



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



ELSEVIER

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Calcaneal skeletal traction versus elastic intramedullary nailing of displaced tibial shaft fractures in children

Shuaidan Zeng¹, Hansheng Deng¹, Tianfeng Zhu, Shuai Han, Zhu Xiong*, Shengping Tang*

Department of Orthopedics I, Shenzhen Children's Hospital, Shenzhen, Guangdong, China

ARTICLE INFO

Article history:

Accepted 7 October 2020

Available online xxx

Keywords:

Tibial shaft fracture

Elastic intramedullary nailing

Calcaneal skeletal traction

Children

ABSTRACT

Background: The objective of this study was to compare the outcomes and complications of patients who underwent either the calcaneal skeletal traction (CST) or the elastic intramedullary nails (EIN) procedure.

Methods: We retrospectively reviewed data of patients who underwent EIN or CST surgery for tibia shaft fracture at our center from 2013 to 2018. The patient demographics, fracture characteristics, radiographic information, length of hospital stay, and medical expenses were recorded. All patients were clinically followed-up until they started to walk or for at least 6 months. The treatment outcomes and postoperative complications of the two procedures were compared.

Results: Overall, 186 patients who underwent EIN and CST were included in the study. The EIN patients had more low-energy mechanism of injury. In radiographic evaluation, significant differences were observed in distributions of fracture classification and location. Moreover, associated fibula fractures were higher in the EIN group than in the CST group. The CST procedure had faster surgical time, cast duration and lower expenses, and longer hospitalization time. Although they required more clinical visits, patients in the EIN group began exercising and endured weight-bearing earlier than those in the CST group. The average time for bone healing was 68.5 days in the EIN group, and 69.6 days in the CST group. However, the CST provided slight better results of coronal correction than EIN. Moreover, CST patients had less malalignment ($> 5^\circ$) in complications. None had delay union, nonunion, and shortening over 10 mm at final assessment.

Conclusions: Both EIN and CST patients showed similar treatment outcomes. Hence, not only the characteristics of the patient and fracture, but also the individual's situation and expectation should be considered when choosing the best approach.

© 2020 Published by Elsevier Ltd.

Introduction

Tibial shaft fractures (TSF) are extremely common in children and adolescents. These fractures result from various causes such as from high-energy trauma in vehicular accidents to low-energy damage from sports injuries or falls on level ground [1,2]. There are multiple surgical and non-surgical management interventions for TSF such as casting with closed reduction, elastic intramedullary nailing (EIN), plate osteosynthesis, external fixation, and rigid intramedullary nailing [2]. Surgeons may select any of them based on the following parameters: age and weight, characteristics of the fractures, and requirements from the parents.

EIN is gaining popularity for treatment of displaced TSF (DTSF) in children as a result of its small incision, earlier weight-bearing, an increased range of motion compared with casting, and physical fracture avoidance. However, implant irritation and a second surgery for implant removal are still potential disadvantages [2]. Calcaneal skeletal traction (CST) with long-leg casting is a traditional and prevalent treatment for DTSF in children and adolescents at our center, and in China. Consequently, it is widely accepted by most families and is more manageable as far as surgeons are concerned. However, studies on CST are comparatively rare and there are no published studies comparing EIN with CST in the management of DTSF. There is no clear policy for the treatment of DTSF in our institution especially for older children, with some surgeons preferring EIN and others, CST.

The main objective of this study was to retrospectively analyse treatment outcomes and complications of DTSF treated with EIN as opposed to CST in children over 5 years old.

* Corresponding authors.

E-mail addresses: bamboobear@163.com (Z. Xiong), tangshengping56@126.com (S. Tang).

¹ These authors contributed equally to this work.

Methods

Patient demographics

We retrospectively reviewed clinical information and radiographs of all patients treated with EIN and CST for DTSF of the tibia, from January 2013 to December 2018. A patient was deemed eligible for the study if (1) age at the time of injury was above 5 years; (2) the fracture was closed and treated by closed reduction; (3) there was clinical follow-up, either for a radiographic union, or 6 months from the surgery, detailed records existed. The exclusion criteria for the study were (1) underlying syndromes and metabolic bone diseases, (2) fracture line extended into the metaphysis, (3) closed growth plates, and (4) incomplete treatment records. The design of the study was granted by the investigational review board (IRB) of our center.

