Original Article

Reconstruction of Gap Non-union Tibia With Composite Use of Extramedullary Fixation and Bone Transport by Monorail Fixator: A Prospective Case Series

Abstract

Introduction: Non-union is a complex, multifactorial orthopaedic problem that requires multiple treatment modalities for its management. It can result from infection, segmental bone loss, soft-tissue loss, and associated host factors. External fixators as management of gap non-union are bulky and give rise to a number of complications In our study, we have described a technique where we have used extramedullary fixation in the form of a tibial locking plate and transportation of part of the tibial bone after corticotomy by a monorail fixator. **Materials and Methods:** The procedure was done in two stages where internal and external fixation was done after creating a gap at the non-union site. The bone was transported after corticotomy and fixed to the internal fixation device in the second stage. The external fixator was removed in the second stage and the patient was then followed up till the bony union. The evaluation was done by functional and radiological assessment along with the complications noted with the described procedure. **Results:** Ten patients were enrolled in the study with a mean age of 33 years. The mean age of the patients was 33.7 ± 11.32 years with a mean size of the defect was 4.8 ± 1.7 cm. At 30 weeks out of nine patients, three patients had excellent and six had good functional results on the Association of Surgeons for Application and Methodology of Ilizarov (ASAMI) scale. The composite Musculoskeletal Tumor Society (MSTS) score was 76.66 % at the end of 30 weeks of follow-up. The mean time of consolidation was 134.4 days, whereas the mean union time was 145 days from index surgery. Ankle stiffness was the most common complication affecting 50% of the patients. Following closely was pin tract infection, which was present in 40% of the patients. According to Paley's classification, there were 11 obstacles, two problems and none were true complications. **Conclusion:** The integrated fixation is both safe and effective and has the advantage of early removal of the external fixator and a low complication rate as compared to use of a bulky conventional fixator alone. Moreover, it gives protection to the regenerated bone for a long period. So, this technique can be recommended for the management of segmental tibial defects.

Keywords: *ASAMI, limb reconstruction system, locking plate, mono-rail fixator, tibia non-union*

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Introduction

Non-union is a complex, multifactorial orthopaedic problem that requires multiple treatment modalities for its management. Non-union of long bone especially that of the tibia results from infection, segmental bone loss, soft tissue loss, and associated host factors.[1] In the myriad of definitions, the standard definition given by Food and Drug Administration states non-union to be 'persistence of fracture for a minimum of nine months without radiological and clinical signs of healing for the last 3 months'.[2]

Gap non-union presents a major challenge and its management is technically difficult, time-consuming, and physically demanding for the patient with an unpredictable outcome. The bone gap may occur due to extrusion of the fragments at the time of injury or because of debridement of the fracture site where a devitalised segment of bone is removed. Moreover, open fracture with bone loss is common in the tibia due to its subcutaneous anatomy.[3]

Bone gap non-union of the tibia has been classified by Paley *et al*.,[4] and the B1 type of non-union with no shortening is the ideal candidate for the combined use of a combination of internal and external fixation to regenerate the bone and allow early mobilisation of the patients.

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Different techniques have been used for the management of tibial gap non-union. Among the oldest ones is Huntington's method where transposition of the ipsilateral fibula with pedicle is used to fill the bone gap.[5] Although it was initially popular, stress fractures are common with this technique and is more suited to the paediatric population.

The Masquelet technique is another method where bone grafting is done in an induced membrane formed with the use of poly methyl methacrylate (PMMA) mixed with antibiotics. It is a staged procedure mostly done in gap non-union in the presence of infection. However, requirements of large amounts of graft and graft rejection in the presence of infection are two major shortcomings of this method.[6]

Popular among current methods is distraction osteogenesis using Ilizarov frame and Mono-rail fixator (limb reconstruction system [LRS]). Here corticotomised bone fragment is transported over the bone gap at a fixed rate. The external fixator index (EFI) which is the time till the external fixator is kept for the length of bone produced is the addition of time to transport the corticotomised bone plus twice the time taken for the initial transportation (consolidation phase). External fixators are bulky and give rise to several complications like pin/wire loosening, infection, joint contractures, and breakage. Due to all these factors, patient compliance decreases with bulky fixators and their associated complications increase over time.[7-9]

In our study, we have described a technique where we have used extramedullary fixation in the form of a tibial locking plate and transportation of part of the tibial bone after corticotomy by a monorail fixator. This decreases the EFI and thus decreases the number of complications associated with improving functional and clinical outcomes.

