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Case Series

# Functional outcomes and complications of tibial lengthening using unilateral external fixation and then plating. A prospective case series

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ABSTRACT

*Introduction:* and Importance: The purpose of this study was to assess the functional outcomes and complications of tibial lengthening using unilateral external fixation and then plating.
*Material and methods:* This was a prospective case series study that enrolled people of short stature or leg length discrepancy of more than 3 cm from January 2019 to January 2021. A total of 11 patients (one male and 10 females) were recruited for the study, including seven short statures and four patients with leg length discrepancies. The external fixaters in this study were Muller's frame or Nhan's frame.
*Results:* The average age of patients at the time of surgery was 25.89 years (range: 13–41 years). The study included 18 tibias that were lengthened and then plated. Average tibial lengthening was 6.89 ± 1.25 cm (21.87 ± 6.59%). The functional result was excellent in seven patients and good in four patients. Pin-track infection occurred in three tibias. There was one case of superficial infection. 12 legs (66.7%) developed ankle equinus after removing the external fixator. Four legs with severe equinus deformity were treated with percutaneous tendo-Achilles lengthening. Valgus deviation occurred in eight tibias. Peroneal nerve neuropraxia occurred in two legs during distraction. Distal migration of the fibula head occurred in four legs.
*Conclusion:* Our study suggested that tibial lengthening using Nhan's external fixater or Muller frame then plating was safe and effective provided complications were looked for and kept in check. Equinus contracture, pin-site infection, and valgus alignment were the most common complications.
*Level of evidence:* Level IV, prospective case series study.

## 1. Introduction

Distraction osteogenesis which can be attributed to the work of Ilizarov is widely used effectively in the treatment of many different orthopaedic pathologies and procedures such as bone defects, nonunion, extremity deformities, and limb-length inequalities, including limb lengthening. Nevertheless, the method is not without disadvantages and complications [1,2]. The most common of which are long external fixation times, high rates of pin-site infection, scarring, axial deviation, and refracture [3–9]. Lengthening techniques over intramedullary (IM) nails or lengthening technique then nailing have become an alternative to the traditional lengthening method with an external fixator [7,10]. The duration of external fixation was reduced resulting in earlier patient rehabilitation and mobilization [7,10–13]. With the advent of new motorized intramedullary nails that can be used to lengthen bone reliably recently [14–20]. However, patients with a narrow intramedullary cavity, joint contracture, or pediatric patients are not suitable for lengthening over an intramedullary nail, lengthening then nailing, or for motorized intramedullary nail. In recent years, the technique of lengthening using external fixater then plating has been applied in these patients [21–26].

In Vietnam, limb lengthening has been conducted since the 1980s using the standard Ilizarov technique [2]. The technique of tibial lengthening using external fixater then plating has been applied in the 108 Central Military Hospital (Hanoi, Vietnam) since 2019 for patients who were suitable for lengthening over nail technique. Thus, this study aimed to assess the functional outcomes and complications of tibial lengthening and then plating and how to correct these complications.

## 2. Materials and methods

### 2.1. Study design and subjects

This was a prospective case series study that enrolled patients who

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had been undergone tibial lengthening and then plating in our hospital (Level I Institue of Trauma and Orthopaedics, Hanoi, Vietnam) from January 2019 to January 2021. The study has been approved by our hospital's Ethical Committee in Biomedical Research. 11 patients (one male and 10 females) were recruited for the study, including seven patients of short stature and four patients of leg length discrepancy. The surgeon was the author (L.V.N, D.V.L), who was senior surgeon in leg lengthening. The inclusion criteria were short statures with age greater than 18 years and skeletal maturity, desire to have stature lengthening, the diameter of tibial medullary canal less than 8 mm; patients had leg length discrepancy of more than 3 cm, who was not suitable for leg lengthening over nail due to small diameter of the tibial medullary canal (less than 8 mm) or knee stiffness. We excluded patients with infection, tumors, mental illness. Individuals with dysmorphophobia or another major depressive illness and those who had unrealistic goals regarding the gain in height were excluded after examination by a psychologist.

### 2.2. The external fixators

Two kinds of domestic external fixater were used in this case series. Nhan's external fixator consists of two steel vertical bars (10 mm diameter) (Fig. 1). The vertical bars included opposing threads (1 mm pitch) to stretch or compress the bone by turning. Nhan's external fixator was designed with arrows to indicate the direction of compression or expansion. By rotating each vertical bar three times daily, with each turn equal to one face in the middle of the bar, the pin clamps at the proximal and distal of the bar would expand approximately 1 mm.

