Case Series

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The results of femoral lengthening using domestic unilateral external fixation and then plating: the first case series in Vietnam

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Introduction and importance: This study aimed to assess the results of femoral lengthening using an external fixator and then plating.

Case presentation: This prospective case series study enrolled 11 patients who underwent femoral lengthening and then plating (LATP) between January 2019 and April 2023. The average age of patients was 14.45 ± 7.54 years. One patient with a femur was lengthened and plated, and one tibia was lengthened over a nail simultaneously. The average femoral lengthening was 8.41 ± 1.35 cm.

Clinical discussion: The femoral healing result was excellent in seven femurs and good in four femurs; the functional outcome was excellent in five patients and good in six patients. Pin-track infection occurred in all patients. A limited range of motion of knee flexion occurred in eight patients. Femoral varus and procurvatum deviation occurred during distraction in four and two patients. Femoral LATP was considered an attractive alternative to intramedullary lengthening nails in a low-income country.

Conclusion: Our research suggests that femoral LATP was an effective method. However, the most common complications were pin-site infection and extensive knee contracture. Further research should be done with a larger sample size and longer follow-up time.

Level of evidence: Level IV—prospective observational case series study.

Keywords: case series, distraction osteogenesis, femoral lengthening, lengthening then plating, Vietnam

Introduction

Limb lengthening using external fixators is widely used to treat limb-length inequalities. The most common disadvantages of this method are long external fixation times, high rates of pin-site infection, scarring, axial deviation, and refracture[1–7]. Lengthening over intramedullary nails (LON) or lengthening and then nailing (LATN) has become an alternative method with a shorter duration of external fixator and an earlier rehabilitation and mobilization[5,8,9]. However, patients with a narrow intramedullary cavity, joint contracture, or pediatric patients are unsuitable for the LON or LATN techniques. During the femoral lengthening over a nail, the deep infection may result from the nail being in contact with the wires and pins. In femoral lengthening, it is not easy to apply the pins of the external fixator far from the IM nail. Some authors used the femoral lengthening technique over the plate[10,11], but simultaneous external and internal fixation may significantly increase the risk of infection. The LATP technique has been applied to these patients with a lateral approach for femoral plating[12–18]. However, femoral plating using the lateral approach took work because the approach must be far from the pins of the external fixator. In recent years, some authors have used the anterior or medial approach for femoral plating with the minimally invasive percutaneous plate osteosynthesis (MIPO) technique. Persico[12] reported 30 femoral lengthening patients then plating at the anterior femoral side; there was one superficial infection. Nayagam *et al*.[14] reported 16 pediatric femoral lengthening and then plating at the femoral medial side. However, which is a good approach for femoral plating?

The femoral lengthening and then plating have been applied in our hospital since 2019. The anterior approach has been used for femoral plating with the minimally invasive percutaneous plate osteosynthesis technique. This study is the first case series of femoral lengthening and then plating in our country. Thus, this

HIGHLIGHTS

- Femoral lengthening and then plating was an alternative method for lengthening over nail and intramedullary lengthening nail methods.
- Plating at the anterior femoral side is a good approach in femoral lengthening and then plating.
- Common complications were pin-site infection, knee extensor contracture, femoral varus or procurvatum deviation.

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study aimed to assess the results of femoral lengthening using a domestic external fixator and then plating using an anterior approach.

Methods

This prospective case series study enrolled 11 patients with leg-length discrepancies over 3 cm who underwent femoral lengthening and then plating between January 2019 and April 2023 in our hospital. The average age of patients was 18.45 ± 7.54 years (6–27 years). Seven out of eleven patients were pediatric. One patient with a femur was lengthened and then plated, and one tibia was lengthened over a nail simultaneously. The inclusion criteria were patients with a femoral length discrepancy of more than 3 cm or patients with a tibial length discrepancy of more than 3 cm who were unsuitable for tibial lengthening due to the soft tissue of the leg or tibia being in bad condition. In patients with lower limb-length discrepancy of more than 9 cm, the patient underwent tibial lengthening and femoral lengthening simultaneously. We excluded patients with infection, tumors, or mental illness.

