7	11	12	99	100	0.3	2-10°
10	48	5	6	13	11	100	100	0.7	<2°
11	45	10	8	13	11	100	100	0.5	<2°
12	50	15	8	15	12	100	100	0.3	<2°
13	49	10	12	13	12	98	100	0.4	<2°
14	51	5	6	13	12	94	90	0.3	<2°

*KSS is the abbreviation of Knee Society Score.

of 93 points. The average KSS functional score was 97.1 points, ranging from 90 to 100 points. These results were comparable to KSS measured by other authors.^{14,19}

Other researchers also propose some techniques, including traction, plaster cast, elastic intramedullary pinning, crossed percutaneous pinning, and locking plates. Closed reduction with percutaneous cross pinning is an optimal choice for younger children. As per our previous result, children younger than 3.6 years old could reach satisfactory outcomes through crossed Kirschner wires fixation.²⁰ When it comes to older and obese children, Kirschner wires typically could not support their weights and even might bring complications such as malunion, peroneal nerve palsy, or septic knee arthritis.⁷ Parikh et al. figured out that the strengths of elastic nailing on pediatric supracondylar femoral fractures lie in the shorter hospital stay, being minimally invasive and no need for rigid mobilization or plaster cast after surgery. However, it is challenging to choose a suitable entry point (usually quite close to physis), cross the elastic nails, and avoid injuring the growth plate simultaneously. Therefore, this surgical technique requires orthopedists with more extensive experience.⁸ Plate fixation also showed satisfactory

results among adults.²¹ But it usually takes 3 to 4 screws in both sides of the fracture, making it challenging to stabilize short fragments without penetrating physis in young children.^{6,22-24} Currently reported techniques of plate fixation are only applied to children older than 12 years.^{6,21,22} External fixation has been used for specific femoral fractures, and some authors recommended it for the treatment of SFF in adults.^{11,18,25-27} To our best knowledge, there was no previous study concerning the application of AO external fixator on SFF in children. The only relevant study was in 2005, in which authors reported the outcomes of only five cases treated with Ilizarov fixator. Therefore, this is the first study focusing on applying the AO external fixator on pediatric SFF, revealing a satisfactory result. However, the age limit for this technique is still uncertain, although the average age in this study was older than other studies treated with Kirschner wires.²⁰

There are still some limitations to this study. The small sample size limits the validity of this study. The absence of matched groups treated with other surgical techniques is another limitation. Although all the patients achieved clinical and radiographic union, follow-up durations still varied. Further studies with more patients and long-term follow-up

