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Distal third femoral shaft fractures in school-aged children

A comparative study of elastic stable intramedullary nail and external fixator

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Abstract

Internal fixation such as elastic stable intramedullary(ESIN) nail and submuscular plate (SMP) is gaining popularity for femoral shaft fractures in school-aged children. However, external fixation (ExFix) might be a valuable option for the distal third femoral shaft fractures, where the fracture heals rapidly, but it is crucial to avoid angular malunion. This study aims to compare the clinical outcomes, postoperative complications of distal third femoral shaft fractures in school-aged children treated by ESIN versus ExFix.

Patients aged 5 to 11 years with distal third femoral shaft fractures treated at our institute from January 2014 to January 2016 were included and categorized into ESIN (n = 33) and ExFix (n = 38) group. The preoperative data, including baseline information of the patients, radiographic parameters, and type of surgical procedure, were collected from the hospital database, and postoperative data, including complications, were collected during the follow-up visit.

In all, 33 patients (average, 8.0 ± 2.1 years, male 20, female 13) in the ESIN group and 38 patients (average, 8.3 ± 2.3 years, male 23, female 15) in the ExFix group were included in this study. There was significantly less operative time for the ExFix group (45.4 ± 7.8 min) as compared to the ESIN group (57.8 ± 11.3 min) ($P < .01$), reduced estimated blood loss (EBL) in the ExFix group (9.9 ± 3.5) as compared to the ESIN group (16.4 ± 6.5) ($P < .01$). As for the frequency of fluoroscopy, there was a significant difference between the ExFix group (13.9 ± 2.4) and the ESIN group (15.5 ± 3.2) ($P = .02$). The rate of major complications was not significantly different between the 2 groups ($P = .19$). The rate of implant irritation was significantly higher in the ExFix group (28/38, 73.7%) than the ESIN group (12/33, 36.4%) ($P < .01$). The rate of surgical site infection (SSI) is significantly higher in the ExFix group (18/38, 47.4%)) than the ESIN group (1/33, 3%) ($P < .01$). The rate of scar concern was significantly higher in the ExFix (9/38, 23.7%) than the ESIN (2/33, 6.1%), ($P = .04$). According to the Flynn scoring system, 30(90.9%) patients in the ESIN group and 24(89.5%) patients in the ExFix group were rated as excellent. None of the patients had poor outcomes.

Both ESIN and ExFix produced satisfactory outcomes in distal third femoral shaft fractures. ExFix remains a viable choice for selected cases, especially in resource-challenged and austere settings.

Abbreviations: ESIN = elastic stable intramedullary nail, ExFix = external fixation.

Keywords: distal third femoral shaft, elastic stable intramedullary nail, external fixator

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1. Introduction

Over the past few years, utilization of the elastic stable intramedullary nail (ESIN) for operative stabilization for femoral shaft fractures in children has been gaining popularity.[1–3] However, numerous reports demonstrated the technical challenges and complications regarding the applications of ESIN in femoral fractures in children,[4–6] especially in distal and proximal femoral fractures. External fixation (ExFix) may be valuable for the distal third femoral shaft fractures, where the fracture heals rapidly; still, there is a high chance of angular malunion, and that should be avoided. This study aims to compare the clinical outcomes, postoperative complications of distal third femoral shaft fractures in school-aged children treated by ESIN versus ExFix.

2. Material and methods

This study was approved by the Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology. Written consent was obtained from the patient's legal guardians.

Patients aged 5 to 11 years with distal third femoral shaft fractures treated at our institute from January 2014 to January 2016 were included and categorized into ESIN (n = 33) and ExFix (n = 38) group. Exclusion criteria were age 12 years or above, body weight over 50 kilograms, pathological fracture, neuromuscular disorder, open fracture, metabolic disease, and previous femoral fracture or instrumentation. Patients of fracture line propagating to the supracondylar region or midshaft region were also excluded. Patients with follow up less than 24 months or incomplete medical history were also excluded.

The patient's legal guardians were thoroughly explained about each of the procedures, and risks and benefits of the procedures as well as hardware designs, and let them choose.

The preoperative data, including baseline information of the patients, radiographic parameters, and types of surgical procedure, were collected from the hospital database, and postoperative data, including complications, were collected during the follow-up visit. Full-length anteroposterior (AP) radiograph was used to determine the total length of the femur, which was defined as the distance between the most superior aspect of the femoral head and the most inferior aspect of the medial femoral condyle. Limb length discrepancy (LLD) was defined as a difference of at least 2 cm with the contralateral limb. Angulation was measured as an angle between the anatomic axes of the proximal and distal fragments, and angular deformity was defined as coronal angulation >10 degrees or sagittal angulation >15 degrees.