Injury mechanisms

The mechanism of the injury that caused the fracture was determined from the medical records. Motor-vehicle collisions, and pedestrians versus automobile incidents were classified as high-energy mechanisms, whereas mechanical falls and sporting injuries were regarded as low-energy mechanisms. The emergency department and hospital records were further reviewed for the presence of coincident traumatic injuries, such as head injuries, solid-organ injuries, and other fractures.

Fracture characteristics

Pre-reduction radiographs for each patient were evaluated and classified according to the AO paediatric comprehensive classification of long bone fractures (PCCF) classification system [3]. In addition, injury films were also assessed for the angulation, shortening, displacement, and location of the diaphysis and its associated fibula fracture.

Surgical techniques

For the CST, we first drew a line to connect the lateral malleolus and heel before the operation, then the line was equally divided into 3 parts by 2 points. The outer point was the optimal location of the percutaneous K-wire. Thereafter, the pin was hammered across the calcaneus, perpendicular to the limb. The primary tractive weight was 1/10 of the patient's body weight up to a maximum 3.5 kg. This was adjusted based on periodic bedside radiographs to ensure the fracture was satisfactorily aligned without shortening or lengthening. Once callus occurred, we removed the traction pin and fixed the patient's limb with a polymer plaster long-leg cast. This could also be done under local anaesthesia for compliant patients to avoid another general anaesthesia. For EIN, we used the standard method to perform the procedure as described by Flynn et al. [4].

Treatment outcomes

Hospital charts were reviewed for relevant clinical and demographic information. The date of injury, duration of surgery, length of hospital stay, and hospitalization expenses were also recorded. Patients were followed up with serial clinical visits, and radiographs were obtained until they were finally healed, or until 6 months after the index procedure. Healing occurred when the fracture lines faded, and the callus bridging across 3 of the 4 cortices, on both anteroposterior and lateral radiographs, appeared [5]. In addition, fracture alignment at the final assessment and changes

in alignment were measured. Coronal alignment was also measured from the anteroposterior radiographs, and sagittal alignment was assessed on lateral films. In addition, fracture shortening was measured as the vertical displacement of the non-opposed fracture ends. Additional patient data were gathered from the final follow-up time records, including total number of X-rays, clinical visits, and complications.

Complications

Compartment syndrome (CS), venous thromboembolic events (VTE), and respiratory infections (RI) were checked from hospital records. Postoperative complications were defined as follows [3,6]: (1) delayed union: union over 6 months; (2) non-union: union after 9 months or union with an additional procedure; (3) malunion: malalignment of over 10° in the coronal or sagittal planes and (4) shortening of over 10 mm.

Statistical analysis

Data are presented as average and standard deviation; count and percentages are used appropriately. The ANOVA or Kruskal-Wallis tests were used for the comparison of continuous parametric variables between the 2 groups according to the homogeneity test of variances. The Pearson's chi-squared test or Yates continuity correction were used for dichotomous variables. A *P* value less than 0.05 was considered statistically significant. Lastly, SPSS v.23 was utilized to perform analysis (SPSS Inc., Chicago, IL).

Results

Patients' demographics and injury mechanisms

Out of the 186 patients who were included in the study, 122 were treated with EIN, and 64 were treated with CST. The treatment decision was made by the orthopaedic surgeon based on the following; injury X-ray films, technical experience, personal circumstances of the patients, and their treatment attempts. Furthermore, the average age, weight, and gender of the patients in both the EIN and CST groups were shown in demographic data (Table 1), which revealed no difference between the groups with respect to age and gender (*P* > 0.05). However, the weight and injury data showed some differences between the 2 groups (*P* < 0.001). Patients in the EIN group were heavier and had lower energy mechanisms of injury. This might be because of their older ages and higher alertness.

Fracture characteristics

Fracture characteristics and alignment data of each cohort are summarized in Table 2. We observed a significant difference in the distribution of the fracture classification (*P* = 0.003). There was a higher percentage of the simple transverse fracture (32.8% vs. 15.6%), while that of the multifragmentary oblique/spiral fracture was lower (6.2% vs. 25.4%) in the CST group. Patients treated with EIN had significantly more midshaft tibial fractures and associated fibula fractures (67.2% vs. 25% and 95.1% vs. 75%, *P* < 0.001). No other differences were noted between the groups with respect to the angulation, shortening, and displacement of fractures.

