

# Operative Choice for Open Tibial Shaft Fracture in Children: A Comparative Study of External Fixator Vs. Elastic Stable Intramedullary Nail

**Pan Hong**

Wuhan Union Hospital <https://orcid.org/0000-0003-2674-3016>

**Saroj Rai**

Department of Orthopaedics and Trauma Surgery, National Academy of Medical Science, Mahankal, Kathmandu, Nepal

**Xin Tang**

Wuhan Union Hospital

**Ruikang Liu**

Huazhong University of Science and Technology Tongji Medical College First Clinical College

**Jin Li** (✉ [lijin2003whxh@foxmail.com](mailto:lijin2003whxh@foxmail.com))

Wuhan Union Hospital <https://orcid.org/0000-0003-0610-2991>

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## Research Article

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# Abstract

## Introduction

External fixator (EF) is a preferred choice for open tibial fractures, but pin tract infection (PTI) and refracture are common complications. Elastic stable intramedullary nail (ESIN) has been reported in the treatment for open tibial fractures. This study aims to compare the clinical outcomes of EF vs. ESIN in the treatment for open tibial shaft fracture in children retrospectively.

## Material and methods

Patients aged 5-11 years old with Gustilo-Anderson II and IIIA tibial shaft fracture treated at our institute from January 2008 to January 2018 were reviewed retrospectively and categorized into EF (n = 55) and ESIN (n = 37) group. Patients with pathological fracture, neuromuscular disorder, metabolic disease, previous tibial fracture or instrumentation, and polytrauma were excluded. Patients with follow up less than 24 months or incomplete medical records were also excluded.

## Results

In all, fifty-five patients (33 males, 22 females) were included in the EF group, whereas 37 patients (21 males, 16 females) were included in the ESIN group. There was no significant difference between the two groups concerning sex, age, body weight, duration from injury to surgery, Gustilo-Anderson (GA) classification, and concomitant injuries. There was no patient of nonunion and malunion in either group. The incidence of implant prominence was higher in the ESIN group (16%) than those in the EF group (0),  $P < 0.001$ . The angulation was higher in the EF group than ESIN group in coronal and sagittal plane,  $P < 0.001$ . The radiological union was faster in the ESIN group ( $7.0 \pm 0.9$ , weeks) than those in the EF group ( $9.0 \pm 2.2$ ),  $P < 0.001$ . Limb length discrepancy (LLD) was significantly longer in the EF group ( $12.1 \pm 4.4$ , mm) than those in the ESIN group ( $7.3 \pm 4.3$ , mm),  $P < 0.001$ .

## Conclusion

ESIN is a viable option in selected patients of GA grade II and IIIA open tibial fractures with comparable clinical outcomes as external fixator, but with less complications including superficial infection, residual angulation and refracture after hardware removal.

## Introduction

Tibial fracture is a common injury in children, and it usually involves the diaphysis and distal metaphyseal region[1]. Closed reduction followed by a well-molded casting remains the primary choice for closed tibial shaft fracture[2,3]. However, in situations like comminuted or unstable fractures, open fractures and polytrauma, surgical stabilization is usually warranted[4-6]. Although debridement followed by casting has been reported[7], external fixator (EF) is a preferred choice for open injuries. However, pin tract infection (PTI) and refracture are common complications during the application of EF[8,9]. Besides,

elastic stable intramedullary nail (ESIN) has been reported in the treatment for open tibial fractures [10,11].

This study aims to compare the clinical outcomes of EF vs. ESIN in the treatment for open tibial shaft fracture in children retrospectively.

## Methods

Patients aged 5-11 years old with open tibial shaft fracture treated at our institute from January 2008 to January 2018 were reviewed retrospectively and categorized into EF (n = 55) and ESIN (n = 37) group. Gustilo-Anderson (GA) classification was adopted to stratify the patients with open injuries[12]. Patients with GA grade I injuries were excluded from this study. Patients with comminuted fracture, pathological fracture, neuromuscular disorder, metabolic disease, previous tibial fracture or instrumentation, and polytrauma were excluded. Patients with follow up less than 24 months or incomplete medical records were also excluded. Patients with body weight over 50 Kg were excluded because ESIN was not adopted for these patients in our hospital.

Full-length anteroposterior (AP) radiograph was used to determine the total length of the tibia. Limb length discrepancy (LLD) was defined as a difference at least 2cm between limbs. Angulation was measured as angle between the anatomic axes of the proximal and distal fragments, and angular deformity was defined as coronal angulation > 5 degrees or sagittal angulation > 10 degrees. Radiographic union was defined as the bridging callus across the fracture site on at least three out of four cortices on AP and lateral radiograph.