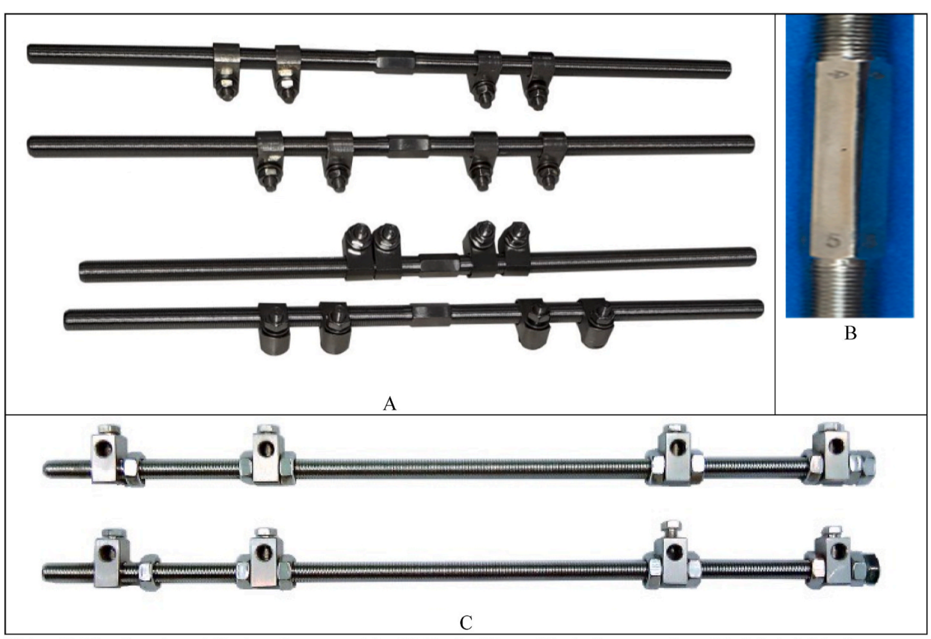
Muller external fixater consists of two steel vertical bars (8 mm diameter) (Fig. 1). The vertical bars included threads (0.8 mm pitch) to stretch or compress the bone by turning adjustable nuts. By rotating all nuts at the proximal 2 bars four times daily with each turn equal to one face in the nuts, the pin clamps at the proximal end of the bar would expand approximately 0.8 mm.

### 2.3. Surgical technique

The patient was in a supine position on the surgical table. All operations were performed under spinal anesthesia. Tourniquets were used to impede blood flow to the operated limbs.