Treatment outcome

Patients in the EIN group who stayed in hospital for 6.5 ± 3.8 days had a mean surgical time of 72.5 ± 34.6 min. All patients were casted on average for 31.7 ± 19.0 days. Some had their cast replaced with an external brace because of its convenience and

Table 1
Patients demographics and mechanism of injury.

	EIN (n = 122)	CST (n = 64)	P
Age (y)	7.3 ± 2.3	6.7 ± 1.9	0.09
Weight (kg)	27.8 ± 10.2	22.7 ± 6.5	< 0.001
Male [n (%)]	80 (65.6)	41 (64.0)	0.83
Mechanism of injury [n (%)]	High-energy: 53 (43.4) Low-energy: 69 (56.6)	High-energy: 44 (68.8) Low-energy: 20 (31.2)	< 0.001

EIN indicates elastic intramedullary nailing; CST indicates calcaneal skeletal traction.

Table 2
Fracture characteristics.

	EIN (n = 122)	CST (n = 64)	P
AO PCCF classification [n (%)]			
4.1 (simple transverse)	19 (15.6)	21 (32.8)	0.003
4.2 (multifragmentary transverse)	4 (3.3)	3 (4.7)	
5.1 (simple oblique/spiral)	68 (55.7)	36 (56.3)	
5.2 (multifragmentary oblique/spiral)	31 (25.4)	4 (6.2)	
Location of fracture [n (%)]	Midshaft: 82 (67.2) Distal: 40 (32.8)	Midshaft: 16 (25.0) Distal: 48 (75.0)	< 0.001
Angulation (degree)			
Coronal plane	6.4 ± 5.9	7.7 ± 6.0	0.232
Sagittal plane	5.3 ± 3.9	5.6 ± 3.8	0.562
Shortening (mm)	4.2 ± 2.8	3.9 ± 4.1	0.648
Displacement (mm)	4.0 ± 2.3	3.5 ± 2.4	0.291
Fibula fracture [n (%)]	116 (95.1)	48 (75)	< 0.001

EIN indicates elastic intramedullary nailing; CST indicates calcaneal skeletal traction.

Table 3
Treatment outcomes.

	EIN (n = 122)	CST (n = 64)	P
Surgical time (min)	72.5 ± 34.6	22.8 ± 11.5	< 0.001
Hospital stays (day)	6.5 ± 3.8	26.9 ± 8.4	< 0.001
Cast duration (day)	57.8 ± 25.5	43.1 ± 20.7	< 0.001
Postoperative clinic visits (n)	7.4 ± 2.8	3.0 ± 1.4	< 0.001
Total X-rays (n)	6.9 ± 1.9	7.3 ± 1.6	0.157
Time to union (day)	68.5 ± 17.9	69.6 ± 16.0	0.420
Functional exercises (day)	65.0 ± 22.6	77.2 ± 18.1	< 0.001
Weight-bearing (day)	79.8 ± 22.6	92.5 ± 17.5	< 0.001
Healed angulation (degree)			
Coronal plane	2.9 ± 2.2	2.6 ± 1.8	0.458
Sagittal plane	2.9 ± 2.0	2.8 ± 2.2	0.853
Shortening (mm)	1.0 ± 1.8	0.7 ± 1.5	0.205
Changes in angulation (degree)			
Coronal plane	3.5 ± 5.9	5.2 ± 5.7	0.063
Sagittal plane	3.1 ± 3.7	3.4 ± 3.4	0.660
Change in shortening (mm)	2.7 ± 2.7	2.6 ± 2.3	0.799
Implants duration (day)	EIN: 149.7 ± 26.7	TP: 22.7 ± 6.4	
Hospitalization expenses (RMB)	20,435.6 ± 5631.9	8468.3 ± 2793.0	< 0.001

EIN indicates elastic intramedullary nailing; CST indicates calcaneal skeletal traction; TP indicates traction pin.

portability. Furthermore, they had clinical followed-ups 7.4 ± 2.8 times and received postoperative X-rays 6.9 ± 1.9 times until the fractures healed every 1–2 weeks. After 65.0 ± 22.6 days, patients were encouraged to perform some proper exercises and allowed to bear weight 79.8 ± 22.6 days later. All fractures healed with a mean time of 68.5 ± 17.9 days, and the EIN was removed 149.7 ± 26.7 days after surgery (Table 3).