Materials and Methods

It is a single-centre prospective interventional study conducted over 2 years from July 2020 to July 2022. The study included all hospital-based cases of the segmental tibial defect (Paley's type B1) in the age range of 18–60 years with no sign of active infection presenting to our centre. Those cases where soft tissue coverage was already done or were planned simultaneously were included in the study. All the infected non-union and those who do not fall under the aforementioned age group were excluded from our study.

Preoperative planning

Patients were first evaluated clinically on the following domains:

1. Adequate soft-tissue coverage
2. Limb length discrepancy
3. Any active infection – clinical signs and symptoms of infection were ruled out. Blood ESR and CRP were sent for investigation.
4. Knee and ankle ROM
5. Bone quality on plain radiographs.

Thus, all the non-infected tibial gap non-unions with adequate soft tissue coverage that fall under Paley's B1 were included.

Surgical technique

The surgery was performed in two stages:

Stage I

1. Debridement of bone was done and margins were freshened to create a bone gap with transverse ends as shown in Figure 1.

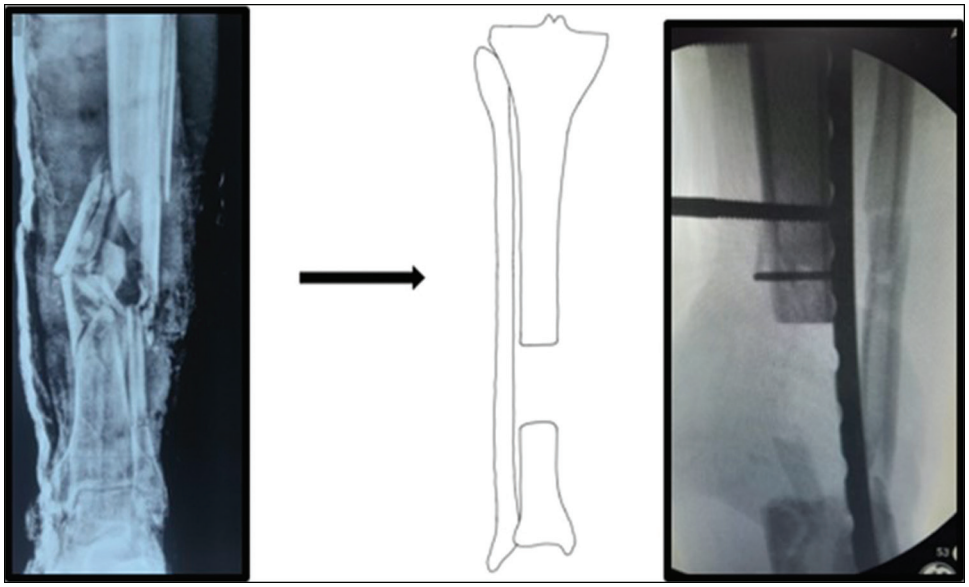

Figure 1: Debridement of bone with removal of loose pieces to create a bone gap

2. Internal fixation was carried out with minimal soft tissue dissection in a percutaneous fashion by the MIPPO technique, fixing the two ends of the bone as shown in Figure 2.
3. Rail fixator was then applied from the opposite side in the longer segment with or without involving the shorter fragment as shown in Figure 3.
4. Corticotomy was then done between the two clamps of the external fixator as shown in Figure 4.
5. Distraction was started after 10 days of surgery at the rate of 1 mm/day and stitch removal was also done on the same day as shown in Figure 5.

Stage II

1. The total gap was assessed on the day of the starting of the distraction and the patient was followed after every 6 weeks or according to the gap calculated.
2. The time at which the middle segment comes in contact with the smaller segment, the patient was readmitted. Two or three screws were inserted percutaneously followed by the removal of LRS as shown in Figure 6.

The outcome assessment was done by the Association for the Study and Application of the Method of Ilizarov (ASAMI) functional and bone outcome and Musculoskeletal Tumor Society (MSTS) functional scoring.[9-11] The quality of the regenerate was assessed by Fernandez-Esteve grading.[11] The assessment was done at the time of surgery, after the removal of the external fixator, and at the end of the consolidation phase.

SPSS version 26.0 was used as a statistical analysis tool.