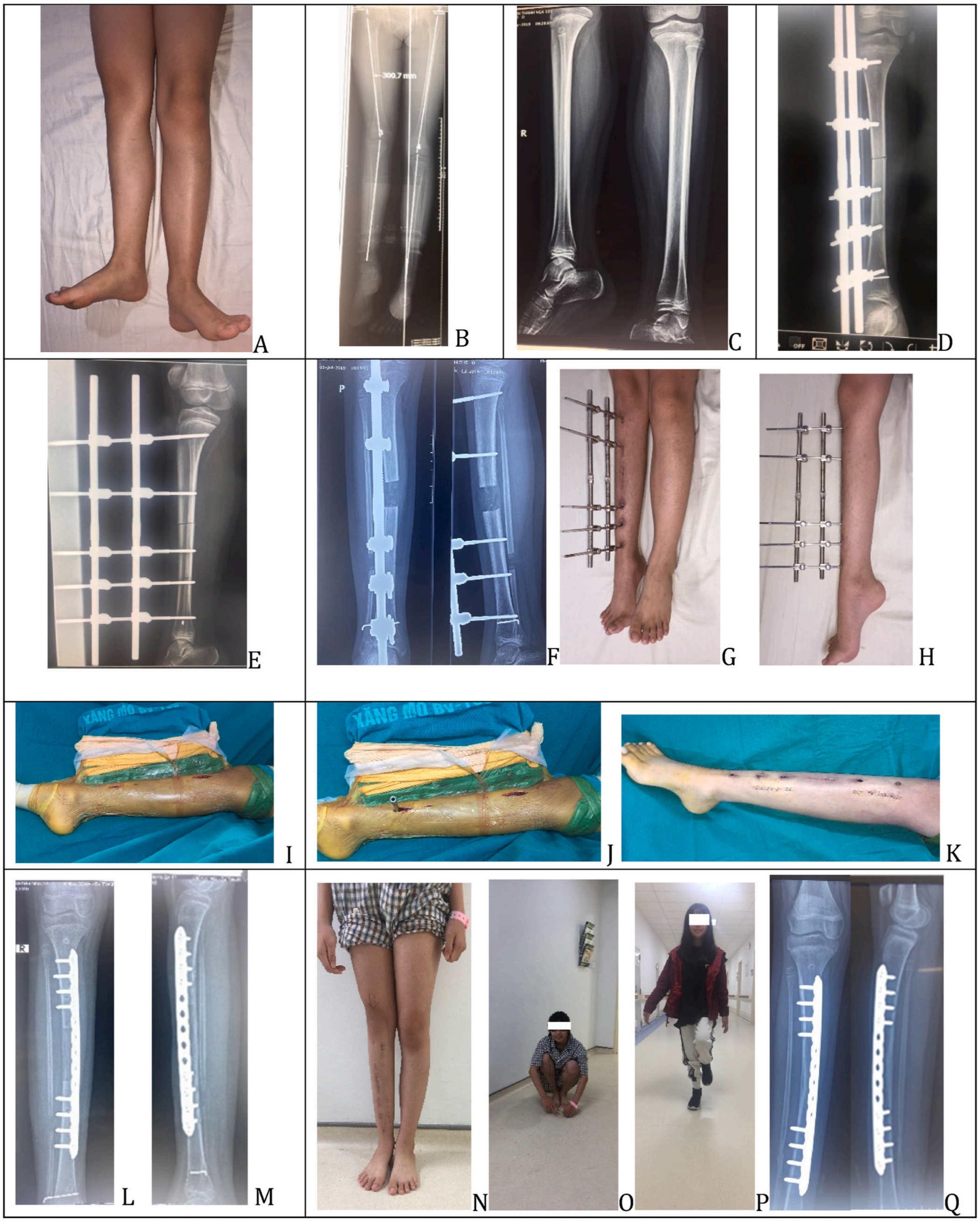
The fibula was osteotomized using a drill and a chisel at the junction of the middle third and distal third. First, a monolateral external fixator (Muller frame or Nhan's frame) was attached to the anterior crest of the tibia using two Schanz pins (with Muller external fixater) or three Schanz pins (with Nhan's external fixater) distally and two Schanz pins proximally. The most proximal Schanz pin should be just distal to the tibial tuberosity. The most proximal Schanz pin should be at just distal to the tibial tuberosity. The most distal Schanz pin should be as more distal as possible. A corticotomy was then performed at the middle diaphyseal of the tibia between the second pin and third pin from proximal to distal using drills and a chisel. The distant between the corticotomy site and the second pin or third pin should be approximately 2 cm–3 cm. The distal fibula was fixed to the tibia using a 2 mm K-wire or a 4.0 mm screw (Figs. 2 and 3).

On the seventh day postoperatively, lengthening was started with a 1/3 mm extension applied three times daily (in Nhan's external fixater) or with a 0.2 mm extension applied four times daily (with Muller external fixater). Patients were discharged once initial lengthening gaps reached 2–3 mm and they could perform partial weight-bearing activities. Before discharge, patients were instructed regarding properly performing distractions at home. Bone healing progress with distraction measurements was tracked monthly and supplemented with radiographs. Upon reaching the desired leg length, the patient had a second operation for percutaneous locking plate of tibia and removal of external fixator. A straight, narrow locking compression plate (Mikromed, Polish) was used for instrumentation. The narrow locking plate was low profile and more available to the MIPO technique. The external fixator was prepared in the field, all of the pin sites were covered with Betadine, and the external fixator was covered with sterile towels. It was necessary to insert the plate with the external fixator still in place. The external fixator also served to maintain the bone in an ideal alignment during plate insertion. The plate was inserted subcutaneously at the medial border of the tibia or submuscular at the lateral border of the tibia using a 3-cm lateral incision over the proximal tibia. Three locking srews were inserted percutaneously at each fragment of the tibia. Contact between




Note: A) Nhan's external fixator after assembly; B) Vertical bar with six faces numbered 1-2-3-4-5-6 in the direction of stretching. C) Muller external fixator after assembly.

**Fig. 1.** The external fixators were used in the study.
Note: A) Nhan's external fixator after assembly; B) Vertical bar with six faces numbered 1-2-3-4-5-6 in the direction of stretching. C) Muller external fixator after assembly.




Note: A,B,C) Clinical and X-rays pre-operative of 13 year-old female patients showed a 7cm leg-length discrepancy; D,E) post-operative, F) X-rays 1.5 months post-operative; G,H) 3 months post-operative; I,J,K) Plating and removal of external fixater; L,M) 2 months post-operative of plating and removal of frame; N,O,P,Q) Clinical and X-rays 1 years post-operative (after plating removal of frame).