In the healing radiographic assessment, patients had achieved mean alignment with $2.9 \pm 2.2^\circ$ in the coronal plane and $2.9 \pm 2.0^\circ$ in the sagittal plane. Furthermore, the EIN procedure corrected 3.5 ± 5.9 and $3.1 \pm 3.7^\circ$ in the coronal and the sagittal planes respectively. The mean cost of both hospitalization and treatment was $20,435.6 \pm 5631.9$ RMB.

For patients in the CST group, their mean surgical time was 22.8 ± 11.5 min, and they stayed in hospital for a mean time of 26.9 ± 8.4 days. All patients in the CST group were casted on average for 43.0 ± 20.9 days and afterwards, the cast was replaced with a removable brace. They had fewer clinical visits than patients

in the EIN group (3.0 ± 1.4 times, $p < 0.001$); however, the total X-rays in both groups were similar (7.3 ± 1.6 times, $P = 0.157$). After 78.7 ± 20.6 days, patients were encouraged to start exercising and allowed to begin weight-bearing at 98.0 ± 20.6 days. As a result, all fractures healed with a mean time of 69.6 ± 15.9 days. The films of the healed fractures showed that the average angulations were $2.6 \pm 1.8^\circ$ in the coronal plane and $2.8 \pm 2.2^\circ$ in the sagittal plane, with mean shortening of 0.7 ± 1.5 mm. Moreover, the changes in angulation in the coronal and the sagittal planes were 5.2 ± 5.7 and $3.4 \pm 3.4^\circ$ respectively, and shortening was improved by 2.6 ± 2.3 mm.

Complications

After surgery, 2 patients (1.6%) in the EIN group who developed compartment syndrome, which was reported to be 2% and 4.5% [5,6], were cured by conservative treatment and subsequently neither of them had further complications. In addition, 1 patient

Table 4
Complications.

	EIN (n = 122)	CST (n = 64)	P
Compartment syndrome [n (%)]	2 (1.6)	3 (4.6)	0.457
Venous thromboembolic events [n (%)]	0	0	
Respiratory infection [n (%)]	1 (0.8)	3 (4.6)	0.232
Malalignment (> 5°)	28 (23)	7 (11)	0.046
Malunion (> 10°)	1 (0.8)	1 (1.6)	0.641
Delay union	0	0	
Non-union	0	0	
Shortening > 10mm	0	0	

EIN indicates elastic intramedullary nailing; CST indicates calcaneal skeletal traction.

had a respiratory infection. There were 28 healed patients (23%) with mild malalignment (5–10°). Malunion occurred in 1 patient (0.8%); a 5-year-old girl with a fractured distal tibia and fibula from a vehicular collision. The preoperative angulations were 12.2° valgus and 8.1° procurvatum, with 1.8 mm shortening and 2.1 mm displacement. After surgery, she still had a 13.0° valgus and 6.0° procurvatum deformity until the fracture union. However, with the persistent correction of the EIN, she finally achieved acceptable alignment without an additional operation, and the nails were removed uneventfully 223 days after surgery. In the CST group, 3 patients (4.6%) had early stage compartment syndrome after surgery. However, without external pressure, they were soon cured by medications. Respiratory infection developed in 3 (4.6%) cases, which may have resulted from the long stay in bed or nosocomial infections. Fifty-four patients (89%), in anatomic positions, healed with excellent alignments, while 63 (98.4%) healed within 10° angular deformity. Malunion occurred in 1 (1.6%) case; a 7-year-old boy who had a ground level fall, resulting in a distal tibia and fibula fracture. The initial X-ray films showed 10.0° valgus and 6.3° recurvatum without shortening and displacement. After the CST and casting, the fracture healed within 66 days, with 4.8° valgus and 15.0° recurvatum deformity. The malunion was corrected by prolonged casting. Similarly, no delayed union, non-union, or shortening above 10 mm was found in this group (Table 4).