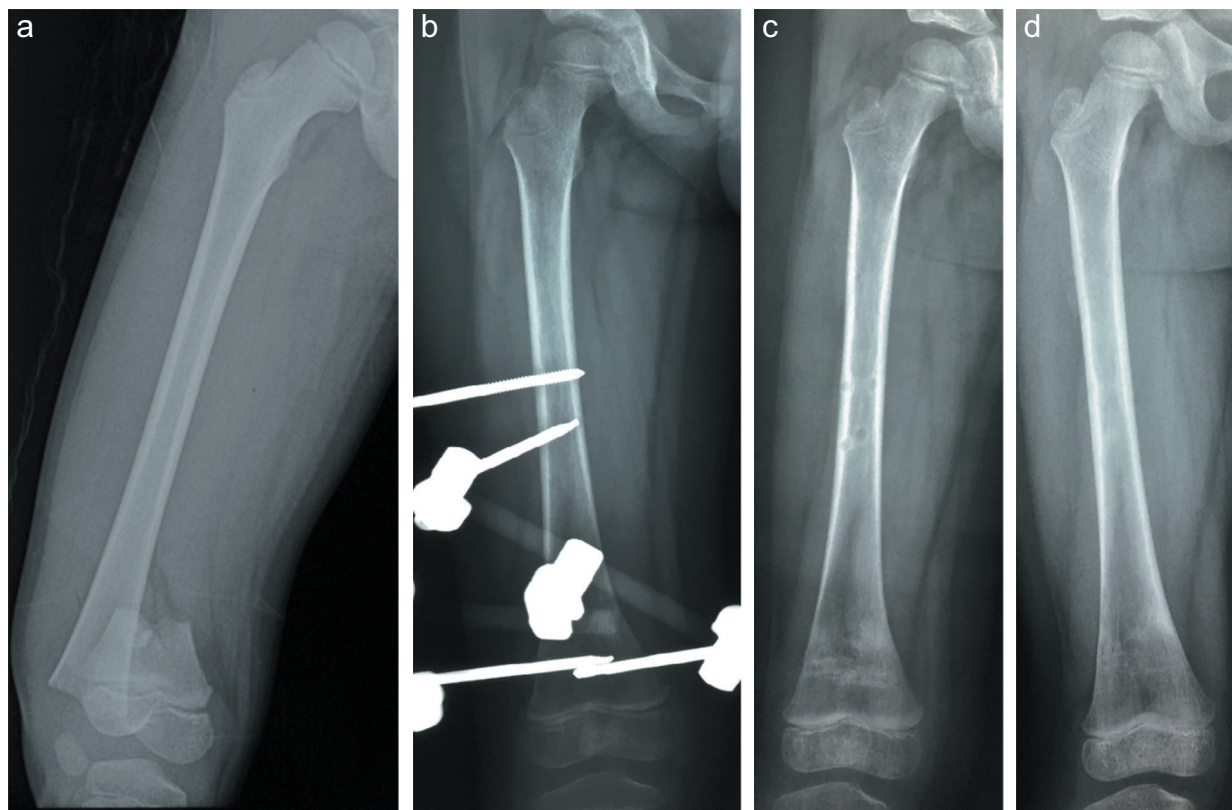


Figure 1. a-d. (a) X-ray AP view of knee with femur right side showing supracondylar femoral fracture in a 5.8-year-old female. (b) X-ray AP view of the same patient 2 months postoperative with external fixation. (c) X-ray AP view of the same patient 3 months postoperative, external fixation removed for one month. (d) X-ray AP view of the same patient 18 months postoperative.

are necessary. Despite the limitations, the result of this study reveals that external fixation provides satisfactory outcomes and may be an alternative for pediatric displaced supracondylar femoral fracture.

Ethics Committee Approval: The Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology (IORG No: IORG0003571) gave final approval on 20/11/2019 for the study Retrospective Research of Surgical Methods in the Treatment of Fractures and malformation in Children in Children, which Xin Tang conducts at the Department of Orthopaedic Surgery, Union Hospital of Tongji Medical College, Huazhong University of Science and Technology.

Informed Consent: The patient's parents have read and understand the information about this project. They have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. They understand that their participation is voluntary and agree to participate in this research. They agree to allow the researcher(s) to use X-ray photographs of their children and grant permission for these to be used by the researcher(s) and their project partners in publications, press articles and websites, exclusively for non profit-making purposes.

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Conflict of Interest: The authors declare that there is no conflict of interest.

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References

- Martinet O, Cordey J, Harder Y, Maier A, Buhler M, Barraud GE. The epidemiology of fractures of the distal femur. *Injury*. 2000;31(Suppl 3):C62-63. [10.1016/S0020-1383\(00\)80034-0](https://doi.org/10.1016/S0020-1383(00)80034-0)
- Smith NC, Parker D, McNicol D. Supracondylar fractures of the femur in children. *J Pediatr Orthop*. 2001;21(5):600-603. [10.1097/01241398-200109000-00009](https://doi.org/10.1097/01241398-200109000-00009)
- Sferopoulos NK, Papavasiliou VA. Supracondylar femoral fractures in children before the age of walking. *Rev Chir Orthop Reparatrice Appar Mot*. 1993;79(6):500-502.
- Newman JH. Supracondylar fractures of the femur. *Injury*. 1990;21(5):280-282. [10.1016/0020-1383\(90\)90040-2](https://doi.org/10.1016/0020-1383(90)90040-2)
- Lam HY, Lo CK, Cheung KY. The use of tibial Less Invasive Stabilization System (LISS) plate [AO-ASIF] for the treatment of paediatric supracondylar fracture of femur: A case report. *J Orthop Surg Res*. 2010;5 1:10. [10.1186/1749-799X-5-10](https://doi.org/10.1186/1749-799X-5-10)
- Baker P, McMurtry I, Port A. The treatment of distal femoral fractures in children using the LISS plate: A report of two cases. *Ann R Coll Surg Engl*. 2008;90(4):4-6. [10.1308/147870808X302985](https://doi.org/10.1308/147870808X302985)
- Butcher CC, Hoffman EB. Supracondylar fractures of the femur in children: Closed reduction and percutaneous pinning of displaced fractures. *J Pediatr Orthop*. 2005;25(2):145-148. [10.1097/01.bpo.0000149860.50400.92](https://doi.org/10.1097/01.bpo.0000149860.50400.92)
- Parikh SN, Nathan ST, Priola MJ, Eismann EA. Elastic nailing for pediatric subtrochanteric and supracondylar femur fractures. *Clin Orthop Relat Res*. 2014;472(9):2735-2744. [10.1007/s11999-013-3240-z](https://doi.org/10.1007/s11999-013-3240-z)
- Bopst L, Reinberg O, Lutz N. Femur fracture in preschool children: Experience with flexible intramedullary nailing in 72 children. *J Pediatr Orthop*. 2007;27(3):299-303. [10.1097/BPO.0b013e3180326713](https://doi.org/10.1097/BPO.0b013e3180326713)
- Wani MM, Rashid M, Dar RA, et al. Use of external fixator versus flexible intramedullary nailing in closed pediatric femur fractures: Comparing results using data from two cohort studies. *Eur J Orthop Surg Traumatol*. 2016;26(2):223-230. [10.1007/s00590-015-1737-8](https://doi.org/10.1007/s00590-015-1737-8)
- Bible JE, Mir HR. External fixation: Principles and applications. *J Am Acad Orthop Surg*. 2015;23(11):683-690. [10.5435/JAAOS-D-14-00281](https://doi.org/10.5435/JAAOS-D-14-00281)
- Hedin H. Surgical treatment of femoral fractures in children. Comparison between external fixation and elastic intramedullary nails: A review. *Acta Orthop Scand*. 2004;75(3):231-240. [10.1080/00016470410001132](https://doi.org/10.1080/00016470410001132)
- Slongo TF, Audigé L. Fracture and dislocation classification compendium for children. *J Orthop Trauma*. 2007;21(Supplement):S135-S160. [10.1097/00005131-200711101-00020](https://doi.org/10.1097/00005131-200711101-00020)
- Gill SPS, Mittal A, Raj M, Singh P, Singh J, Kumar S. Extra articular supracondylar femur fractures managed with locked distal femoral plate or supracondylar nailing: A comparative outcome study. *J Clin Diagnostic Res*. 2017;11(5):RC19-RC23.