The domestic fixator was used for femoral lengthening. The fixator was made from SUS 304 steel and consists of three vertical bars (Fig. 1). The three vertical bars have reverse thread, allowing stretching or compression of the cut bone, with a thread length of 1 mm and diameter of 10 mm. The total length of each bar is 320 mm to 350 mm. The middle of the bar has six sides, numbered 1-2-3-4-5-6, in the stretching direction. The arrows are used to indicate the compression direction of the frame. By turning a vertical bar three times a day, the pin clamps at the proximal and distal sides of the bar would expand ~1 mm.

Patients underwent spinal anesthesia. Then, the patient was in a supine position. Our external fixator with three vertical bars was attached to the femoral anterior lateral side using three Schanz pins distally and three Schanz pins proximally. The corticotomy site was at the middle third of the femur. The proximal Schanz and distal Schanz pins were as far as possible from the corticotomy site. The first, the third, the fourth, and the sixth Schanz pins from proximal to distal femur were inserted in the anterior lateral plan of the femur. The second and the fifth Schanz pins were inserted in the lateral plane of the femur. All six Schanz pins were attached to the first bar, which was nearest to the femur. The first, the third, the fourth, and the sixth Schanz pins were attached to the second bar. The second and the fifth Schanz pins were attached to the third bar. A corticotomy was then performed at the middle third of the femur between the third Schanz pin and the fifth Schanz pin from proximal to distal using drills and a chisel (Fig. 2).

Femoral lengthening was started at 1 mm per day (1/3 mm, three times daily) seven days post-operation. Patients were instructed appropriately for femoral lengthening and were discharged two days later. Patients were tracked monthly with clinical signs and A-P and lateral X-rays.

The patient had a second operation for the femoral percutaneous locking plate and removal of the external fixator when the femoral lengthening gained its target. Plating using a straight, broad locking plate with 5 mm self-tapping locking screws (Mikromed, Polish) was performed before removing the external fixator using a minimally invasive anterior approach that combines exposure of the proximal and distal femur through two incisions of ~3-4 cm. The proximal approach was made on the anterior side of the subtrochanteric region, and the interval between tensor fasciae lata and the anterior rectus femoris muscles was developed to reach the femoral metaphyseal portion, then splitting the underlying vastus muscles to reach the anterior surface of the femur. The distal approach was made in the suprapatellar region by making a longitudinal incision of 3–4 cm, then splitting the interval between the medial border of the quadriceps tendon and vastus medialis to approach the distal third of the femur. The vastus intermedius was split longitudinally, and the submuscular blunt dissection was done to connect two incisions. The plate was inserted submuscular at the femoral anterior side, and three locking screws were inserted at each proximal fragment or distal fragment. After that, the frame was removed, and the incisions were closed without drainage. All operative steps are presented in Fig. 2.

