Original Article

Limb lengthening over plate

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Abstract

Background: The limb lengthening over plate eliminates the associated risk of infection with limb lengthening over intramedullary nail. We present our experience of limb lengthening in 15 patients with a plate fixed on the proximal segment, followed by corticotomy and application of external fixator.

Materials and Methods: 15 patients (7 females, 8 males) were included in this consecutive series. The average age was 18.1 years (range 8–35 years). Fifteen tibiae and one femur were lengthened in 15 patients. Lengthening was achieved at 1 mm/day followed by distal segment fixation with three or four screws on reaching the target length.

Results: The preoperative target length was successfully achieved in all patients at a mean of 4.1 cm (range 1.8–6.5 cm). The mean duration of external fixation was 75.3 days (range 33–116 days) with the mean external fixation index at 19.2 days/cm (range 10.0–38.3 days/cm). One patient suffered deep infection up to the plate, three patients had mild procurvatum deformities, and one patient developed mild tendo achilles contracture.

Conclusion: Lengthening over a plate allows early removal of external fixator and eliminates the risk of creating deep intramedullary infection as with lengthening over nail. Lengthening over plate is also applicable to children with open physis.

Key words: Consolidation index, external fixator index, lengthening over plate, limb lengthening

Introduction

The advent of ring fixator and distraction histogenesis started a new era of limb lengthening.[1] Limb lengthening with external fixator alone is fraught with complications of long external fixator period and the risk of fracture of regenerate once the fixator is removed.[2]

The technique of lengthening over nail (LON) is effective in decreasing external fixator duration and consolidation index.[3] The decreased external fixator duration may help patients regain joint range of motion faster in case of femoral lengthening where the complication of joint stiffness can be very high[4,5] and the nail protects the regenerate from fracture after external fixator removal.[3,6,7] These benefits make this procedure attractive to surgeons, but the high incidence of deep intramedullary infection of up to 22% is a universal concern.[8] The inability to use this limb lengthening procedure in children with open physis is another limitation. Lengthening over plate (LOP) eliminates the risk of creating a deep intramedullary infection and this procedure can also be used in any age group of patients because without the risk damage to the physis.

We report a procedure where the external fixator was used for distraction histogenesis for limb lengthening and it was combined with a Low Contact Dynamic Compression Plate (LCDCP), the LOP.

Materials and Methods

The study was approved by institutional review board and was conducted after obtaining informed consent from the patients or their parents. In a retrospective review of 16 limb lengthening procedures performed by a single surgeon using external fixator and LCDCP between 2006 and 2009. Seven females and eight males were included in this consecutive series. The average age was 18.1 years (range 8–35 years). Fifteen tibiae and one femur were lengthened in 15 patients. There was one case of bilateral tibial lengthening for short stature due to achondroplasia; the causes for limb length discrepancy in other patients are enumerated in Table 1.

Amongst the patients for whom tibia was lengthened, there were two patients each with tibial hemimelia, posttraumatic

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Table 1: Clinical details of patients

Age (Years)	Sex	Diagnosis	Segment	T L (CM)	E D (Days)	E I	C I	Complications	Additional procedures	Followup duration (months)
11	F	Tom smith Arthritis	Tibia	5.1	96	18.8	28.8	Nil	Nil	58.3
15	M	Tom smith Arthritis	Tibia	3.6	90	25.0	49.7	TA contracture Plate prominence	PSO by plating+TA fractional lengthening	25.6
10	M	Tom smith Arthritis	Tibia	3.6	72	20.0	38.9	10' procurvatum	Nil	22.7
08	F	Congenital short Femur	Tibia	4.6	66	14.3	20.0	Nil	Nil	54.2
10	M	Achondroplasia	Tibia	5.1	107	21.0	32.4	Nil	Nil	57.4
10	M	Achondroplasia	Tibia	4.5	107	23.8	36.7	Nil	Nil	57.4
16	F	Tibial hemimelia	Tibia	4.5	64	14.2	35.6	12' procurvatum	Tibialization of fibula+tibia lengthening with ring fixator alone	31.8
18	F	Coxa vara	Tibia	4.6	46	10.0	37.0	Nil	Plating+bone grafting	48.7
25	M	trauma	Tibia	3.9	78	20.0	53.3	pin tract infection	Nil	37.8
17	F	Tibial hemimelia	Tibia	6.5	77	11.8	29.2	18'Pprocurvatum	Ankle fusion	41.2
26	M	Trauma	Tibia	1.8	69	38.3	43.3	Pin tract infection	Nil	46.4
24	M	Tom smith Arthritis	Tibia	4.4	60	13.6	40.9	Nil	PSO by plating	28.6
20	F	Idiopathic Chondrolysis	Tibia	3.5	79	22.6	40.6	Nil	Girdlestone excision+PSO by plating	31.2
28	M	Post polio	Tibia	2.2	33	15.0	34.1	Nil	SCO+Jones procedure	34.8
35	F	Post polio	Tibia	2.7	45	16.7	40.7	Nil	SCO	28.6
17	M	Fibular hemimelia	Tibia	5.0	116	23.2	28.2	Deep infection	Ankle fusion+two sessions of tibial lengthening with ring fixator alone	18.3