**Fig. 2.** A 7 cm right tibial lengthening using Nhan's external fixator then locking plating.
Note: A,B,C) Clinical and X-rays pre-operative of 13 year-old female patients showed a 7 cm leg-length discrepancy; D,E) post-operative, F) X-rays 1.5 months post-operative; G,H) 3 months post-operative; I,J,K) Plating and removal of external fixater; L,M) 2 months post-operative of plating and removal of frame; N,O,P,Q) Clinical and X-rays 1 years post-operative (after plating removal of frame).

internal and external fixation was avoided. After completing the insertion of all screws, the frame was removed completely and the stability was controlled clinically and radiologically (Fig. 2).

### 2.3.1. *Follow up*

Patients could perform partial weight-bearing activities until the presence of mature bridging callus across two of three visible cortices on anteroposterior and lateral radiographs. Lastly, plates were removed once complete and solid healing was observed in the tibia. Monthly follow-ups were conducted until complete consolidation, after which follow-up times were extended to every three months.

## 2.4. *Statistical analysis*

Descriptive analyses were conducted regarding all patients participating in this study. Continuous variables including age, number of tibias, tibial lengthening, tibial healing index (BHI), external fixation index (EFI), etc. were reported as means and standard deviations.

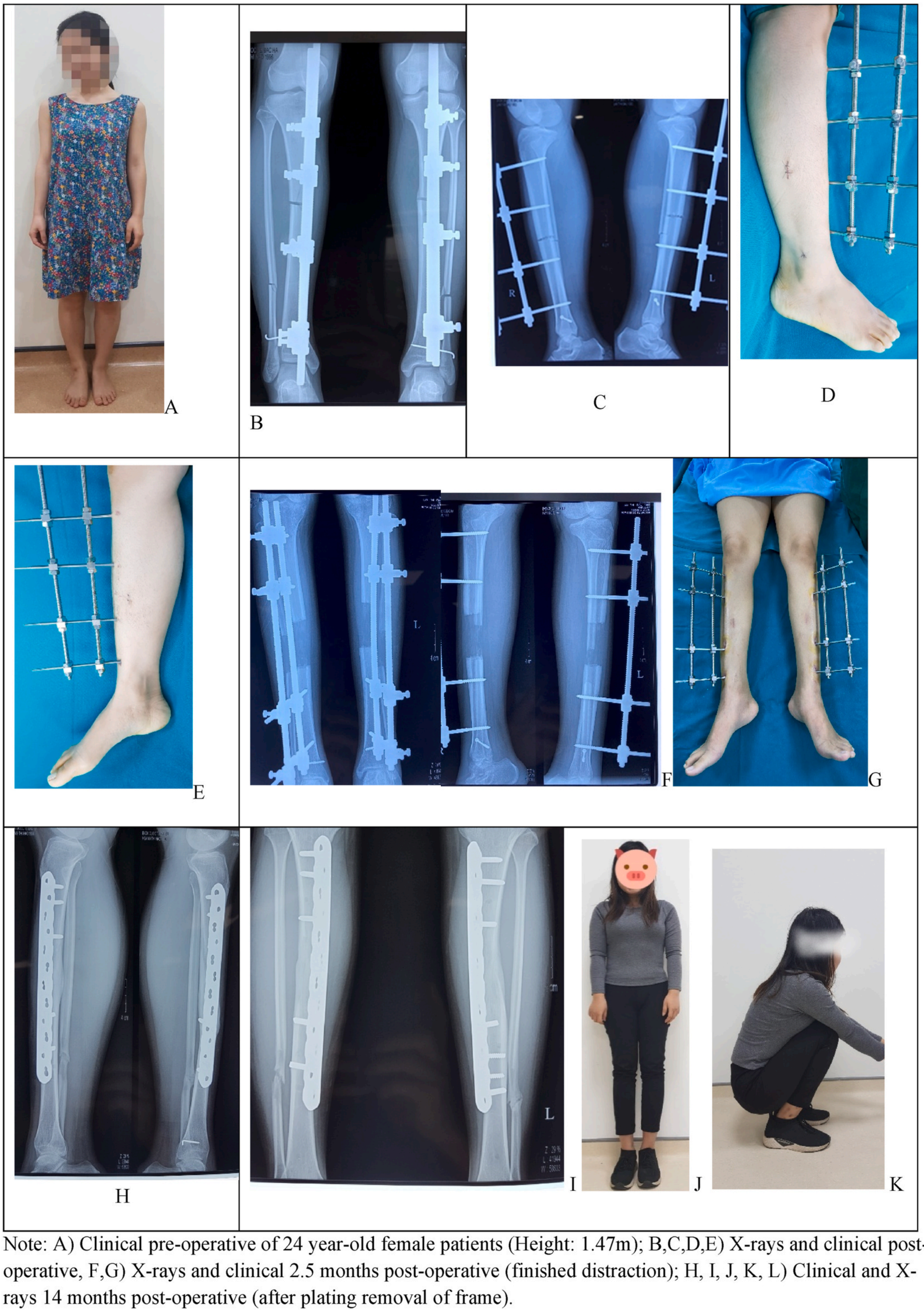



**Fig. 3.** A 7 cm bilateral tibial lengthening using Muller external fixator then locking plating.
Note: A) Clinical pre-operative of 24 year-old female patients (Height: 1.47 m); B,C,D,E) X-rays and clinical post-operative, F,G) X-rays and clinical 2.5 months post-operative (finished distraction); H, I, J, K, L) Clinical and X-rays 14 months post-operative (after plating removal of frame).

Proportions were compared using the chi-squared test or Fisher's exact test. All analyses were conducted using STATA 14, and $p$-values $< 0.05$ were considered statistically significant.

We used the LLRS AIM Index to quantify the severity of lower extremity deformities [27]. This included evaluation of the location of deformity (0–4), leg length inequality (0–4), risk factor (0–4), soft tissue covering (0–4), angulation deformity (0–4), infection/bone quality (0–4), motion/stability of the joint above and below. The total scores are range from 0 to 28. The severity of lower extremity deformities was classified as normal (0), minimal complexity (1–5), moderate complexity (6–10), substantial complexity (11–15), or high complexity (16–28). The outcome was evaluated according to ASAMI classification