Radiographic union was defined as the formation of a bridging callus across the fracture on at least 3 out of 4 cortices on AP and lateral radiographs. The final functional outcome was evaluated according to the Flynn scoring system.[7]

Complications were categorized into major and minor ones. Major complications included malunion, nonunion, or loss of reduction, which required revision before fracture union. Minor complications included minor LLD or angular deformity, implant prominence/irritation, and superficial infection.

In our institute, the application of the ESIN was performed using the retrograde technique (see Fig. 1); whereas, the ExFix was performed using a hybrid external fixator (see Fig. 2).

Spica casting or long-leg fiberglass cylinder casting was used in the ESIN group for 4 to 6 weeks, whereas long-leg slab was used in the ExFix group for 3 to 4 weeks after surgery. Non-weight bearing exercises were encouraged after slab removal in the ExFix group. In the ESIN group, toe-touch weight was initiated when the radiological union was noticed at the out-patient clinical visit, and progression to full weight-bearing was allowed according to the radiographic and clinical manifestation. In the ExFix group, toe-touch weight-bearing was initiated when the radiological evidence of union was noticed at the out-patient clinical visit, and progression to full weight-bearing was allowed according to the radiographic and clinical manifestation.

ESIN was routinely removed 4 to 7 months after the surgery in the operating room under general anesthesia, while ExFix was removed at out-patient visit 6 to 12 weeks, followed by immobilization in a long leg brace for 3 to 4 weeks with restricted activities.

All descriptive data were presented as the mean ± SD. Statistical analysis was performed using SPSS (SPSS Inc, Chicago, IL). A *P*-value of $< .05$ is regarded as statistical significance.

3. Results

As shown in Table 1, 33 patients (average, 8.0 ± 2.1 years; male 20, female 13) in the ESIN group and 38 patients (average, 8.3 ± 2.3 years; male 23, female 15) in the ExFix group were included in this study. Patients in both groups were followed up for more than 24 months. There was no significant difference between the 2 groups concerning the patient's demographic parameters, including sex, age, and weight, affected side, mechanism of injury, duration from injury to surgery.

Comparing operative variables (Table 2), there was significantly less operative time for ExFix (45.4 ± 7.8 min) as compared with ESIN (57.8 ± 11.3 min) ($P < .01$), reduced estimated blood loss (EBL) in ExFix (9.9 ± 3.5) as compared with ESIN (16.4 ± 6.5) ($P < .01$). As for the frequency of fluoroscopy, there was a significant difference between the ExFix (13.9 ± 2.4) and ESIN (15.5 ± 3.2) group ($P = .02$). There was no significant difference between the 2 groups concerning the length of hospital stay ($P = .78$).

As shown in Table 3, patients in both groups showed significantly reduced pain after surgery. There was no significant difference between the 2 groups concerning pain response after surgery.

As shown in Table 4, the rate of major complications was not significantly different between these 2 groups ($P = .19$). The rate of implant irritation was significantly higher in the ExFix group (28/38, 73.7%) than the ESIN group (12/33, 36.4%) ($P < .01$). The rate of surgical site infection (SSI) is significantly higher in the ExFix group (18/38, 47.4%) than the ESIN group (1/33, 3%), ($P < .01$). The rate of scar concern was significantly higher in the ExFix group (9/38, 23.7%) than the ESIN group (2/33, 6.1%), ($P = .04$). There was a significant difference between the ExFix group (4.2 ± 2.8, mm) and the ESIN group (2.5 ± 1.6, mm) group concerning limb length discrepancy ($P < .01$).

According to the Flynn scoring system (Table 5), 30(90.9%) patients in the ESIN group and 24 (89.5%) patients in the ExFix group were rated as excellent. None of the patients had poor outcomes. And, the clinical outcome was not different significantly.

Figure 1. 6 yr-old girl of left distal third femoral shaft fracture treated with ESIN. AP view of femur before surgery. Lateral view of femur before surgery. AP view of femur after surgery. Lateral view of femur after Surgery. AP view of femur at 1st month follow-up. Lateral view of femur at 1st month follow-up.