T L - Target Length, E D - Exfix Duration, E I - Exfix Index - Exfix duration for 1 cm lengthening (Days/CM), C I - Consolidation Index: Consolidation Period for 1 cm lengthening (Days/CM), TA Contracture - Tendo Achilles Contracture, SO - pelvic support osteotomy, SCO - Supracondylar extension osteotomy

shortening of tibia, and limb shortening secondary to postpolio residual paralysis (PPRP) and one patient each of achondroplasia and of fibular hemimelia. The patients with tibial hemimelia, posttraumatic tibial shortening, and fibular hemimelia were advised tibial lengthening because the leg itself was the source of deformity and to avoid the complications of femoral lengthening which are always more than tibial procedures.[4,5] The two patients with PPRP were operated with supracondylar extension osteotomy of the distal femur and internal fixation with a plate. Tibia was chosen for lengthening in order to avoid any interference of the external fixator with the plate and minimize the risk of infection. The 10 year old child with achondroplasia underwent bilateral tibial lengthening because the complications of femoral lengthening are more than those of tibial lengthening and the child would bear rings on both the legs better than on both the thighs.

There were four cases of septic arthritis of hip and one each of congenital short femur, proximal femur nonunion, and idiopathic chondrolysis of femoral head. Only one patient with congenital short femur underwent femoral lengthening. Out of four patients with septic arthritis of hip, two underwent pelvic support osteotomy (PSO) by plating at the intertrochanteric level, and the mechanical axis was aligned and the tibia was lengthened to minimize complications at the knee joint. The other two patients were stable at the hip joint and the femur bone quality was not very good; so, we lengthened the tibia to avoid complications at the hip and knee joint. The case with proximal femur nonunion was plated and bone grafted and tibial lengthening was done over a plate because of the following reasons: (1) The plate used for nonunion would have come into the way of plate used for femoral lengthening because of small size of bone. (2) The plate used for nonunion would have been exposed to the external fixator wires, thus risking infection. This was a long standing case of nonunion in a young girl where we did not want to risk a nonunion or infection at any cost, and thus we decided to lengthen the tibia. The single case of idiopathic chondrolysis underwent PSO by plating and tibial lengthening over a plate at the same sitting.

Ilizarov ring external fixator was used for distraction in all patients and a 3.5-mm LCDCP was used in two cases of achondroplasia and a 4.5-mm LCDCP was used in the rest. The level of osteotomy was proximal diaphysis in 15 and distal diaphysis in one. Four patients had previous lengthening procedures done with conventional Ilizarov technique. The average duration of followup was 2 years. On a subsequent followup the various parameters recorded were:

1. External fixator index – Number of days between external fixator application and its removal divided by the lengthening in centimeters, i.e. the external fixator duration for 1 cm lengthening.
2. Consolidation index – Number of days between external fixator application and three cortex regenerate consolidation divided by the lengthening achieved in centimeters.

The complications with the procedure were classified and document using Paley's system:[2]

Problems – Difficulties that arose during treatment and resolved completely

Obstacles – Difficulties arising during treatment, which only resolved following an operation.

Sequelae – Defined as permanent difficulties remaining after treatment

Operative procedure

With the patient supine on a radiolucent table, fibular osteotomy was done 7 cm above the lateral malleolus. Following this, a 3.5/4.5 mm LCDCP (Pitkar, Pune, India) was placed externally over the medial surface of the bone around the proposed lengthening site [Figure 1a] and viewed under a fluoroscope [Figure 1b]. The plate on the tibia was placed over the medial surface. The plate was slid extraperiosteally through a small vertical incision at the planned corticotomy site so that plate insertion and corticotomy could be done through one incision. Also, no muscle dissection was required as would have been needed for lateral plating. We had only one complication of plate prominence, and so we prefer the medial surface for the tibia. Over the femur, the plate was placed on the lateral surface.The plate was positioned such that there were at least three holes distal to the planned corticotomy after taking into account the proposed lengthening and three holes proximal to the corticotomy.