[28]. In the ASAMI classification, the bone result is based on four criteria: union, infection, deformity, and leg length discrepancy. An excellent result of bone is defined as a union without infection, deformity <7°' and a leg length discrepancy <2.5 cm. A good result is defined as union plus any two of the last three features of excellent. A fair result was defined as union plus any one of the last three features of excellent. A poor result is defined as nonunion, refracture, or failure to meet three of the last three features of excellent. The ASAMI functional result is based on five criteria: the presence of a limp, stiffness of the knee or the ankle, pain, soft-tissue sympathetic dysfunction, and the ability to perform previous activities of daily living. An excellent result is defined as a fully active of daily living (ADL), no pain or mild pain; no limp, no soft tissue sympathetic dystrophy, knee or ankle joint contracture $< 5°$, loss of ankle or knee motion $< 15°$. A good result is defined as almost all ADL, with minimal difficulty, no pain or mild pain, failure to meet one of the other criteria. A fair result is defined as most ADL with minimal difficulty, no pain or mild pain, failure to meet two of the other criteria. A poor result is defined as significantly limited ADL, significant pain requiring narcotics, failure to meet three of the other criteria. Delayed union was defined as a healing time of more than 6 months. Bony union was defined as the presence of mature bridging callus across three of four visible cortices on anteroposterior and lateral radiographs and painless full weight-bearing. The complications were recorded according to the Paley classification [29]. This case series has been reported in line with the PROCESS Guideline [30]. We submit our work with a Research Registry unique identifying number is researchregistry7465.

Hyperlink to our specific registration: https://www.researchregistry.com/browse-theregistry#home/registrationdetails/61befce018dca8001efe15bc/

## 3. Results

### 3.1. The characteristics of patients

Summary characteristics of patients enrolled in the study are reported in Table 1. The average age of patients at the time of surgery was 41 years for male patients and 24.47 years for female patients. The study included 18 tibias. 4 patients had a history of smoking and no patient had a history of diabetes mellitus. The average duration of follow-up was 1.8 years (range: 0.8–2.5 years). The causes of leg length discrepancy were polio (one patient), post-infection (one patient), post-traumatic (two patients). Seven patients experienced difficulties related to short stature and suffered from inferiority complexes, and they reported difficulty finding a job due to their height. The severity of lower extremity deformities according to the ASAMI classification was normal in 3 patients, minimal complexity in 4 patients, moderate complexity in 4 patients. We used Nhan's external fixater for tibial lengthening in four out of 11 patients of tibial lengthening and used Muller frame for tibial lengthening in seven out of 11 patients of tibial lengthening.