All patients returned to their activities without symptomatic complications at the final clinical visit. Although some cases had muscle weakness, the range of motion of the injured limb was nearly normal.

Comparison

While comparing the EIN group with the CST group, the surgical time for CST was approximately 50 min faster than that for EIN ($P < 0.001$). However, patients needed approximately 20 days more in hospital for traction ($P < 0.001$). The EIN group required an approximate 2 weeks immobilization ($P < 0.001$) and had 4 times more clinical visits ($P < 0.001$). In addition, although there were no significant differences in union time between the groups, the EIN group began functional exercises and weight-bearing 12 days earlier ($P < 0.001$). For the alignment outcomes, no significant difference was observed in sagittal angulation and shortening changes between both groups. However, the CST group tended towards more coronal angulation corrections ($P = 0.063$). Considering the cost, the mean treatment expenses of the EIN was more than twice the CST cost ($P < 0.001$).

Discussion

To date, this is the first and largest study that compares the outcomes of EIN with CST for the treatment of displaced tibial shaft fractures in a Chinese population. There were noticeable significant differences in the mechanism of injury and fracture char-

acteristics between the two groups. In the EIN group, the incidence of low-energy injuries was higher (56.6%) than in the CST group, and the fracture types were mainly simple oblique and spiral fractures (55.7%), followed by multifragmentary spiral and oblique fractures (25.4%). Midshaft fracture accounted for about 67.2% of cases. However, in the CST group, the proportion of high-energy injuries was higher (68.8%). Simple oblique or spiral fractures (56.3%) were also the most common type of fracture, followed by simple transverse fractures (32.8%). Distal tibia fractures accounted for 75% of cases.

We thought the differences were because the ideal patients for EIN were those with transverse, length-stable, midshaft tibial fractures [2], while traction was more suitable for patients with high risks of unacceptable shortening, which was more likely in children older than 6 years or in children with high-energy injuries [7]. The surgeon considers these factors when choosing the appropriate treatment modality. Hence, the EIN group comprised patients with midshaft fractures due to low-energy injuries, and low-energy injuries are more likely to lead to oblique and spiral fractures because of the mechanisms of applied force [8]. The CST group mainly consisted of distal tibial fractures due to high-energy injuries. In addition to simple oblique and spiral fractures, high-energy direct trauma was more likely to lead to transverse fractures [8]. Concerning the weight and age of the patients, previous studies confirmed that poor outcomes of EIN were associated with increasing age and higher body mass index [9]. Finally, regarding parents' concerns and expectations, the risks and benefits of treatment should be discussed with the parents to allay their fears [7]. However, the surgeon's proficiency and experience with each operation also played an important role. This implies that a certain degree of selection bias existed. Therefore, the differences between the two groups were inevitable.

Predictably this study showed that both approaches provided satisfactory outcomes. However, we noted the different advantages and disadvantages of each procedure. Patients in the EIN group had a shorter stay in hospital, and began functional exercises and weight-bearing earlier than subjects in the CST group. This was probably because the effective internal fixation provided patients a faster recovery of motion than the isolated external fixation. In addition, early weight-bearing was probably beneficial for patients with transverse tibial shaft fractures that were treated by EIN [10]. Some studies report that tibial shaft fractures can be treated successfully without cast immobilization [11][12]. However, patients incurred higher expenses, had more clinical visits, and underwent 2 surgeries under general anaesthesia simultaneously. Prior to this study, we thought that CST would be better than EIN in the shortening correction. However, gaps between the fracture showed up in some of the postoperative X-ray films in the EIN group. This could be because the nail pushed the distal fracture site away when the surgeon placed it and reversed the shortening. Hence, surgeons need to pay attention to this and check the EIN location by intraoperative radiography to prevent excessive lengthening.