15. Marsh JL, Jansen H, Yoong HK, Found EM. Supracondylar fractures of the femur treated by external fixation. *J Orthop Trauma*. 1997;11(6):405-411. [10.1097/00005131-199708000-00004](#)
16. Gregory P, Pevny T, Teague D. Early complications with external fixation of pediatric femoral shaft fractures. *J Orthop Trauma*. 1996;10(3):191-198. [10.1097/00005131-199604000-00007](#)
17. Skaggs DL, Leet AI, Money MD, Shaw BA, Hale JM, Tolo VT. Secondary fractures associated with external fixation in pediatric femur fractures. *J Pediatr Orthop*. 1999;19(5):582-586. [10.1097/01241398-199909000-00005](#)
18. Bedes L, Bonneville P, Ehlinger M, Bertin R, Vandenbusch E, Piétu G. External fixation of distal femoral fractures in adults' multicentre retrospective study of 43patients. *Orthop Traumatol Surg Res*. 2014;100(8):867-872. [10.1016/j.otsr.2014.07.024](#)
19. Su Y, Nan G. ORIF with percutaneous cross pinning via the posterior approach for paediatric widely displaced supracondylar femoral fractures. *Injury*. 2016;47(6):1242-1247. [10.1016/j.injury.2016.02.024](#)
20. Li J, Ma J, Guo X, et al. Closed reduction with crossed Kirschner wire fixation for displaced supracondylar femoral fractures in young children. *Medicine (Baltimore)*. 2020;99(13):e19666. [10.1097/MD.00000000000019666](#)
21. Xing W, Lin W, Dai J, et al. Clinical effect of locking compression plate via posterolateral approach in the treatment of distal femoral fractures: A new approach. *J Orthop Surg Res*. 2018;13(1):57. [10.1186/s13018-018-0756-7](#)
22. Bor N, Rozen N, Dujovny E, Rubin G. Fixator-Assisted plating in pediatric supracondylar femur fractures. *Global Pediatric Health*. 2019;6:2333794X1984392-2333794X1984392. [10.1177/2333794X19843922](#)
23. Wilson CH, Smith CS, Gay DM, Loveless EA. Submuscular locked plating of pediatric femur fractures. *J Surg Orthop Adv*. 2012;21(3):136-140. [10.3113/JSOA.2012.0136](#)
24. Kanlic EM, Anglen JO, Smith DG, Morgan SJ, Pesantez RF. Advantages of submuscular bridge plating for complex pediatric femur fractures. *Clin Orthop Relat Res*. 2004;(426):244-251. [10.1097/01.blo.0000138961.34810.af](#)
25. Oh JK, Hwang JH, Sahu D, Jun SH. Complication rate and pitfalls of temporary bridging external fixator in periarticular comminuted fractures. *Clin Orthop Surg*. 2011;3(1):62-68. [10.4055/cios.2011.3.1.62](#)
26. Sala F, Capitani D, Castelli F, La Maida GA, Loviseti G, Singh S. Alternative fixation method for open femoral fractures from a damage control orthopaedics perspective. *Injury*. 2010;41(2):161-168. [10.1016/j.injury.2009.07.008](#)
27. Parekh AA, Smith WR, Silva S, et al. Treatment of distal femur and proximal tibia fractures with external fixation followed by planned conversion to internal fixation. *Journal of Trauma - Injury, Infection and Critical Care*. 2008;64(3):736-739. [10.1097/TA.0b013e31804d492b](#)