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

Short leg slab was used to immobilize the operated leg for 3-4 weeks postoperatively. Follow-up was scheduled at postoperative 4th, 8th, 12th week, 6th, 9th, 12th month and annually after first year.

This study was approved by the Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology on November 20, 2019. Written consent was obtained from the patient's legal guardians.

SPSS statistical package program (SPSS 19.0 version; SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. The categorical data were analyzed using the Chi-square ( $\chi^2$ ) test, and the continuous data were analyzed using Student's t-test. Fisher exact test was used under those circumstances with fewer subjects in groups of interest. Data were presented as mean  $\pm$  SD (range), median (range), or n (%). P < 0.05 was considered significantly different.

## Results

As shown in Table 1, fifty-five patients including 33 males and 22 females were included in the EF group, whereas 37 patients including 21 males and 16 females were included in the ESIN group,  $P = 0.453$ . The average age of patients in the EF group was  $9.0 \pm 2.8$  year-old, and that of ESIN was  $9.1 \pm 2.9$  year-old,  $P = 0.659$ . Patients in both groups were followed-up for at least 2 years, with an average of 2.4 years (2-3 years). There was no significant difference between the two groups concerning sex, age, body weight, duration from injury to surgery, GA classification, and concomitant injuries.

As shown in Table 2, there was no patient of nonunion and malunion in either group. Three patients in the EF group suffered refracture after the hardware removal, but there was no case of refracture in the ESIN group. The incidence of implant prominence was higher in the ESIN group (16%) than those in the EF group (0),  $P < 0.001$ . The angulation was higher in the EF group than ESIN group in coronal and sagittal plane,  $P < 0.001$ . Besides, the angulation in coronal plane was less than 5 degrees and in sagittal plane was less than 10 degrees in both groups. The incidence of superficial infection was significantly higher in the EF group (36.3%) than those in ESIN (5.4%) group,  $P < 0.001$ . The radiological union was faster in the ESIN group ( $7.0 \pm 0.9$ , weeks) than those in the EF group ( $9.0 \pm 2.2$ ),  $P < 0.001$ . Limb length discrepancy (LLD) was significantly longer in the EF group ( $12.1 \pm 4.4$ , mm) than those in the ESIN group ( $7.3 \pm 4.3$ , mm),  $P < 0.001$ .

## Discussion

ESIN proved to be a viable option in selected patients of open tibial shaft fractures with satisfactory clinical outcomes, but less complications than EF, including superficial infection, residual angulation and refracture after hardware removal.

Tibial shaft fractures in children usually are not complicated and treated with closed reduction and casting[13,14]. However, in patients with open fractures, and compartment syndrome, surgical intervention is usually recommended[14]. Still certain authors recommended manipulation followed by casting for open tibial fractures in children without the necessity of vascular reconstruction[15]. However, the malunion rate was not meticulously measured and analyzed[7,15]. Besides, the surgical stabilization for earlier mobilization and better alignment was gaining popularity recently[16]. Therefore, for GA II and IIIA tibial shaft fracture, surgical stabilization was adopted in our hospital.

EF has been reported as a simple and effective choice for open tibial fracture[17]. There were many available construct designs including circular fixator[18], monolateral fixator and hybrid external fixator[19], hexapod[20] and externalized locking plate[21]. Hybrid external fixator is easily assembled and applied with Schanz pins of different size, and it is the preferred choice in our hospital. Usually, 4 pins were sufficient for patients with simple tibial fracture. However, pin tract infection (PTI), nonunion, loss of reduction and refracture are known complications according to the literature[22]. Therefore, other instrument modality was explored.

ESIN has been reported in the treatment for open tibial fractures in children, but there were also complications including infection, delayed union and angulation [10,11,23]. Besides, in Gustilo-Anderson

Type III B and C injuries, only external fixator is applied in our hospital, consistent with a previous study[24]. In patient with limited contamination such as GA grade I and II, minimal invasive technique of locking plate has also been reported[25,26]. However, the removal of plate might be troublesome. Therefore, in patients of GA grade I injury, casting followed debridement was preferred in our hospital if the fracture is stable. And ESIN was preferred if the fracture is unstable. EF was only reserved for GA grade II and III injuries. Therefore, ESIN was adopted in our hospital for selected open injuries including GA grade I, II and IIIA, after aggressive debridement.