EIN has always been a straightforward and effective internal fixation method for long bone fractures in children since Ligier, et al. [13] initial report from France. This is now known as “the gift from god to children” in China. Since then, the scope of treatment with EIN is wider than before. Research has shown that EIN can be used for femoral shaft fractures in patients who are 2 years old to school-age, who weigh a maximum of 50 kg [14][15]. The EIN technique is also reliable for tibia fractures in patients younger than 16 years who weigh between 21 to 122 kg [9]. However, EIN has potential disadvantages that may be unacceptable to the general Chinese population. The disadvantages of EIN which make it less appealing to parents are as follows; the second surgery under is general anaesthesia, hospitalization of children for nail removal, more time commitment, and higher expenses. Besides, meta-analysis conducted by Stenroos, et al. [16] showed that patients treated with EIN had a higher incidence of complications than those conservatively treated (24% vs. 9%). Additionally, after spending a lot of time and money, it is difficult for parents to accept complications or extra operations which are inevitable during the process. Similarly, most pediatric orthopaedists at our center are not willing to take treatment failure risks because of the heavy workload and strained patient-doctor relationship with Chinese doctors [17]. Consequently, these factors make CST another good option for the treatment of displaced tibial shaft fractures.

CST is a incision-free treatment with a shorter surgical time, a wide range of indications, and is more economical. Additionally, this procedure can be done under spinal anaesthesia in older compliant children. Although the CST procedure is simple, some complications may arise. If the pin goes in too deep, there could be damage to the posterior tibial artery. In addition, if traction tends outwards, recurvatum may occur as exemplified by the patient with malunion in the CST group. Although the CST costs longer hospitalization, it can significantly maintain the alignment persistently to avoid shortening and malunion, without affecting the union time. If a procedure achieves better alignment, then longer immobilization is not a shortcoming of a treatment. This is because correcting a malunion is harder than regaining motility of a limb in children². Additionally, when the patient is transferred to a cast after traction, the fracture would have begun to heal. Consequently the casting time of CST was 2 weeks shorter than that of EIN, which decreased casting related problems and shortened the uncomfortable period.

Objectively, several factors play an important role in determining the treatment of DTSF at our center. Firstly, the cost of treatment is always a crucial problem compared to developing countries. Most patients without medical insurance are more likely to choose a more economic treatment even if it would cost them more time. Secondly, the number of emergency patients who need surgery. As the only paediatric specialized hospital in this area, we may receive 7 trauma cases on average in a single day. This may increase up to 20 during summer vacation. Therefore, we must treat them as efficiently as possible if many operations are required, because more emergency patients could come the following day.

An unfortunate but valuable case in the EIN group should be discussed. A 6-year-old boy admitted to our hospital in December 2018 for left TSF (Fig. 1A, B) had closed reduction with EIN fixation surgery. After follow-up, he successfully returned to daily activities about 3 months postoperatively. However, in July 2019, he presented to our hospital again because of a similar type of right TSF (Fig. 1C, D). This time we recommended that his parents select CST for him. This was because after the completion of traction, we could cast his right leg and remove the EIN in the left tibia in 1 operation. Finally, we conducted the operation 25 days after traction. This was an extremely rare case of a treatment involving both EIN and CST, which could help us compare the out-



Fig. 1. Radiographs of the left tibia (A, B) and right tibia (C, D) of the 6-year-old boy at the time of trauma. The long oblique fracture of the left distal tibia occurred in December 2018, and the fracture of the right tibia with similar type occurred in July 2019.



Fig. 2. Radiographs of the left tibia (A, B) treated with elastic intramedullary nailing, and right tibia (C, D) treated with calcaneal skeletal traction 2 weeks postoperatively.

comes of both procedures in 1 individual. It is rather unfortunate that his secondary fracture was not included in this study owing to the dates of this study. However, the radiographs were still obtained from routine clinical follow-up (Figs. 2-4), which was halted because of the Coronavirus Disease 2019 (COVID-19) pandemic. As a result of this, we failed to take radiographs of the right tibia at 6 months' follow-up. The radiographs revealed that the fractures in both tibia healed in anatomically correct positions without malunion or shortening. Nonetheless, the long-term follow-up of this patient is warranted to further compare the outcomes of CST and EIN.