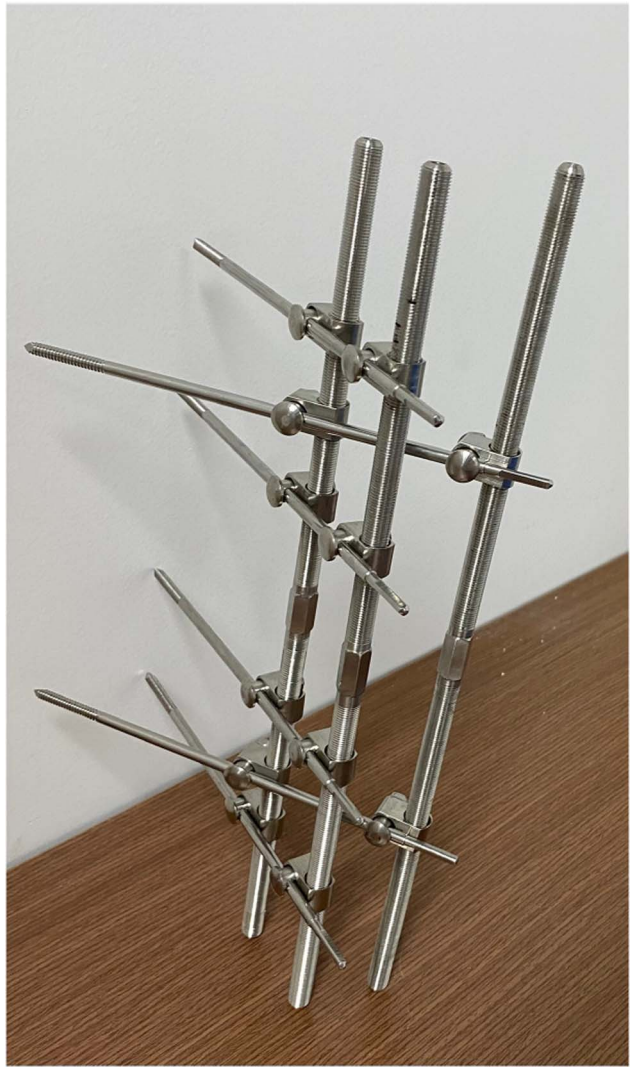

Figure 1. The domestic external fixators with three vertical bars used in the study.

Partial weight-bearing was permitted post-operation. Full weight-bearing could be done when a mature callus was present across two cortices on femoral A-P and lateral X-rays. Patients