In our study, there was no case of serious deep infection requiring secondary surgery in either group, possibly due to aggressive debridement and timely administration of antibiotics. The incidence of implant prominence was higher in the ESIN group, possibly caused by the painful bursitis around entry point[27]. Although the angulation was higher in the EF group, but the angulation in both group was within acceptable range, consistent with previous reports[28]. Superficial infections were mostly around the pin tract in the EF group, and it was managed successfully with oral antibiotics. The radiological union was faster in the ESIN group, possibly caused by the micro-motion and its stimulus to bone formation[29].

LLD is a common complication in pediatric long bone fracture[30], and the LLD was more serious in the EF group than the ESIN group, consistent with previous report[27,28]. It is a powerful testament of the superiority of ESIN.

There were 3 cases of refracture at Schanz pin site in the EF group 4-6 weeks after hardware removal because of accidental fall, and they were all managed by conservative methods. Moreover, there was no case of refracture in ESIN group. It is possibly caused by the instrumentation nature of intramedullary versus extramedullary.

We undertook a retrospective investigation; therefore, our findings should be interpreted with caution. The follow-up was not long enough, and the long-term impact upon growth remains unclear. Besides, the presence of fibular fracture was not clearly discussed in subgroup analysis. Furthermore, cost-effectiveness remains to be investigated.

## **Conclusion**

ESIN is a viable option in selected patients of GA grade II and IIIA open tibial fractures with comparable clinical outcomes as external fixator, but with less complications including superficial infection, residual angulation and refracture after hardware removal.

## **Abbreviations**

ESIN = elastic stable intramedullary nail; EF = External fixation; LLD = limb length discrepancy; GA = Gustilo-Anderson; PTI = pin tract infection; AP = anteroposterior

## **Declarations**

### **Ethics Approval**

Approval was given by the Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology (IORG No. IORG0003571) on November 20, 2019.

### **Consent to Participate**

Written consents to participate in this study were obtained from the legal guardians of every patient.

### **Consent for publication**

Written consents were obtained from the legal guardians of every patient in this study for publication of this paper.

### **Availability of data and materials**

Not applicable

### **Competing interests**

The authors declare that they have no competing interests

### **Funding**

None

### **Author's contributions**

JL\* is in charge of the main idea and is the guarantor of integrity of the entire clinical study; PH and XT are in charge of the study concepts, design, manuscript preparation and editing; PH and SR are in charge of the language polishing and the grammar revision; RL and XT is in charge of the collection of the study data. All authors read and approved the final manuscript.

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## Tables

**Table 1 Patient demographics**

Parameters		EF (N=55)	ESIN (N=37)	P value
Sex	Male	33 (60.0%)	21 (56.8%)	0.453
	Female	22 (40.0%)	16 (43.2%)	
Age (y)		9.0±2.8	9.1±2.9	0.659
Body weight (kg)		27.9±4.8	28.4±5.2	0.561
Side	Left	27 (49.1%)	19 (51.4%)	0.856
	Right	28 (50.9%)	18 (48.6%)	
From injury to surgery (h)		4.1±1.5	4.3±1.3	0.496
Gustilo-Anderson Classification	II	31 (56%)	21 (56.7%)	0.479
	IIIA	24 (44%)	16 (43.3)	
Concomitant injuries		35 (64%)	27 (72%)	0.128
Presence of fibular fracture		20 (36%)	14 (37.8%)	0.147

EF = hybrid external Fixator; ESIN = elastic stable intramedullary nail

Concomitant injuries: head, thoracic and abdominal, pelvic injuries

**Table 2 Clinical outcomes**

Complication	EF (N=55)	ESIN (N=37)	P value	
Malunion	0	0	> 0.999	
Non-union	0	0	> 0.999	
Refracture	3 (5%)	0	0.100	
Implant prominence	0	6 (16%)	< 0.001	
Angulation(Degree)	Coronal	3.4±1.4	1.9±1.2	0.017*
	Sagittal	5.7±3.1	4.6±3.1	0.043*
Superficial infection	20 (36.3%)	2 (5.4%)	<0.001*	
Hardware removal (w)	12.7±3.6	24.9±4.8	<0.001*	
Radiological union (w)	9.0±2.2	7.0±0.9	0.025*	
LLD(mm) at last follow-up	12.1±4.4	7.3±4.3	<0.001*	