There are several limitations to this study. First is the nature of the retrospective study for which data were collected and reviewed. Additionally, patients were followed up only for 6 months or until radiographic healing. Thus, the long-term outcome measures are not included. Finally, the initial treatment method was determined by the emergency surgeon who decided to admit the patient, and the senior orthopaedic surgeon in the ward who actually managed each case depending on their experience. It is

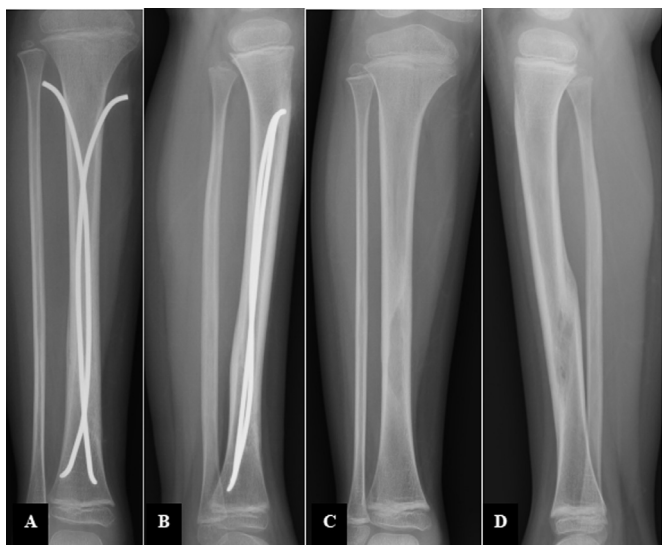


Fig. 3. Radiographs of the left tibia (A, B) treated with elastic intramedullary nailing, and right tibia (C, D) treated with calcaneal skeletal traction at 3 months' follow-up.

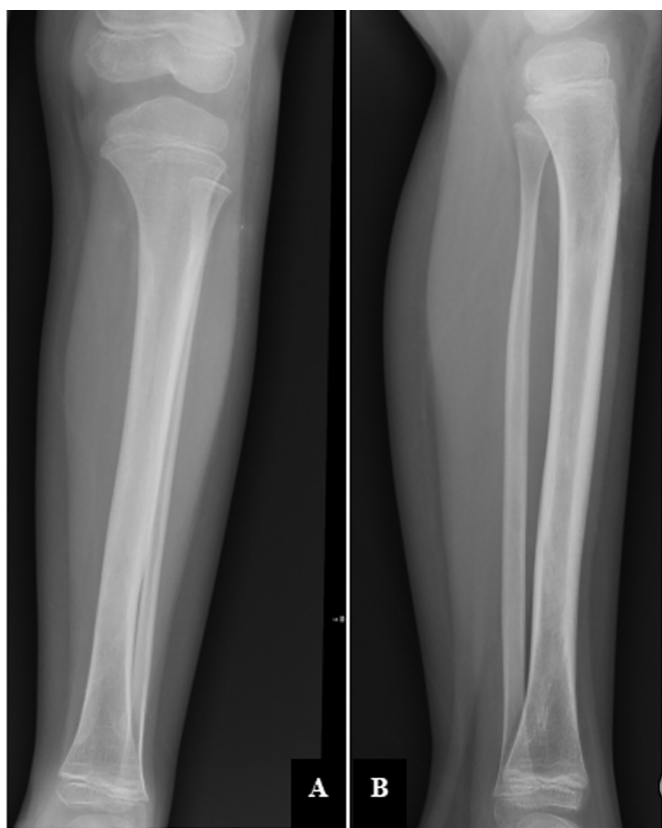


Fig. 4. Radiographs of the left tibia 6 months after elastic intramedullary nailing surgery with the nails removed.

difficult to account for surgeon bias to determine why each of the treatment approaches were selected. Furthermore, the decision could be influenced by considering the different expectations and economic capabilities of the guardians. However, those would be perhaps more reflective of actual clinical practice.

Conclusion

This study revealed that both procedures have acceptable clinical and radiographical results at final follow-up. However, each procedure has its own comparative advantages and favourable conditions. Patients with EIN had shorter hospital stays and faster recovery, which complies with the concept of enhanced recovery after surgery (ERAS). The CST procedure, however, provided a faster surgical time and a slightly better correction of coronal angulation with a lower rate of malalignment and economic costs. Furthermore, the shorter casting time reduced casting related problems and patient's discomfort. Therefore, a variety of factors should be considered when determining the optimal initial intervention for each individual patient, even in different regions.