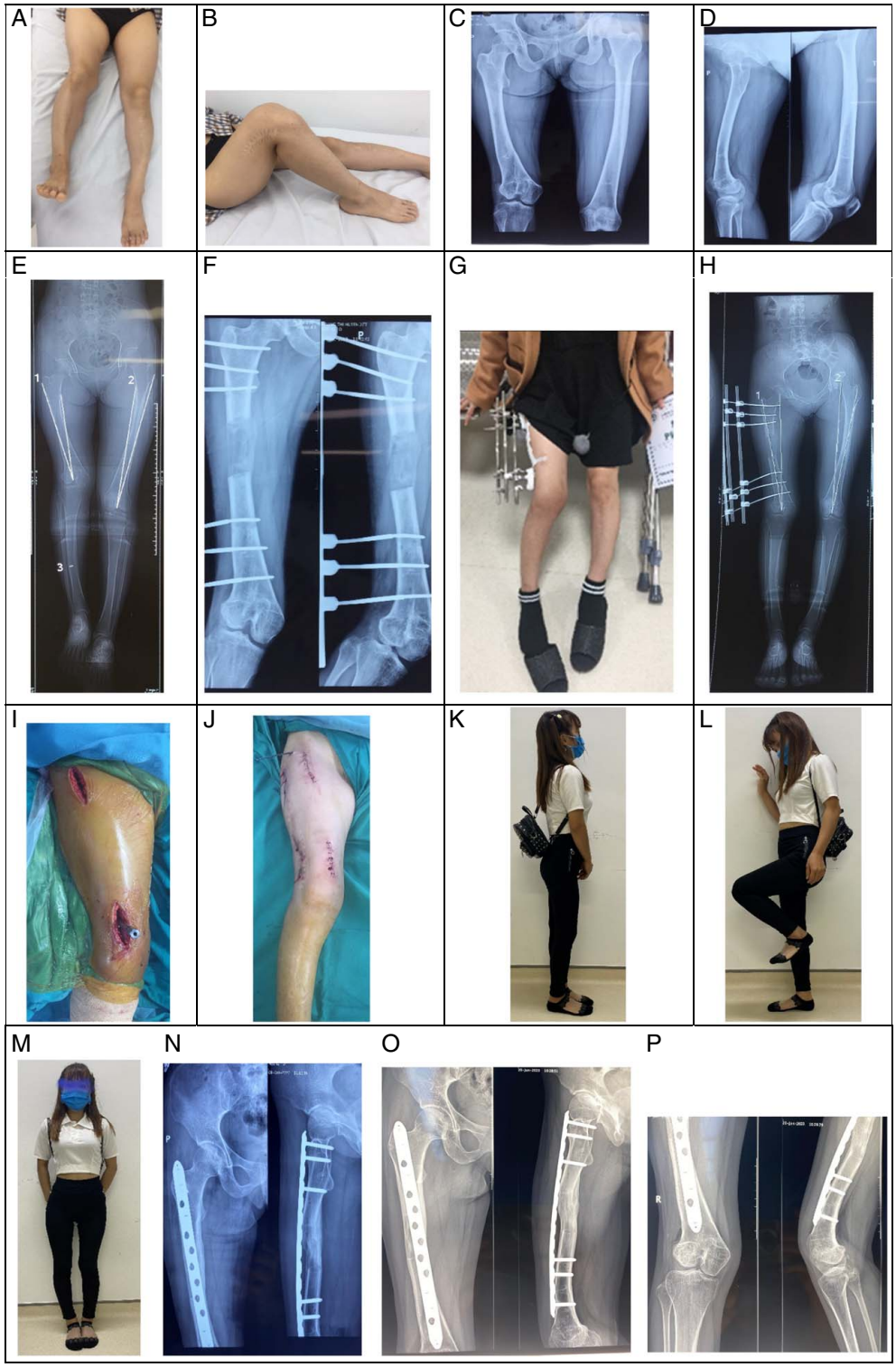

Figure 2. A 7 cm right femoral lengthening using the domestic external fixator and then locking plating. (A–E) Clinical and X-rays pre-operation of 26-year-old female patients showed a 7 cm leg-length discrepancy and valgus deviation of right femur; (F) X-rays 2 months postoperative; (G, H) clinical and X-rays 3 months postoperative, the right femur was lengthened 7 cm and right femoral valgus deviation was reduced gradually by the domestic external fixator; (I, J) plating and removal of external fixator; (L–O) clinical and X-rays 1 year postoperative after plating and removal of frame; (O, P) X-rays 2.5 years postoperative after plating and removal of the frame.

were followed up monthly until the femoral completed healing. After that, patients were followed up every three months. Plates and screws could be removed once the femoral completed solid healing. Femoral consolidation was defined as a solid union when there was a mature callus across three cortices on A-P and lateral X-rays, and patients could do full weight-bearing without pain.

The severity of lower limb deformities was classified according to the Limb Lengthening and Reconstruction Society AIM severity score[19] (Table 1).

The bone result and functional results were evaluated according to the ASAMI classification[20] and classified into four groups (Table 2).

The complications were recorded according to the Paley classification[21]. This case series has been reported in line with the PROCESS Guideline[22].

Table 1

Limb Lengthening and Reconstruction Society AIM severity score[19]

Criteria	Scores
Location (number of deformities per limb of ≥10° in separate planes and rotation all count as separate deformities)	
No deformity	0
One deformity	1
Two deformities	2
Three deformities	3
More than three deformities	4
Leg-length inequality (estimate at skeletal maturity)	
0–2 cm	0
>2–5 cm	1
>5–10 cm	2
>10–15 cm	3
>15 cm	4
Risk factors (assessed clinically)	
None	0
Age of less than 5 or more than 40 years	Add 1 point
Smoker	Add 1 point
Obesity	Add 1 point
Other diseases (e.g. diabetes)	Add 1 point
Soft tissue coverage	
Normal	0
Bruising or contusion	1
Scarring (open grade I)	2
Poor coverage (open grade II)	3
Inadequate coverage (open grade III)	4
Angular deformity (measure and assign greatest primary deformity)	
0°–10°	0
>10°–20°	1
>20°–40°	2
>40°–60°	3
>60°	4
Infection and bone quality (select the most severe)	
Normal	0
Osteoporotic	1
Dysplastic	2
Infection	3
Combination	4
Motion and stability of the joints above and below	
Normal	0
Decreased motion (<60% of normal)	1
Subluxation of joint	2
Dislocation of joint	3
More than one joint was affected	4
LLRS-AIM index scoring (scores range from a minimum of 0 points to a maximum of 28 points)	Total scores
Normal	0
Minimal complexity 1–5	1–5
Moderate complexity 6–10	6–10
Substantial complexity 11–15	11–15
High complexity 16–20	16–20

LLRS, Limb Lengthening and Reconstruction Society.

Results

Characteristics of patients enrolled in our series are reported in Table 3. The average age of patients was 14.45 ± 7.54 years (range: 6–27 years). Seven out of 11 patients were pediatric patients with an age range from 6 to 13 years old. The causes of lower limb-length discrepancy were congenital deficiencies in ten patients and post-infection in one patient. The average lower limb discrepancy length was 9.23 ± 3.2 cm (6–18 cm). The severity of lower extremity deformities was moderate complexity in eight patients, substantial complexity in two patients, and high complexity in one patient.

The average duration of follow-up was 2.1 years (range: 0.8–4 years). Average femoral lengthening was 8.41 ± 1.35 cm (7–10 cm). The mean percentage increase in femoral length was 24.01± 2.39% (Table 4). One patient with 18 cm leg-length discrepancy simultaneously underwent a 9 cm tibial lengthening over the nail and a 9 cm femoral LATP.