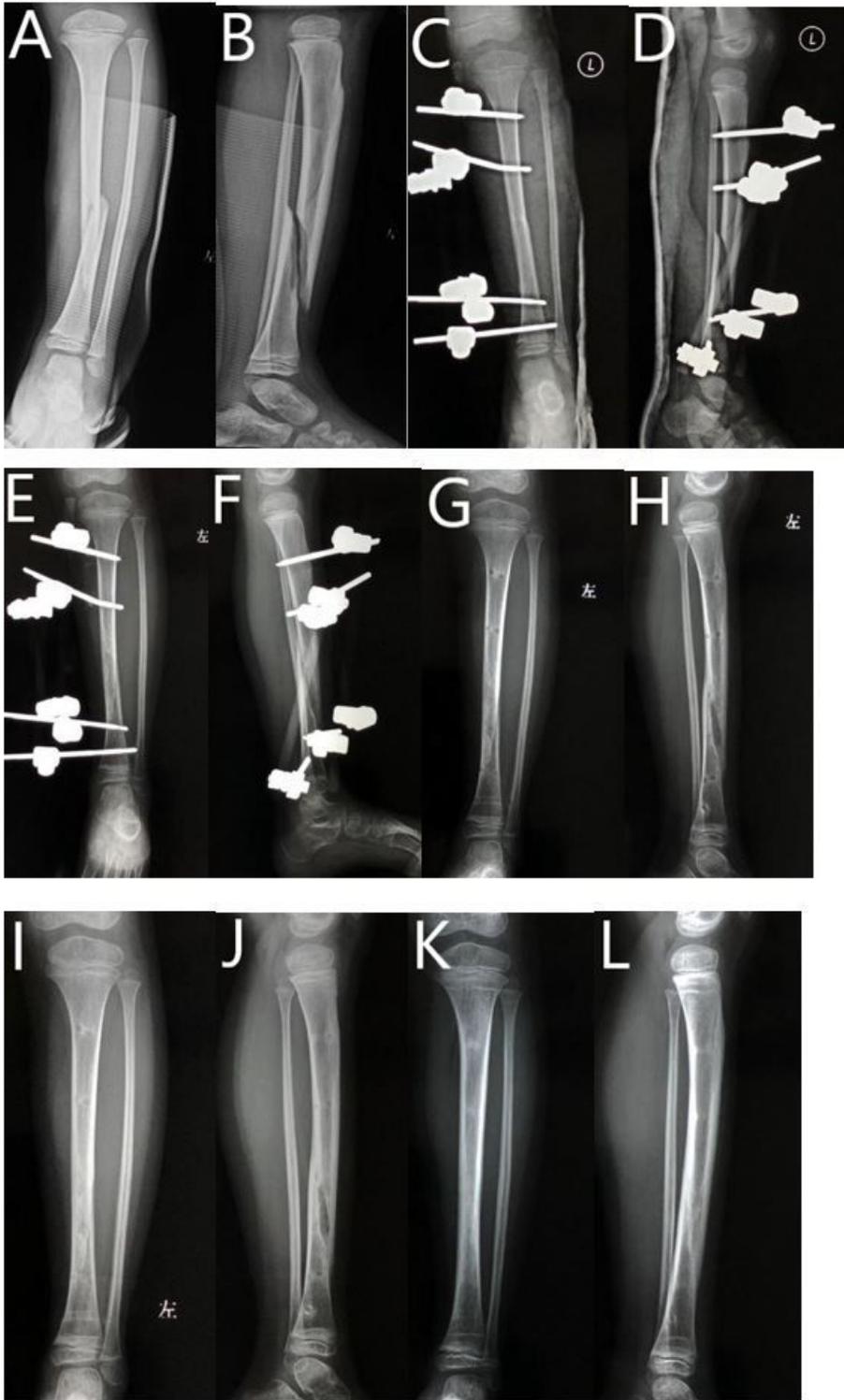
Major complications: loss of reduction, non-union, refracture