Case example

A 21-year-old man presented in our outpatient clinic following an alleged history of road traffic accident

Figure 2: Type B1 fracture where internal fixation is carried with a locking plate applied extraperiosteally

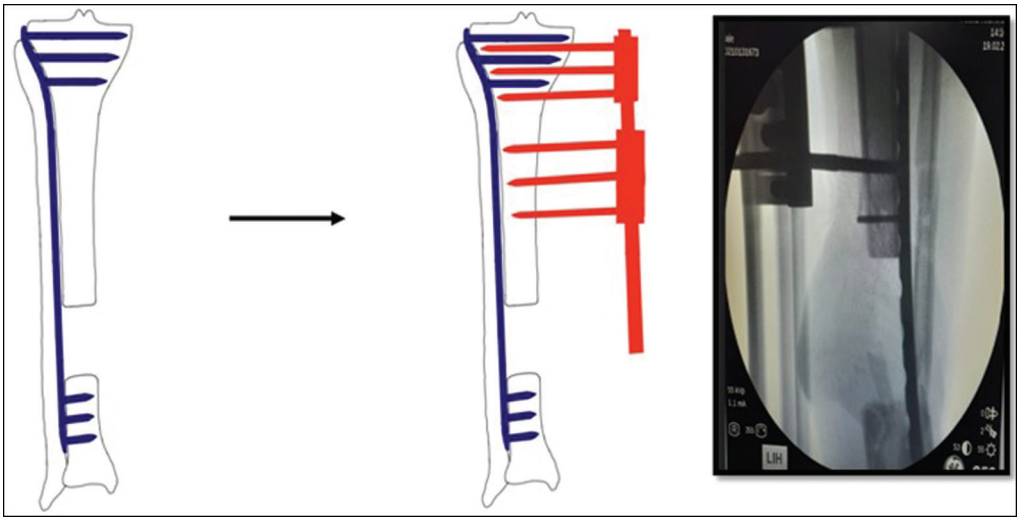

Figure 3: Application of LRS on longer segment with or without involvement of shorter segment