### 3.2. The primary and secondary outcomes

Mean clinical intervention data was shown in Table 2. Limb lengthening goals were achieved in all patients. Average tibial bone lengthening was 6.89 ± 1.25 cm (range: 5–8 cm). The mean percentage increase in tibial length was 21.87 ± 6.59%.

All patients experienced good wound healing except one case of superficial infection. All patients had been achieved the expected leg length. Bone regenerate healing was not altered by insertion of the plate. According to the ASAMI classification, the tibial calluses were excellent in ten tibias, good in eight tibias. No bone required bone grafts. According to the ASAMI classification, the functional result was excellent in seven patients, good in four patients. We did not observe incidents of neurovascular compromise or compartment syndrome, premature consolidation, or refracture (Table 3). The range of motion at the knee and ankle were normally restored for all patients at the final follow-up examination. All patients were able to carry out daily life activities without difficulty (Figs. 2 and 3).

### 3.3. The complications

Pin-track infection occurred in three out of 18 tibias, that were treated with an oral antibiotic. There was one case of superficial infection that improved with oral antibiotics. No case of deep infection was observed. 12 legs (66.7%) developed ankle equinus after removing the external fixator. Four legs with severe equinus deformity were treated with percutaneous tendo-Achilles lengthening while eight out of 12 legs only had mild equinus deformity that underwent physiotherapy and was recovery soon after removing external fixator. Four legs with severe equinus that had a tibial lengthening over 25% of the tibial length and in patients who had not used foot splints during sleep. All patients had normal ankle range of motion at the final follow-up examination. The common peroneal nerve was not released in any patient. Peroneal nerve neuropraxia occurred in two legs during distraction. The lengthening speed was reduced. All of them were in full recovery at the final follow-up.

No case of delayed consolidation was observed. Distal migration of the fibula head (0.2 cm–0.5 cm) occurred in four legs. The knee functions of these patients were restored at the final follow-up examination.

Valgus deviation occurred in eight tibias out of 18 tibias during lengthening in patients that had neutral or valgus alignment preoperatively, and valgus deviation increased during lengthening. Closed reduction of the tibia was done before inserting the locking plate and locking screws at the proximal segment and distal segment using C-arm. Closed reduction of the tibial valgus alignment could be done by hand easily.

No tibial fracture or proximal migration of the distal fibula was noted. However, fibula nonunion occurred in 6 legs. Overall, all patients attained complete recovery. Neither limited movement nor knee or ankle instability were observed.

**Table 1**
Characteristics of the 11 patients enrolled in the study.

| Parameter | Male (n = 1) | Female (n = 10) | Total |
|---|---|---|---|
| Age (year) | 41 | 24.27 (3.29) | 25.89 (6.53) |
| Number of tibia | 1 | 17 | 18 |
| Polio | 0 | 1 | 1 |
| Congenital deficiencies | 0 | 0 | 0 |
| Post-infection | 0 | 1 | 1 |
| Post-traumatic | 1 | 1 | 2 |
| Short stature | 0 | 7 | 7 |
| Severity of lower extremity deformities | | | |
| Normal | 0 | 3 | 3 |
| Minimal complexity | 0 | 4 | 4 |
| Moderate complexity | 1 | 3 | 4 |
| Substantial complexity | 0 | 0 | 0 |
| High complexity | 0 | 0 | 0 |

**Table 2**
The results after tibial lengthening using external fixators then plating.

| Variable | Value |
|---|---|
| Tibial lengthening (cm) | 6.89 (1.25) |
| Percentage increase in tibial length (%) | 21.87 (6.59) |
| BHI (days/cm) | 43.63 (5.48) |
| EFI (days/cm) | 12.36 (0.81) |
| ASAMI bone results | |
| Excellent | 10 |
| Good | 8 |
| Fair | 0 |
| ASAMI functional results | |
| ASAMI score | |
| Excellent | 7 |
| Good | 4 |
| Fair | 0 |

**Table 3**
A summary of the complications.

| Complications | Number of problems | Number of obstacles | Number of sequelae | Total number |
|---|---|---|---|---|
| Soft tissue-related | | | | |
| Pin-track infection | 3 | 0 | 0 | 3 |
| Superficial infection | 1 | 0 | 0 | 1 |
| Deep infection | 0 | 0 | 0 | 0 |
| Ankle equinus | 8 | 4 | 0 | 12 |
| Knee flexion contracture | 6 | 0 | 0 | 1 |
| Peroneal nerve injury | 2 | 0 | 0 | 2 |
| Bone-related | | | | |
| Valgus alignment | 0 | 8 | 0 | 8 |
| Rotation deformity | 0 | 0 | 0 | 0 |
| Premature consolidation | 0 | 0 | 0 | 0 |
| Delayed consolidation | 0 | 0 | 0 | 0 |
| Fibular nonunion | 0 | 0 | 6 | 6 |
| Distal migration of proximal fibula | 4 | 0 | 0 | 4 |
| Proximal migration of distal fibula | 0 | 0 | 0 | 0 |
| Leg length discrepancy | 0 | 0 | 0 | 0 |
| Implant related | 0 | 0 | 0 | 0 |
| Total | 24 | 12 | 6 | 42 |