Minor complications: implant prominence, mild angulation, superficial infection

LLD = limb length discrepancy

\*<0.05

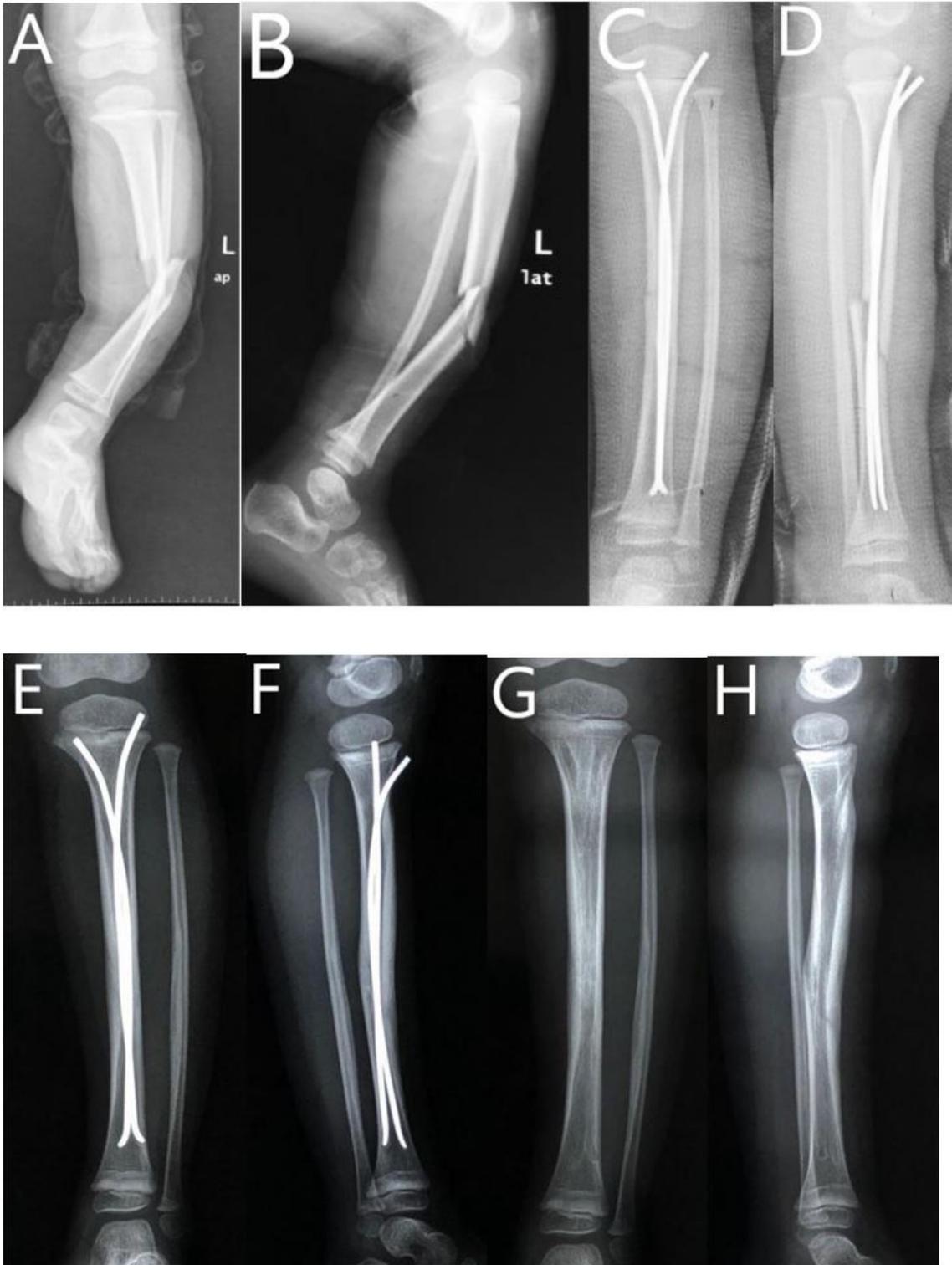
## Figures



**Figure 1**

Six year-old boy with Gustilo-Anderson grade II tibial fracture treated with EF A. AP view of tibia before surgery B. Lateral view of tibia before surgery C. AP view of tibia after surgery D. Lateral view of tibia after surgery E. AP view of tibia at 8th week follow-up F. Lateral view of tibial at 8th week follow-up G. AP view of tibia after hardware removal at 11th week follow-up H. Lateral view of tibia after hardware removal at

11th week follow-up I. AP view of tibia at 5th month follow-up J. Lateral view of tibia at 5th month follow-up K. AP view of tibia at 12th month follow-up L. Lateral view of tibia at 12th month follow-up



**Figure 2**

Five year-old girl with Gustilo-Anderson grade IIIA tibial fracture treated with ESIN A. AP view of tibia before surgery B. Lateral view of tibia before surgery C. AP view of tibia after surgery D. Lateral view of

tibia after surgery E. AP view of tibia at 5th month follow-up F. Lateral view of tibia at 5th month follow-up G. AP view of tibia after hardware removal H. Lateral view of tibia after hardware removal