All patients had good wound healing and achieved their femoral lengthening goals. The external fixation index was 12.81 days/cm, and the bone healing index was 36.92 days/cm. According to the ASAMI classification, the femoral bone healing result was excellent in seven femurs and good in four femurs. Five out of eleven patients had femoral plate removal. The complications of neurovascular injury and premature consolidation did not occur. The range of movement of the hip, knee, and ankle joints was normally restored at the final follow-up examination. At the final follow-up examination, all patients could carry out daily life activities without difficulty, and the functional result was excellent in five patients and good in six patients, according to the ASAMI classification.

Pin-track infection was observed in all patients treated with oral antibiotics during a lengthening period. There was no complication of deep infection, nerve injury, delayed consolidation, femoral fracture, and knee or ankle joint instability (Table 3). At the end of the lengthening period, eight patients had a limited range of motion of the knee joint due to extensor contracture, six were managed by physical therapy, and two underwent knee arthrolysis. The knee functions of these patients were restored at the final follow-up examination. Femoral varus and procurvatum deviation occurred in four patients and two during lengthening. These deformities could be reduced closed under the C-arm by rotating the second and third vertical bar before inserting the locking plate and locking screws at the proximal segment and distal segment. No complications of femoral axial deviation, refracture, or fracture of the plate and screws were observed (Table 5). All patients and their parents were satisfied with their treatment results.

Discussion

The LON technique shortens the external fixator period and increases patient comfort, resulting in earlier patient

Table 2

ASAMI classification of outcome[20]

The bone results	
Excellent	Union without infection, deformity $<7^{0,}$ and a leg-length discrepancy <2.5 cm.
Good	Union plus any two of the last three features of excellent
Fair	Union plus any one of the last three features of excellent.
Poor	Nonunion, refracture, or failure to meet three of the last three features of excellent.
The functional result	
Excellent	A fully active of daily living (ADL), no pain or mild pain; no limp, no soft tissue sympathetic dystrophy, knee or ankle joint contracture $< 5^0$; loss of ankle or knee motion $< 15^0$
Good	Almost all ADLs, with minimal difficulty, no pain, or mild pain, fail to meet one of the other criteria
Fair	Most ADL with minimal difficulty, no pain or mild pain, and failure to meet two of the other criteria.
Poor	Significantly limited ADL, significant pain requiring narcotics, failure to meet three of the other criteria

ASAMI, Association for the Study and Application of the Method of Ilizarov.

rehabilitation and mobilization[5,8]. However, Kim, Kocaoglu[9,21], and Paley[6,8] reported a high rate of deep infection due to contact between the intramedullary nails and pins of the external fixator. The pins of the external fixator should be applied far from the intramedullary nail to prevent deep infection. However, it takes work to do this advice in femoral lengthening. LON technique or lengthening then nailing is also unsuitable for pediatric patients or patients with a femoral narrow or sclerotic intramedullary cavity. In these patients, femoral lengthening and then plating technique or femoral lengthening over a plate has been used[10,11]. In our research, seven out of 11 were pediatric patients aged 6–13. Because the simultaneous use of an external fixator and a plate and screws in the technique of femoral lengthening over a plate may increase the risk of deep infection, the method of lengthening and then plating has been used[12–17]. In femoral lengthening, it is uncomfortable for patients to wear Ilizarov frames. Besides, applying the plate in the safe zone far from the wires in femoral lengthening using an Ilizarov frame is challenging. In our country, other external fixators such as Orthofix frame and Taylor Spatial Frame, which are more comfortable for the patient and permit safe zones for plating, are costly and available.

Our research uses the domestic frame with three vertical bars for femoral lengthening. The domestic frame consists of three vertical bars with reverse threads. It permits the patient to adjust the frame, either distraction or compression. The severity of lower extremity deformities was moderate complexity in eight patients, substantial complexity in two patients, and high complexity in one patient. However, the femoral target lengthening was reached in all patients. Average femoral lengthening was 8.41 ± 1.35 cm (7–10 cm). One patient underwent a 9 cm tibial lengthening and a 9 cm femoral lengthening. Premature consolidation was not encountered.