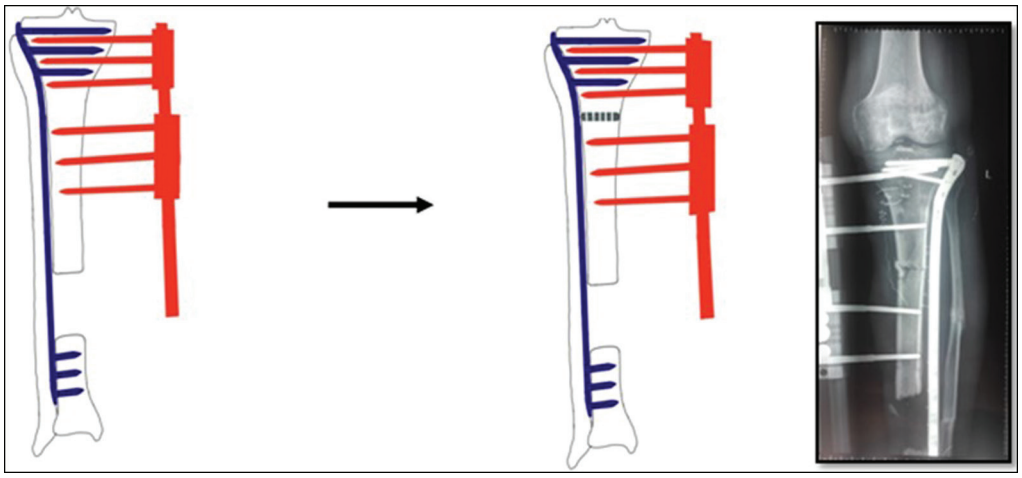

Figure 4: Corticotomy done between two clamps of external fixator

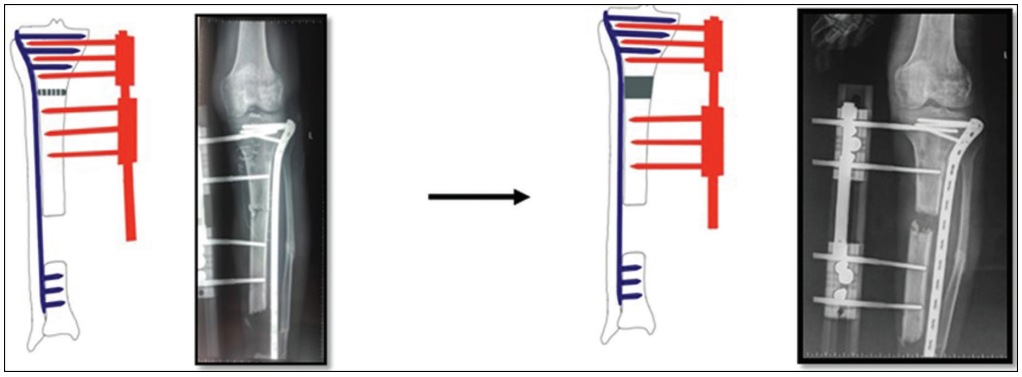

Figure 5: Starting of distraction on 10th day

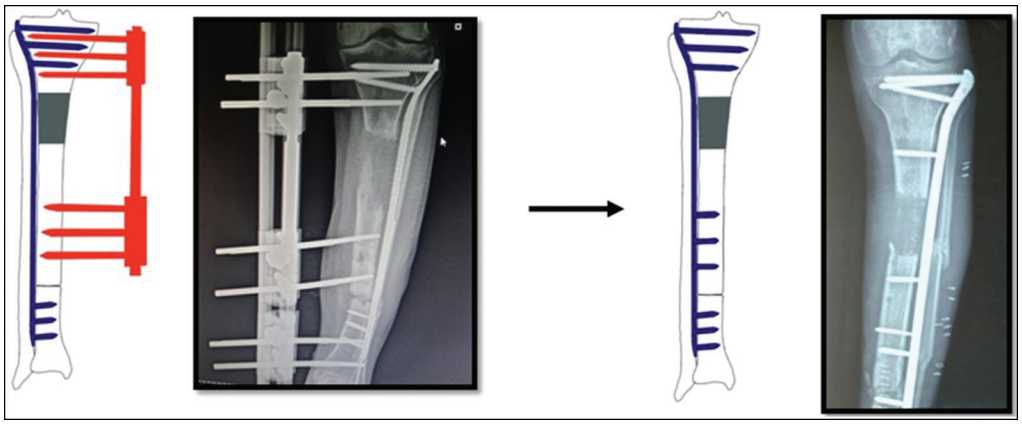

Figure 6: Transportation of bone segment to smaller fragment, application of screws percutaneously and removal of LRS

(2-wheeler vs 2-wheeler collision) 3 years back following which he sustained open fracture distal both bone leg right side. He underwent three surgeries prior (first-wound debridement and external fixator application, in the second stage- Flap coverage over the distal leg, and third surgery – re-debridement of wound). Active infection was ruled out and after pre-op assessment patient was subjected to LRS application with a tibial locking plate in the first phase. Detailed procedure is shown in Figure 7.

The patient was followed up at 10 days in OPD and distraction was started at the rate of 1 mm/day. After the end of the distraction phase at 50 days, post-operative patient was again intervened for the removal of the LRS fixator and percutaneous insertion of two cortical screws in the distracted fragment. The patient was started on a protected weight bearing on the walker. The patient was regularly followed up every 6 weeks for assessment of regenerate, union at docking site, and any complications.