## 4. Discussion

Since Paley et al. described the technique of lengthening over the nail (LON) in 1997, this technique became increasingly popular because of shortening the external fixator period and increasing patient comfort, resulting in earlier patient rehabilitation and mobilization [7,10]. Nevertheless, the LON technique has some disadvantages. The high rate of deep infection (6%, 2.4%, 3.5%) were reported by Kim et al. [13,31], Kocaoglu et al. [13,31], Paley et al. [7,10]. Deep infection may be the result of the IM nail being in contact with the wires and pins. The new motorized intramedullary nails that could be used to lengthen bone reliably recently [14–20]. However, patients with a narrow or sclerotic intramedullary cavity or pediatric patients were not suitable for lengthening over an intramedullary nail, lengthening then nailing or motorized intramedullary nails. In recent years, the technique of tibial lengthening using external fixater and plating had been applied in these patients. Some authors used tibial lengthening technique over the plate [32,33], but the simultaneous use of external and internal fixation may be the major factor in increasing the risk of infection, and it was not easy to apply the pins of external fixator far from the plate. So, some authors used tibial lengthening technique and then plating [21–26]. The Ilizarov frame, Orthofix frame, or Taylor Spatial Frame had been used. The Ilizarov frame was not comfortable and not easy for plating. The Orthofix frame and Taylor Spatial Frame were more comfortable for the patient, it permitted more safe zones for plating, but it was not cheap and not available in a low-income country like Vietnam.

This study showed positive results from using domestic external fixators then locking plating in tibial lengthening. The lengthening goals had been reached in all patients. Nhan's frame consists of two vertical bars with reverse threads, using a design that allows patients can adjust the frame themselves at home through either distraction or compression. Closed reduction of posterior angulation of the tibia could be done by maintaining the first vertical bar (the nearest bar from the skin) and rotating the second vertical bar. However, in tibial lengthening, we had to use five Schanz pins in Nhan's external fixator to prevent torsion deformity. We could use Muller external fixater with four Schanz pins for tibial lengthening. Muller external fixater became popular in the treatment of open fracture in Vietnam. This is the first research using Muller external fixater for leg lengthening. We used the Muller frame for 14 tibial lengthening in 8 patients. The tibial lengthening was 6.89 ± 1.25 cm (range: 5–8.5 cm).

The EFI in our study was 12.36 days/cm, which was approximately one-third of the duration reported in limb-lengthening studies that used only an external fixator [4,11]. The duration of external fixation was reduced resulting in a low rate of pin-site infection, less patient pain and discomfort, and earlier patient rehabilitation and mobilization.

Some authors emphasized canal reaming and intramedullary nail insertion may disrupt and injure the bone marrow, causing slow consolidation and may increase the risk of fat embolism in the LON technique [1,4,34,35]. The lengthening technique then locking plating allowed the application of the MIPPO technique that preserved the periosteal and endosteal circulation of the diaphyseal bone. The locking plate also provided rigid fixation. No fracture of the locking plate was observed in our research. No case of delayed consolidation or large bone defects that required bone graft was observed.

The use of the MIPPO technique through a percutaneous fixation technique in the medial aspect or lateral aspect of the tibia, that permitted minimal dissection of the soft tissues while preventing cross-contamination with the pin tracts of the external fixators. In our experience, plating should be done in the medial aspect of the tibia, and the pins of the external fixator should be inserted at just the lateral tibial crest. If the soft tissue at the medial aspect of the tibia did not permit plating, the pins of the external fixator should be inserted at just the medial tibial crest. This kind of inserting pins of the external fixator may permit preventing cross-contamination with the pin tracts of the external fixators during plating. In our research, there was one case of superficial infection that improved with oral antibiotics. In this case, the cause of infection may be the contact between the pin and plate during plating due to the prominence of broad locking plate. We recommended using a narrow locking plate for the MIPPO technique in tibia lengthening in a safe zone without pins of external fixator.