The femoral lengthening technique using an external fixator obeyed Ilizarov's principle of distraction osteosynthesis. At the end of the distraction period, the femoral was fixed using a locking plate with the MIPPO technique, which preserved the periosteal and endosteal circulation of the femur. In our series, the lengthened femurs were fixed using a straight, broad locking plate and six 5 mm locking screws (Mikromed company, Polish) that provided rigid fixation. Good femoral consolidation was gained in all patients. The femoral healing index was 36.92 days/cm. No fracture of the locking plate or screws; no case of delayed consolidation or bone defects was observed. The femoral external fixation index was 12.81 days/cm. The shorter duration of external fixation resulted in less patient pain and discomfort, earlier patient rehabilitation and mobilization, and a reduced rate of extensor contracture of the knee. The functional result was excellent in five patients and good in six patients. Eleven patients could carry out daily activities.

In our study, extensor contracture of the knee was one of the most common complications during the femoral lengthening period. All patients underwent physiotherapy with stretching of the quadricep tendon and partial body-weight-bearing. Eight patients with femoral lengthening over 25% of their preoperative femoral length had a limited knee joint range of motion due to extensor contracture. Six out of eight were managed by physical therapy, and two underwent knee arthrolysis. The knee functions of these patients were restored at the final follow-up examination. The loss of the mobility of the knee joint, usually when in external fixation during femoral lengthening, was reported by some authors. Persico[12] reported that 17 of the 30 femoral lengthening patients had an extension contracture of the knee before the surgical procedure of substituting the plate for the external fixator. One year postoperative, 12 patients had a knee range of mobility equal to or greater than 70^0. Yucel[13] reported an extension contracture of the knee in one femoral lengthening and plating case. We found that the preventive measures of extensor contracture of the knee joint were good postoperative rehabilitation. However, in patients with the target femoral lengthening over 25% of the preoperative femoral length or signs of hip instability, the tenotomy of the iliotibial tract and the left rectus femoris muscle should be done at its origin in the index operation.

Table 3

Characteristics of the 11 patients enrolled in the study

Parameter	Value
Age (year)	14.45 ± 7.54 (6–27)
Average lower limb discrepancy length (cm)	9.23 ± 3.2 (6–18)
Adult: Pediatric	4:7
No. lengthened tibias	1
No. lengthened femurs	11
Congenital deficiencies	10
Post-infection	1
Severity of lower extremity deformities	
Normal	0
Minimal complexity	0
Moderate complexity	8
Substantial complexity	2
High complexity	1

Table 4

Clinical results after lengthening using external fixators and then plating

Parameter	*N* (%) or mean (SD)	
	Tibial lengthening (*n* = 1)	Femoral lengthening (*n* = 11)
Bone lengthening (cm)	9	8.41 ± 1.35 (7–10)
Percentage increase in bone length (%)	24.21	24.01 ± 2.39
BHI (days/cm)	34.81	36.92
EFI (days/cm)	13.56	12.81
ASAMI bone results		
Excellent	1	7
Good	0	4
Fair	0	0
ASAMI functional results	0	
Excellent	0	5
Good	1	6
Fair	0	0

ASAMI, Association for the Study and Application of the Method of Ilizarov; BHI, bone healing index; EFI, external fixation index.

In our series, pin-site infection occurred in all patients. However, these were treated by oral antibiotics. There was no superficial and deep infection. Pin-site infection may be due to techniques of inserting Schanz, patients' hygiene, and the long times of wearing frames…Fixing the femur using a plate at the femoral lateral side is common. Still, we recommended using a broad locking plate for the MIPPO technique in femoral lengthening in a safe zone at the femoral anterior side, without the pin site of the external fixator. The percutaneous locking plate fixation technique on the femoral anterior side instead of the lateral side permitted a minimal dissection of the soft tissues while preventing cross-contamination with the pin tracts of the external fixator at the lateral femoral side. Persico[12] reported 30 femoral lengthening patients then plating at the anterior femoral side; there was one superficial infection. Nayagam *et al*.[14] reported 16 pediatric femoral lengthening and then plating at the femoral medial side. Our research did not use a medial approach for femoral plating because of a high nerve and femoral vessel injury rate. In our series, no infection was observed. It was similar to those of other authors who used the lengthening technique and then plating[12–17]. To prevent deep infection, it is recommended to cover the pin sites and frame with sterile towels carefully to minimize contact and contamination and apply for a femoral locking plate percutaneously in the safe zone (Fig. 2). In our series, the plate was inserted through minimal incision approaches in the safe zone at the anterior aspect of the femur, that was far from the external fixator. The proximal incision was made in the anterior thigh around the level of the subtrochanteric region, and the distal approach was made in the suprapatellar region. The contact between the internal and external fixation during plating was not permitted.