On correct positioning, a 2-cm incision was made at the proposed corticotomy site and the plate was slid over the bone extraperiosteally on the medial surface [Figure 2a]. The plate was fixed to the proximal fragment with at least three screws using stab incisions [Figure 2b].

Using multiple drill holes and osteotome, corticotomy was done through the same incision which was used for plate sliding. Plate fixation before the osteotomy prevents the instability of the fragments and makes the procedure easy to perform.

A standard Ilizarov three-ring frame was applied. In our technique using a conventional straight LCDCP without any contouring, the plate rested on the medial surface of the tibial diaphysis. The wires for the proximal ring of the fixator passed above the plate. The middle ring in the construct is a free ring. Thus, no wire adjustment or angulation was required to miss the implant inside. The distal ring in Tibia was at the level of the distal Tibio-fibular joint. The distal ring in the Femur was 1 cm distal to the end of the plate and proximal to the distal Femur physis.

Postoperative care

Patients were allowed to walk full weight bearing from the next day. Distraction was started from postoperative day 7 at the rate of 1 mm/day. The use of graduate telescoping rods (clickers) in place of conventional distraction rods makes the job of lengthening easy. We did use clickers for four of our patients after showing them the direction to rotate the clickers. The clickers were placed exactly at the position of the distraction rods, i.e. anterolateral, anteromedial, posterolateral, and posteromedial, in order to avoid their coming in the way of orthogonal radiographs. The patients were put on range of motion exercises for the knee.

Followup radiographs were taken every 4 weeks to monitor lengthening and the quality of regenerate.

Figure 1: (a) Plate placed externally over the bone; (b) plate position viewed under fluoroscope to confirm correct position of plate

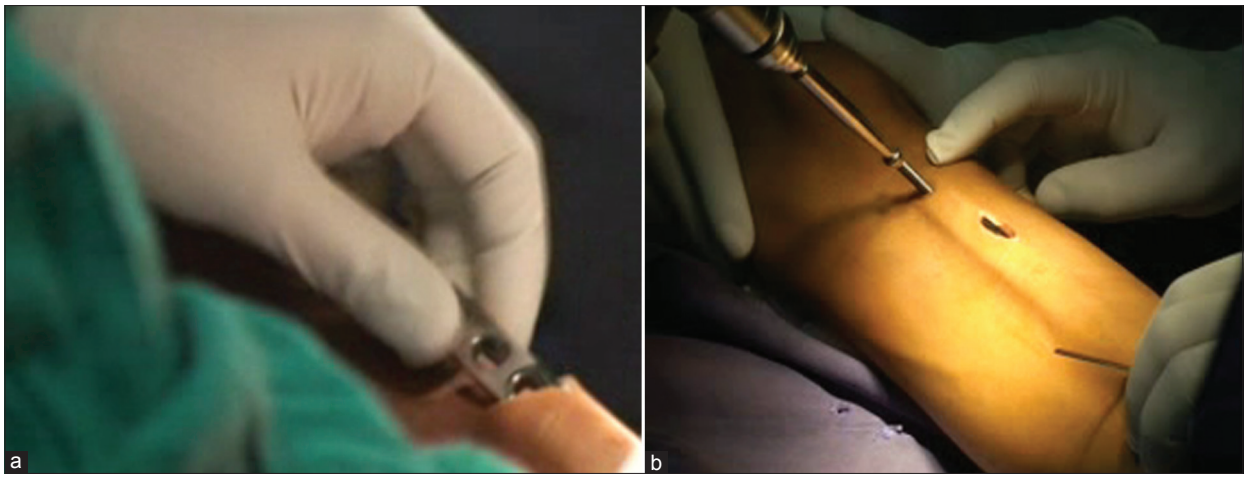

Figure 2: (a) Plate slid extraperiosteally over the medial surface of the bone; (b) proximal locking of the plate done before corticotomy and external fixator application

On achieving the target length, the screws were inserted in at least three distal holes of the plate. Two patients were over distracted and we were left with only two holes for distal locking. We went ahead with distal locking with two screws but the patient's recovery was uneventful. One 3.5 mm cortical screw was inserted through the distal tibio-fibular joint just before the external fixator was removed to prevent proximal migration of fibula. This screw was inserted during the second procedure before the external fixator was removed.