4. Discussion

ExFix has the potential advantages of being the minimally invasive approach, lower blood loss, shorter operative time, and no requirement of secondary surgery for hardware removal. Besides, the ExFix produces satisfactory clinical outcomes and is comparable with the ESIN.

There are several surgical choices for treating femoral shaft fractures in children and adolescents, including submuscular plate,[8] intramedullary nails[9] and ExFix.[10,11] In recent few years, the enthusiasm for ExFix is waning because of good outcomes reports on internal fixation. Submuscular bridging plating has gained popularity for the treatment of length-unstable and proximal or distal femoral shaft fractures,[8,12,13] however, the likelihood of distal femoral valgus deformity after plating of distal femoral shaft fractures has also been reported.[14] Besides, large incision and secondary operation for hardware removal made it unacceptable for most patient's parents. ESIN is a useful and established technique for femoral shaft fractures.[4,7] In the distal third, the retrograde technique produces better stability according to biomechanics analysis.[15,16] In our institute, all ESIN was performed in a retrograde fashion. However, the ESIN requires secondary surgery of hardware removal. After a thorough discussion with the patient's legal guardians, some of them might choose ExFix as it also produces satisfactory

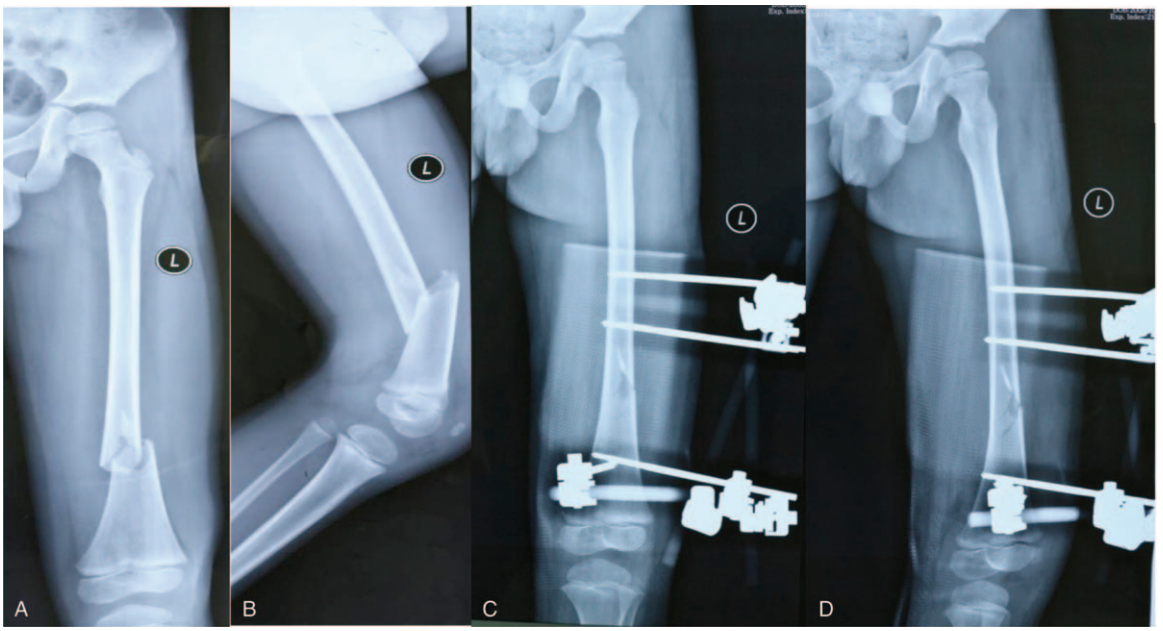

Figure 2. 7 yr-old boy of left distal third femoral shaft fracture treated with ExFix. AP view of femur before surgery. Lateral view of femur before surgery. AP view of femur after surgery. Lateral view of femur after surgery.

clinical outcomes with acceptable minor complications such as pin tract infection (PTI), and pin site scarring.

In this study, almost all patients in ExFix healed uneventfully, consistent with previous reports.[17,18] All patients in the ExFix demonstrated less than 10 degrees angulation in the last follow-up, possibly due to 3 to 4 weeks long leg slab immobilization after surgery.