Table 5

A summary of the complications

Complications	No. problems	No. obstacles	No. sequelae	Total number
Soft tissue-related				
Pin-track infection	11	0	0	11
Superficial infection	0	0	0	0
Deep infection	0	0	0	0
Ankle equinus	0	0	0	0
Knee flexion contracture	0	0	0	0
Knee extensor contracture	6	2	0	8
Peroneal nerve injury	0	0	0	0
Bone-related				
Valgus alignment	0	0	0	0
Varus alignment	0	4	0	4
Procurvatum deviation	0	2	0	2
Rotation deformity	0	0	0	0
Premature consolidation	0	0	0	0
Delayed consolidation	0	0	0	0
Fibular nonunion	0	0	0	0
Distal migration of proximal fibular	0	0	0	0
Proximal migration of distal fibula	0	0	0	0
Leg-length discrepancy	0	0	0	0
Implant related	0	0	0	0
Total	17	8	0	25

In our series, varus and procurvatum deviation were one of the most common complications during the distraction period of femoral lengthening. Femoral varus and procurvatum deviation occurred in four patients and two patients, respectively. Closed reduction of the femoral varus and procurvatum deviation could be made by maintaining the first vertical bar (the nearest bar from the skin) and adjusting the frame's second and third vertical bar. Our results were similar to those of Georgiadis *et al*.[23]. Complications in his series were commonly encountered during femoral lengthening, including procurvatum and varus deformity, which were usually corrected by frame adjustment before plating. In our research, after reaching the target femoral lengthening, the femur was fixed using a broad locking plate with six screws. No complications of femoral axial deviation or fracture of the plate and screws were observed. This result was similar to those of Persico *et al*.[10] and Nayagam *et al*.[14]. Persico[12] reported 30 femoral lengthening patients and then plating at the anterior side of the femur. Nayagam *et al*.[14] reported 16 femoral lengthening in pediatric patients and then plating at the medial aspect of the femur. Axial deviation or fracture of the plate was not observed in their series. We recommended that the femoral lengthening technique and then plating be indicated for pediatric or adult patients with a femoral narrow or sclerotic intramedullary cavity.

Intramedullary lengthening nails have been utilized in the past three decades as an alternative to external fixation distraction systems because of their lower complication rates and higher patient comfort and satisfaction. However, it is very expensive and unavailable in low-income countries[24–30].

Our study showed that the femoral lengthening technique and then plating were considered an attractive alternative to intramedullary lengthening nails in a low-income country like our country. However, the number of patients in our study was small, with seven pediatric and four adults. The femoral locking plate was removed in 5 out of 11 patients. Further research should be done with a larger sample size and longer follow-up time.

Conclusion

Our research recommended that femoral lengthening using an external fixator and plating was effective and safe. The most common complications during the femur lengthening period were pin-site infection, extensor contracture of the knee, and femoral varus or procurvatum deviation. This method should be considered an attractive alternative to femoral lengthening over a nail or intramedullary lengthening nails. Further research should be done with a larger sample size and longer follow-up time.

Ethical approval

The 108 Central Military Hospital Hospital's Institutional Review Board, Hanoi, Viet Nam, approved all procedures.

Consent

Written informed consent was obtained from the patient for the 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.

Parental Consent for Minors: Written informed consent was obtained from the patient's parents/legal guardians for publication and any accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

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Author contribution

L.V.N. and G.N.N. had equal contributions and were the first authors. L.V.N.: conceptualization, surgery, writing—review and editing, supervision. G.N.N.: conceptualization, surgery, writing—review and editing, supervision.

Conflicts of interest disclosure

The authors declare that they have no conflicts of interest.

Research registration unique identifying number (UIN)

We submit our work to a research registry whose unique identifying number is researchregistry10107. The link: https://www.researchregistry.com/browse-the-registry#home.

Guarantor

Luong Van Nguyen.

Availability of data and materials

The data used to support the findings of this study are available from the corresponding author upon request.

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