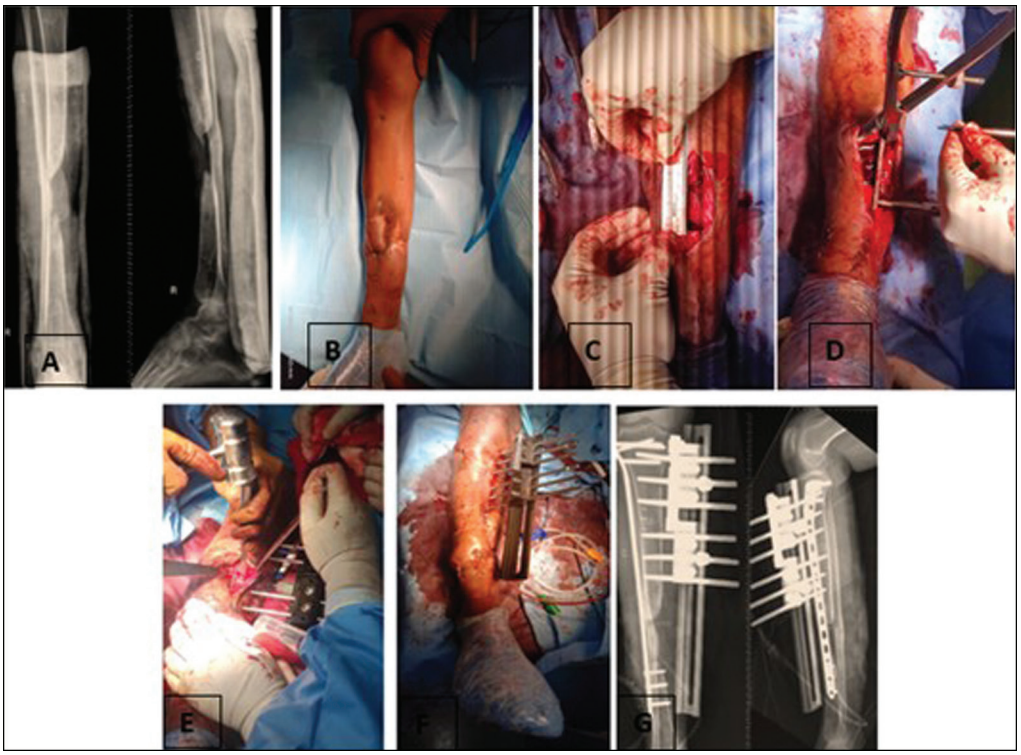

Figure 7: Case example showing. (A) Preop radiograph showing segmental tibial defect in lower third of tibia. (B) Intraop clinical image showing healed flap site with no active discharge. (C) Intraop debridement with freshening of bony edges and measurement of bony gap (4.5 cm in this case). (D) Insertion of lateral tibial plate with minimal invasive technique. (E) Corticotomy between two LRS clamps after LRS application from medial side. (F) Intraop image after completion of surgery. (G) Postop radiograph showing LRS and tibial plate in place

At 120 days, the patient completed the consolidation phase and full weight bearing was started. There were no significant complications apart from the pin tract infection, which was treated with regular dressing alone. Details are shown in Figure 8.

Results

With a mean age of 33 years, 10 patients were enrolled in this case series over a period of two years.

Demography

The first patient was enrolled in July 2020 and the last patient in March 2022 with all the patients having reached consolidation phase. All the patients in our study had multiple prior surgeries with mean of 2.7 and mean duration of trauma to enrolment was 17.7 months. Detailed demographic data are shown in Table 1.

The mean bone gap was 4.7 cm with a minimum of 2.7 cm to a maximum of 9 cm [Table 2]. The second patient in our study had skewed EFI due to non-compliance and poor follow-up. So median EFI gives a more accurate outcome, which was 15.63 cm/days, and the median duration of external fixator was 75.50 days.

All the patients were followed up for at least 30 weeks after removal of LRS except for the second patient who died due to chest infection secondary to HIV infection. Patients were assessed in terms of functional, bony outcomes and complications. At 30 weeks out of nine patients, three had an excellent functional outcome on ASAMI functional scale as well as on ASAMI bony scale, whereas six had a good outcome. The composite MSTS score was 76.66 % at the end of the 30-week follow-up. The mean time of consolidation was 134.4 days, whereas the mean union time was 145 days from index surgery.

Ankle stiffness was the most common complication affecting 50% of the patients. Following closely was pin tract infection, which was present in 40% of the patients. Only two patients reported none of the implant, bone, or joint-related complications. According to Paley's classification, there were out of all complications eleven were obstacles, two problems and none was true complications.

Discussion

In spite of being a highly effective technique of managing the segmental tibial defects among all available methods, distraction osteogenesis with its prolonged use of an external fixator has various shortcomings and is difficult for patients, and complications, such as pin-tract infections, pin loosening and joint stiffness are almost inevitable.[12,13] Such complications may lead to poor ASAMI bone (0%–26.3%) and functional scores (0% to 48%).[14] In one systematic review on 898 patients with a mean follow-up of 46.04 months and it was reported that rates of amputation were between 0% and 16.7% with the use of classical