The external fixator was removed only after the plate had been secured distally to prevent loss of length. Patients were kept on crutches and weight bearing on the leg was not allowed until three cortex consolidation was seen on two orthogonal views, following which weight bearing was increased gradually and as per the patient's comfort.

Results

The mean lengthening was 4.1 cm (range 1.8–6.5 cm). The mean external fixator duration was 75.3 days (range 33–116 days). The mean external fixator index was 19.2 days/cm (range 10–38.3 days/cm) and the mean consolidation index was 36.8 days/cm (range 28.2–53.3 days/cm).

There were a total of eight complications with three problems (two pin tract infections and one plate prominence), two obstacles (one tendo achilles contracture and one deep infection), and three sequelae.

The single case of infection in our series was a 17 year old boy with tibial lengthening with fibular hemimelia. He was multiply operated before with ankle fusion and two limb lengthening procedures over tibia with ring fixator alone. The skin condition over the leg was not very good. The patient reported with fever, erythema, and pain 2 weeks after the second surgery, i.e. external fixator removal. The fact that his time in the external fixator was completely eventless suggests that the plate was completely safe. Probably, the poor skin quality and multiple surgical and lengthening procedures may have been the cause of infection. The two pin tract infections resolved with oral antibiotics.

One patient had a problem of plate prominence that impinged on the skin. This same patient also had restricted ankle dorsiflexion. Tendo-Achilles fractional lengthening and plate adjustment were done in one sitting when the patient returned to the operation theatre for distal locking and external fixator removal.

One patient with tibial lengthening had a deep infection up to the plate, which occurred 2 weeks after distal locking and external fixator removal. Debridement was done and antibiotic beads were put close to the plate. The regenerate was allowed to consolidate for the next 12 weeks after which the plate was removed. The patient's recovery was uneventful.

There were three procurvatum deformities of 10°, 12°, and 18°, all in tibia. Minor deformities of 10° and 12° procurvatum remained uncorrected. The patient who developed 18° procurvatum was a girl with tibial hemimelia. She was walking comfortably, attending school, and able to do all her daily activities. Till today, she has refused an extra surgical procedure to correct her deformity.

There are two possibilities: (1) the plate construct in these patients was not strong enough or (2) these patients started premature weight bearing against our advice. We counsel all patients not to put weight after fixator removal until three cortex consolidation. These patients probably did not take it very seriously. With the new slotted plate, we have

lengthened six segments till now and have not observed any deformity in any of the cases. No patient in our series had a regenerate bone fracture or implant failure.

Discussion

Limb lengthening using Ilizarov ring external fixator has been very effective, but the long fixator duration of a bulky external fixator is considered undesirable by many patients. The long duration of soft tissue transfixion can cause recurrent pin tract infections.[2] Long duration of external fixator also commonly results in knee joint stiffness in femoral lengthening.[4,5] Attempts have been made to reduce the fixator duration and improve the patient's experience of the procedure. In this direction, LON has been very effective. It reduces the external fixator duration and the consolidation index, and the reduced fixator time may help patients regain joint range of motion faster.[3,6,7] Chaudhary (2008) performed 27 lengthening surgeries in 22 tibiae and 5 femora using LON. The external fixator duration was reduced significantly to a mean of 17.8 days/cm. There were no complications of knee joint stiffness in any of the five femur lengthenings.[9]

However, the risk of creating a deep intramedullary infection with LON is a universal concern. Infection rates of up to 22% have been reported,[6,8,10] so much so that some authors have discontinued this technique and have returned to conventional Ilizarov method.[8] Though many published articles show high infection rates, Chaudhary in his 27[9] and Kocaoglu *et al*.[11] in their 42 LON procedures reported 0% and very low infection rates, respectively. Simpson *et al*. in their series of LON had three infections, all occurring in patients with limb shortening secondary to open fractures.[6] Hence, appropriate patient selection may prevent this complication. Chaudhary concluded that the risk of infection in LON is real, but if meticulous technique of wire placement and other precautions to prevent infection are observed, the rate of this complication in LON can be brought down.[9]