Declarations of Competing Interest

None.

Acknowledgments

We would like to express gratitude to all the patients and their families. We also acknowledge the Radiology Department of our hospital for providing support, and colleague Ting Cai for statistical analysis.

References

- [1] Rickert KD, Hosseinzadeh P, Edmonds EW. What's new in pediatric orthopaedic trauma: the lower extremity. *J Pediatr Orthop* 2018;38(8):e434–9.
- [2] Raducha JE, Swarup I, Schachne JM, Cruz AI, Fabricant PD. Tibial shaft fractures in children and adolescents. *JBS Rev* 2019;7(2):e4.
- [3] Slongo TF, Audigé L. AO Pediatric Classification Group. Fracture and dislocation classification compendium for children: the AO pediatric comprehensive classification of long bone fractures (PCCF). *J Orthop Trauma* 2007;21(10 Suppl):S135–60.
- [4] Flynn JM, Hresko T, Reynolds RA, Blasler RD, Davidson R, Kasser J. Titanium elastic nails for pediatric femur fractures: a multicenter study of early results with analysis of complications. *J Pediatr Orthop* 2001;21(1):4–8.
- [5] Kinney MC, Nagle D, Bastrom T, Linn MS, Schwartz AK, Pennock AT. Operative versus conservative management of displaced tibial shaft fracture in adolescents. *J Pediatr Orthop* 2016;36(7):661–6.
- [6] Pennock AT, Bastrom TP, Upasani VV. Elastic intramedullary nailing versus open reduction internal fixation of pediatric tibial shaft fractures. *J Pediatr Orthop* 2017;37(7):e403–8.
- [7] Fynn JM, Schwend RM. Management of pediatric femoral shaft fractures. *J Am Acad Orthop Surg* 2004;12(5):347–59.
- [8] Setter KJ, Palomino KE. Pediatric tibia fractures: current concepts. *Curr Opin Pediatr* 2006;18(1):30–5.
- [9] Goodbody CM, Lee RJ, Flynn JM, Sankar WN. Titanium elastic nailing for pediatric tibia fractures: do older, heavier kids do worse? *J Pediatr Orthop* 2016;36(5):472–7.
- [10] Stenroos A, Jalkanen J, Sinikumpu JJ, Palmu S, Koskimies-Virta E, Laaksonen T, et al. Treatment of unstable pediatric tibia shaft fractures in Finland. *Eur J Pediatr Surg* 2019;29(3):247–52.
- [11] Griffet J, Leroux J, Boudjouraf N, Abou-Daheer A, El Hayek T. Elastic stable intramedullary nailing of tibial shaft fractures in children. *J Child Orthop* 2011;5(04):297–304.
- [12] Marengo L, Paonessa M, Andreacchio A, Dimeglio A, Potenza A, Canavese F. Displaced tibia shaft fractures in children treated by elastic stable intramedullary nailing: results and complications in children weighing 50 kg (110 lb) or more. *Eur J Orthop Surg Traumatol* 2016;26(03):311–17.
- [13] Ligier JN, Metaizeau JP, Prevot J. Closed flexible medullary nailing in paediatric traumatology. *Chir Pediatr* 1983;24:383–5.
- [14] Moroz LA, Launay F, Kocher MS, Newton PO, Frick SL, Sponseller PD, et al. Titanium elastic nailing of fractures of the femur in children: predictors of complications and poor outcome. *J Bone Joint Surg Br* 2006;88:1361–6.
- [15] Sink EL, Faro F, Polousky J, Flynn K, Gralla J. Decreased complications of pediatric femur fractures with a change in management. *J Pediatr Orthop* 2011;31(5):633–7.
- [16] Stenroos A, Puhakka J, Nietosvaara Y, Kosola J. Treatment of closed tibia shaft fractures in children: a systematic review and meta-analysis. *Eur J pediatr Surg* 2019;22 [Online ahead of print].
- [17] Sun Tao, Gao Lei, Li Fujun, Shi Yu, Xie Fengzhe, Wang Jinghui, et al. Workplace violence, psychological stress, sleep quality and subjective health in Chinese doctors: a large cross-sectional study. *BMJ Open* 2017;7(12):e017182.