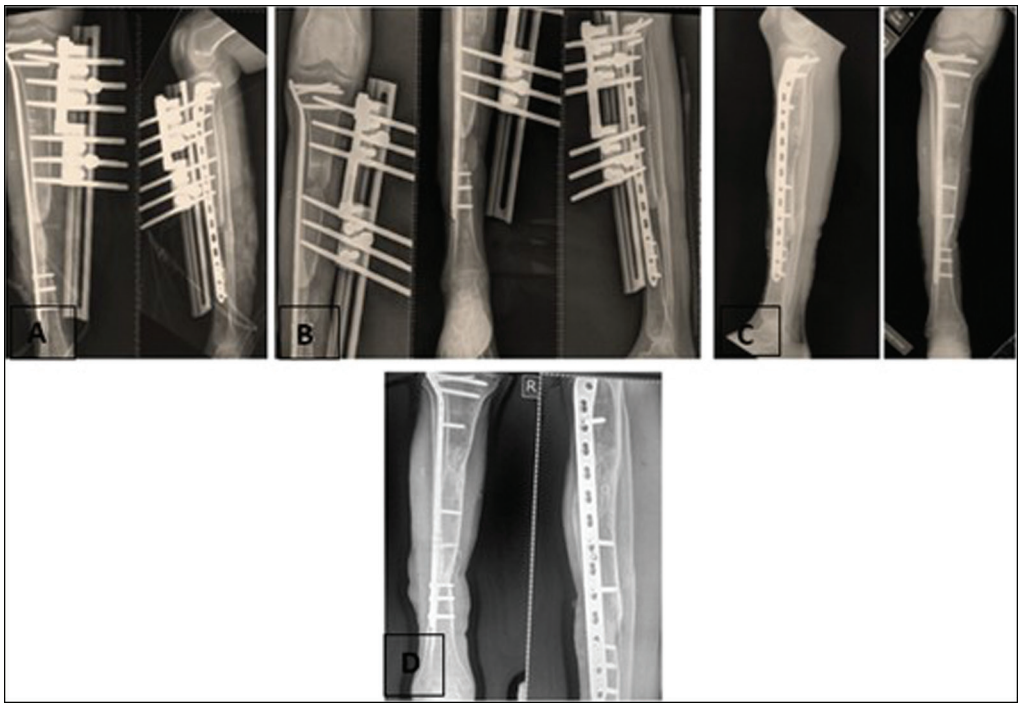

Figure 8: Radiographs of patient. (A) Immediate post op radiograph. (B) Radiograph after 2 weeks of distraction. (C) Radiograph after completion of distraction phase at 50 days post-op, followed by removal of LRS and Percutaneous insertion of screws in distracted segment. (D) Radiograph at the end of consolidation phase at 120 days postop

Table 1: Study demographics

Mean age of pt	33.7 ± 11.32
Gender	
Male	10
Female	0
Mean size of defect	4.8 ± 1.7
Site of defect	
Proximal	0
Middle	3
Distal	7
Side	
Right	4
Left	6

Table 2: Size and site of defect

Mean size of defect	4.8 ± 1.7
Site of defect	
Proximal	0
Middle	3
Distal	7
Side	
Right	4
Left	6

external fixator technique.[15] Fenton *et al*.[16] in their study reported that, if given a choice 28.75 % of patients would not like to have a circular fixator.

In our study, we have used integrated fixation using both external fixator and locking plate to address the complications of using external fixator alone. The EFI for classical tibial reconstruction with a fixator alone has been reported to range from 48 days/ cm to 75 days/cm for a mean tibial defect of between 4.7 cm and 6.5 cm in length.[17,18] With the use of the technique in the current study, the mean EFI was reduced to 18.82 days/cm (SD 10.49) for a mean defect of 4.76 cm (SD 1.85) in length. Median EFI in our study was 15.63 days/cm. Same was the case with the median duration of the fixator which came out to be 75.5 days. Fixator time would have been increased by nearly three times to 204 days had we not used the locking plate as found and quoted by Khan *et al*.[11]

For the conventional technique of distraction osteogenesis with external fixator, the common complications were related to pins or wires, because of the prolonged time of external fixator.[12] In our study, less time was required for external fixation, pin tract infection was present only in 40 % of the patient, and the mean complication rate was only 1.3 per patient. With the use of external fixator alone, axial malalignment and fracture at distraction site are common. But with the addition of a tibial locking plate, the technique of composite fixation corrects the angular deformity, prevents the sagittal deformity of the tibia, and also protects the regenerate sufficiently while enabling early mobilisation.[17] We did not experience any case of mal-alignment > 5° or fracture at distraction site.

The limitations of the study included small sample size and a short duration of follow up. We acknowledge the added

economic burden of using locking plates on patients along with LRS fixator devices but with the less complications and better functional outcomes, the composite fixation has added advantages.

Conclusion

Although the use of both locking plates with LRS fixator has some inherent complications related to the pin tract, this integrated fixation is both safe and effective and has the advantage of early removal of the external fixator and a low complication rate as compared to use of bulky conventional fixator alone. Moreover, it gives protection to the regenerated bone for a long period. So, this technique can be recommended for the management of segmental tibial defects.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Consent to participation

Informed, written consent from all patients was derived before including them in this study.

Ethical review committee statement

Institutional ethical clearance was obtained for the paper.

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