The wires for the external fixator in our technique of limb lengthening pass few centimeters above the plate in the proximal short segment of tibia. There is no need of wire adjustment or angulation to miss the implant inside. The middle ring is a free ring and the wires for the distal ring are far away from the plate. In spite of these advantages, we had one case of deep infection in our small series of 16 LOP procedures. This case was a 17 year old boy with tibial lengthening done over a plate for fibular hemimelia. He was multiply operated earlier with ankle fusion and two tibial lengthening procedures with conventional Ilizarov technique. The patient reported with fever, erythema at the site of distal locking, and pain 2 weeks after the second surgery, i.e. distal locking of the plate and external fixator removal. The fact that his time in the external fixator was completely eventless suggests that the plate was safe with the Ilizarov ring fixator. Probably, the poor skin condition at the distal locking site (where the focus of infection was) and multiple earlier surgical procedures which included limb lengthening with ring fixator alone gave rise to this complication. There are two published reports on LOP, by Dahl *et al*.[12] and Song *et al*.[13] Both reported 0% infection rates in their series of 6 and 10 patients, respectively.

The inability to use the technique of LON in children with open physis is a potential limitation. In our series, there were 7 LOP procedures done in children with open physis (six tibia and one femur) without any complications of damage to the growth plate. However, Gordon *et al*. successfully lengthened nine femurs in patients (average age 9 years 10 months) using humerus interlocking nails through the greater trochanter.[14]

Our series demonstrates that the procedure is effective in lengthening (mean lengthening 4.1 cm), it drastically reduces the fixator time (mean ex-fix index – 19.2 days/cm), and maintains low complication rates (complication rate 0.5 per segment lengthened) [Figure 3a–c].

The plate protects and supports the regenerate after external fixator removal, thereby preventing fractures of the regenerate bone and promoting early consolidation. No patient in our series had a regenerate fracture or implant failure.

There were four cases of septic arthritis of hip and one each of congenital short femur, proximal femur nonunion, and idiopathic chondrolysis of femoral head. The only patient in whom we lengthened the femur was the case with congenital short femur; for the other six with femoral shortening, we lengthened the tibia. Out of four patients with septic arthritis of hip, two underwent PSO at the intertrochanteric level, the mechanical axis of the limb remained aligned, and we lengthened the tibia to minimize complications at the knee joint because the hip was already affected. The other two patients were stable at the hip joint and the femur bone quality was not very good, so we lengthened the tibia to avoid a poor regenerate and complications at the hip and knee joint. The case with proximal femur nonunion treated by plating was plated and bone grafted and tibial lengthening was done over a plate because the plate used for nonunion was coming in the way of plate to be used for femoral lengthening andthe plate used for nonunion could have been exposed to the external fixator wires, thus risking infection. The single case of idiopathic

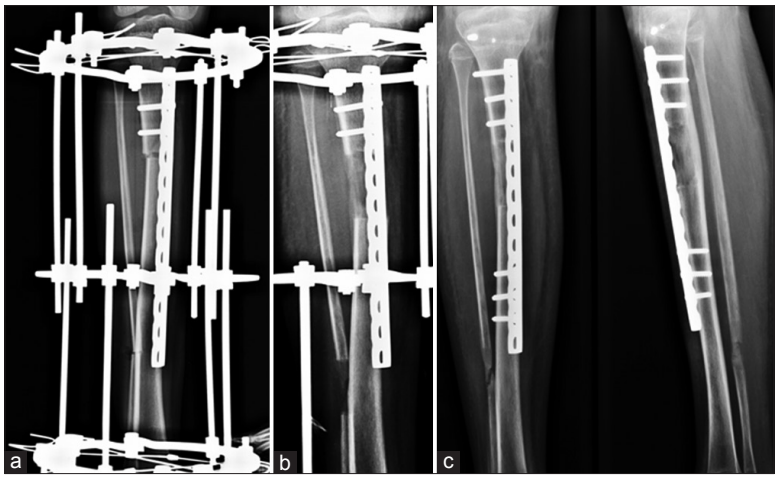

Figure 3: An 11 year old girl with 5.0 cm shortening underwent limb lengthening over plate. (a) Immediate postoperative radiograph showing proximal locking of the plate, corticotomy, and external fixator in place. (b) Radiograph prior to second surgery, showing 5.1 cm lengthening after 96 days in external fixator. At this stage, distal locking of the plate was done and external fixator was removed. (c) Radiograph after 150 days of first surgery, showing fully consolidated regenerate. Patient was walking unassisted and full weight bearing