In this research, the valgus deviation was one of the most common complications during the distraction period of tibial lengthening due to contraction of a muscle in the leg (eight out of 18 legs), especially in those who had neutral or valgus alignment preoperatively. Closed reduction was done before inserting the locking plate and locking screws at the proximal segment and distal segment using C-arm. Closed reduction of the tibial valgus alignment could be done by hand easily. Harbacheuski [26] observed a 27% incidence of varus malalignment in tibial lengthening using Taylor Spatial Frame after plating. The corticotomy site was at the proximal third of the tibia. He reported that the cause of varus deviation was the lateral proximal tibia locking plate was not strong enough to support an immature regenerate after full weight-bearing; fracture of plate occurred in two cases. In our series, the corticotomy site was at the middle third of the tibia (instead of metaphyseal corticotomy) and a narrow straight locking plate with 5.0 mm locking screws was used for plating at the medial aspect of the tibia in most cases (nine out of 11 cases). In addition, patients could perform partial weight-bearing activities until the presence of mature bridging callus across two of three visible cortices on anteroposterior and lateral radiographs and. Any complications of varus deviation, fracture of locking plate after plating of the tibia was observed. Other authors reported no axial deviation after plating of the tibia [24].

Nonunion occurred in six fibulas, most likely due to periosteal damage during the osteotomy, but this did not affect limb functions. Kim et al. also encountered a similar situation [13]. Deep infection is the most dangerous complication from limb lengthening, but we did not observe it. It was similar to those of other authors who used the tibial lengthening technique then plating [21–26]. To prevent deep infection, these authors recommended covering carefully the pin sites and frame maximally with sterile towels to minimize contact and contamination (Fig. 2 I, J). The plate should be inserted through a minimal incision approach in the safe zone. Care must be taken to avoid contact between the internal and external fixation during plating.

In this study, all patients underwent physiotherapy with stretching of the Achilles tendon, partial body-weight bearing, and application of foot splints. Four legs had severe contractures of Achilles tendons and underwent percutaneous tendo-Achilles lengthening. The rate and severity level of Achilles tendon contracture observed in this series are most likely related to the degree of limb lengthening and poor post-operative rehabilitation. A lengthening level of less than 20% in the tibia was previously recommended due to a lower rate of Achilles tendon contracture; however, this level was typically met with dissatisfaction from short stature patients [11,12]. It was found that the preventive measures of severe equinus deformity were good post-operative rehabilitation and application of foot splints during sleep.

Common peroneal nerve injury in our series occurred in only two legs of which no patients needed decompression; this is contrary to the results of Nogueira [36] who reported 9.3% cases of nerve injury in 814 cases of limb lengthening of which 70% needed decompression. Kim [13] reported one case of peroneal nerve injury (2,5%) when the common peroneal nerve was routinely released through a small oblique incision over the fibular neck in all cases of leg-lengthening over the nail.

Our study has some limitations. The number of patients studied was small and their follow-up was 1.8 years (range: 0.8–2.5 years). The locking plate was not removal in most patients. Further research should be based on the larger sample size, longer follow-up time.

## 5. Conclusion

The tibial lengthening using Nhan's external fixater or Muller frame then plating method shortened the external fixater index and increased patient comfort, decreasing complications during the lengthening of extremities. It was an easy, effective, and relatively safe method provided the complications should be looked for and kept in check Equinus contracture, pin-site infection, and valgus deviation were the most common complications during the tibial lengthening period. This method should be considered an attractive alternative to that of tibial lengthening over a nail or motorized intramedullary nails.

## Ethical approval

All procedures were approved by the 108 Central Military Hospital's Institutional Review Board, Hanoi, Viet Nam.


## Sources of funding

No financial support was received for the completion of this study.


## Author contribution

LVN designed and conceptualized the study. LVN, DVL conducted the data analysis, interpreted results. LVN prepared the manuscript. All authors contributed to critical revision of the manuscript regarding important intellectual content and read and approved the final manuscript.

## Consent

Written informed consent was obtained from the patient for publication of this case series and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

## Registration of research studies

Name of the registry: Research Registry.

Unique Identifying number or registration ID: researchregistry7465.

Hyperlink to our specific registration: https://www.researchregistry.com/browse-the-registry#home/registrationdetails/61befce018dca8001efe15bc/

## Guarantor

Dr. Luong Van Nguyen; Dr. Doan Van Le.

## Provenance and peer review

Not commissioned, externally peer-reviewed.

## Declaration of competing interest

The authors declare that they have no conflicts of interest.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.103262.

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