The most common complications of ExFix include malunion, delayed union, refracture and PTI.[19,20] The fracture in the distal third is in proximity to the metaphyseal region and normally heal faster than midshaft fractures. The rate of delayed union in our study was nil in both groups. There were 2 patients of refracture in the ExFix after hardware removal. Both of them suffered an accidental fall within 1 month after fixator removal. The implant irritation was much higher in the ExFix than ESIN, and it is because of the thick muscle enveloping the femur. However, the external fixator was routinely removed at 7 to 12 weeks postoperatively, while the intramedullary nails were routinely removed at 4 to 7 months. The rate of scar concern was higher in the ExFix (9/38, 23.7%) than the ESIN group (2/33, 6.1%). Although both the techniques are minimally invasive, the pin site scarring was more evident in the ExFix group because of continuous friction between Schanz pins and adjacent skin. Pin

Table 1

Patient demographic.

Parameters	ESIN (N = 33)	ExFix(N = 38)	*P* value
Sex			
Male	20	23	1
Female	13	15	
Side			
Left	17	19	.89
Right	16	19	
Age	8.0 ± 2.1	8.3 ± 2.3	.55
Weight	29.0 ± 5.8	29.9 ± 6.6	.52
Injury to surgery (d)	2.2 ± 0.8	1.9 ± 0.8	.14

ESIN = elastic stable intramedullary nail.

Table 2

Operative parameters for fracture surgery.

Parameters	ESIN (N = 33)	ExFix(N = 38)	*P* value
Operative time (min)	57.8 ± 11.3	45.4 ± 7.8	<.01
EBL (mL)	16.4 ± 6.5	9.9 ± 3.5	<.01
Fluoroscopy (times)	15.5 ± 3.2	13.9 ± 2.4	.02
Length of stay (d)	4.0 ± 0.9	4.0 ± 0.8	.78

EBL = estimated blood loss.

Table 3

Pain management.

Parameters	ESIN (N = 33)	ExFix(N = 38)	*P* value
VAS before surgery	7.2 ± 0.8	7.0 ± 0.8	.29
VAS (1st d)	5.0 ± 0.7	5.0 ± 0.9	.98
VAS (1–3 d)	3.6 ± 0.7	3.9 ± 0.8	.20

VAS = Visual Analogue Scale.

Table 4

Complications after surgery.

Complication	ESIN (N = 33)	ExFix(N = 38)	*P* value
Loss of reduction	0	0	1
Non-union	0	0	1
Refracture	0	2(5.3%)	.19
Major complications	0	2 (5.3%)	.19
Implant irritation	12 (36.4%)	28 (73.7%)	<.01
SSI	1 (3.0%)	18 (47.4%)	<.01
Scar concern	2 (6.1%)	9 (23.7%)	.04
LLD	2.5 ± 1.6	4.2 ± 2.8	<.01

Major complications: loss of reduction, non-union, refracture.
SSI = surgical site infection; LLD = limb length discrepancy.

Table 5

Clinical parameters after implant removal.

Parameters		ESIN (N = 33)	ExFix (N = 38)	*P* value
Flynn	Excellent	30 (90.9%)	34 (89.5%)	.81
Score	Satisfactory	3	4	
System	Poor	0	0	
Excellent + satisfactory		33	38	1

tract infection (PTI) and drainage were quite common during the application of an external fixator.[10,11,17] Still, no patient in the ExFix required intravenous antibiotics or supplemental surgery, consistent with previous reports.[17,20,21] Oral antibiotics and extra care alleviated the PTI effectively. Therefore, most of the children and their caretakers were able to tolerate the minor complications of ExFix well. Besides, there was no need for another surgery under general anesthesia, which was a significant concern for most parents.

Limb length discrepancy (LLD) is a common complication in pediatric femoral fractures.[22] However, in our study, there was no case of LLD over 2 cm in both groups, probably due to the closed reduction techniques during the operation without excessive stripping of the periosteum as in open reduction and internal fixation (ORIF).

There were several limitations in our study. First, it was a retrospective study with a modest sample size; therefore, our findings should be interpreted with caution. Second, The allocation process of patients to either the ESIN group or the ExFix group partly depended on the preference of the surgeon in charge, and this strategy may cause allocation bias. Third, the follow-up was not long enough to monitor the long term impact on skeletal growth and development. Finally, patients of plating were not included in this study to elucidate the optimal choice for this type of fracture

5. Conclusion

Both ESIN and ExFix produce satisfactory outcomes in distal third femoral shaft fractures. ExFix remains a viable choice for selected cases, especially in resource-challenged and austere settings.

Author contributions

Conceptualization: Pan Hong.
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Validation: Xin Tang.
Writing – original draft: Pan Hong.
Writing – review & editing: Jin Li, Saroj Rai, Pan Hong.

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