chondrolysis underwent PSO at the intertrochanteric level, the mechanical axis did not have significant deviation, and tibial lengthening over a plate was done at the same sitting. We had one complication of plate prominence during the distraction period which impinged on the skin [Figure 4a]. We have tried to address this problem by modifying the conventional LCDCP with a longitudinal slot in between the proximal and distal locking holes (Pitkar, Pune, India) [Figure 4b and c]. The plate has a slot through which one unicortical screw is fixed to the distal fragment and the screw slides down along with the distal segment during lengthening. This ensures the plate close to the bone at all times and may also prevent deformity. Till today, we have lengthened six segments with this plate and we have not experienced any complications. The slot weakens the plate However, with a followup of a maximum of 1.5 years, with this new plate we have had no complications of implant failure of excess deformity. A biomechanical testing of the plate is required. The slot does not decrease near fixation because the plate comes in different slot lengths and we use the slot length based on the amount of shortening or the target length. So, a case with desired 4 cm lengthening will have a plate with 4 cm slot. Also, there is one unicortical screw through the slot in the distal segment, which may add to the stability.

Another doubt of decreasing near fixation in the distal segment with this slotted plate arises. The slot does not decrease near fixation because the plate comes in different slot lengths and we use the slot length based on the of target length. There is one unicortical screw through the slot in the distal segment, which may add to the stability.

A significant concern with the procedure was that three of our patients developed procurvatum deformities in tibia.

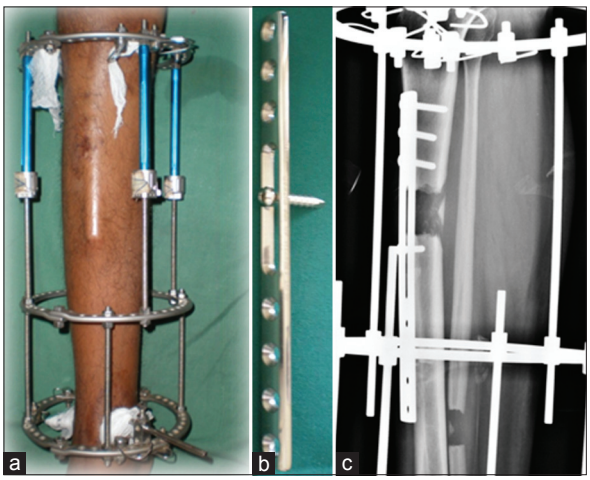

Figure 4: (a) Clinical photograph of plate prominence with impingement on the skin. It resolved after plate adjustment and distal locking during second procedure. (b) The modified plate with a longitudinal slot between the proximal and distal locking holes. (c) Radiograph of a procedure done with the slotted plate. The unicortical screw through the slot in the distal segment keeps the plate close to the bone during the distraction period

These deformities developed only after the external fixator removal. There are two possibilities the LCDCP construct in these patients was not strong enough to combat the deforming muscle forces or these patients started premature weight bearing after external fixator removal.

With the new slotted plate, we have lengthened six segments till now and have not observed any deformity and the followup is of short duration (maximum 1.5 years). Another observation that the deformities are developing at right angles to the plane of screws suggests that the muscle deforming forces in these patients overpowered the screw fixation. The reason why it happened in only these cases could not be conclusively drawn. Under these circumstances,

the use of a locking plate with stronger screw fixation to the plate and bone may prevent such complications, as has already been suggested by Dahl *et al*.[12]

Uysal *et al*.[15] reported a technique, plating after lengthening (PAL), of decreasing the external fixator duration. During the first surgery, conventional ring fixator was applied and distraction continued till the target length was achieved. Once the desired length was achieved, a locking compression plate (LCP) was inserted to stabilize the regenerate and the external fixator was removed. In a series of five lengthening procedures (one femur and four tibia), they reported a mean lengthening of 50 mm and a mean external fixator duration of 100 days. They had one complication of stiffness of knee joint. The process of achieving an entire plating procedure in the presence of an external fixator may be cumbersome. There is always a risk of infection after plating because of the pin tracts. Also, the plating procedure cannot be performed if there is active pin tract infection. Plating was delayed in two patients in their series due to this problem. In our technique, there is no hindrance to plate application and proximal locking because this is achieved before the external fixator application. During the second surgery, only one distraction rod needs to be removed to accomplish distal locking, which makes the procedure very simple. In none of our patients, there was any need to delay the distal locking and in all patients fixator was removed early.

To conclude, LOP reduces external fixator duration in limb lengthening. It can also be used in children with open physis. It avoids the risk of creating a deep intramedullary infection. However, more work in the form of randomized studies with the LON technique needs to be done to delineate its role.

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