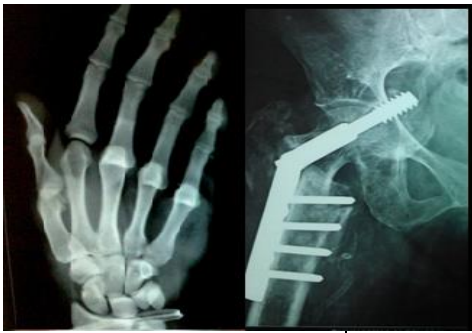

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Management of complex long bone nonunions using limb reconstruction system

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Abstract
Background: Management of complex nonunions is difficult due to the presence of infection, deformities, shortening and multiple surgeries in the past. Complex nonunions are traditionally managed by Ilizarov fixation. The disadvantages of Ilizarov are poor patient compliance, inconvenience of the frame and difficult frame construction. We conducted a study on 30 long bone complex nonunions treated by the limb reconstruction system (LRS).
Materials and Methods: Between April 2009 and September 2012, we treated 30 cases of complex nonunion of long bone with the LRS. 28 were male and 2 females. Average shortening was 5.06 cm and 14 cases presented with infected implants. Initially we managed with implant removal, radical debridement followed by fixation with the LRS. In 16 cases, corticotomy and lengthening was done. The average duration of treatment was 9.68 months. We compressed the fracture site at the rate of 0.25 mm per day for 1-2 weeks and distracted the corticotomy at the rate of 1 mm/day till lengthening was achieved.
Result: The union occurred in 89.28% cases and eradication of infection in 91.66% cases. Average lengthening done was 4.57 cm. We had 79% excellent, 11% good and 10% poor bony result and fnctional result was excellent in 40% cases, good in 50% and failure in 10% cases using ASAMI scoring system.
Conclusion: LRS is an alternative to the Ilizarov fixation in their management of complex nonunion of long bones. It is less cumbersome to the patient and more surgeon and patient friendly.

Keywords: complex nonunion, corticotomy, limb reconstruction system

Introduction
Incidence of open fractures of long bones are increasing due to the increase in road traffic accidents (RTA) leading to increased incidence of complex nonunions. These patients are usually operated upon several times for stabilization (and healing) or to eradicate infection, which in turn produces scarring of the soft tissues and devitalization of any surviving bone. They present with indolent infection, which is almost always associated with deformity, limb length discrepancy, joint stiffness, disuse osteoporosis and soft tissue atrophy [1]. As a result, it is considered to be one of the most complex and challenging orthopedic situations to manage [2]. External fixation is able to address these problems simultaneously [3, 4]. Traditionally complex nonunions are managed by the Ilizarov ring fixators. But, it is cumbersome, heavy and complicated, both for the surgeon and the patient [5]. Limb Reconstruction System (LRS Pitkar, Pune, India) is uniplanar and less bulky. It has the advantage of allowing distraction and compression at fracture site. It also allows dynamization of the fracture site which is the essential principle in the treatment of nonunions [6].
This study was conducted to assess the union rates, infection control, lengthening and the complications associated with the LRS.

Materials and Methods
Complex nonunion is defined as an established nonunion (of at least 6 months) with one or more of the following criteria: (a) infection at the site of nonunion; (b) a bone defect of more than 4 cm (defect nonunion); (c) an attempt to achieve union that failed to heal after at least one supplementary intervention, for example, bone grafting or exchange nailing [7].
This is a prospective study carried out between April 2009 and September 2012.

The study was approved by ethical committee of our institution. We included 30 cases of complex nonunion of long bones (16 tibia, 10 femur and 4 humerus) [Figures [Figures11–4] which were diagnosed clinically and radiologically and satisfied the inclusion criteria. Patients presenting with complex nonunion due to congenital disorders and following pathological fractures were excluded from the study. Final 30 cases were subjected to thorough clinical, systemic and local evaluation. Out of 30 cases, 28 were males with a mean age of 36.57 years (range 19-66 years) and 2 females with a mean age of 22 years (17 and 27 years). Fourteen cases presented with infected implants. The average shortening was 5.06 cm (1-10 cm).

Fig 1A: X-ray anteroposterior (a) and lateral (b) view of thigh showing infected nonunion left femur (c) immediate postoperative X-ray showing LRS in place (d, e) followup X-ray showing union (f) clinical photograph showing LRS system in place.

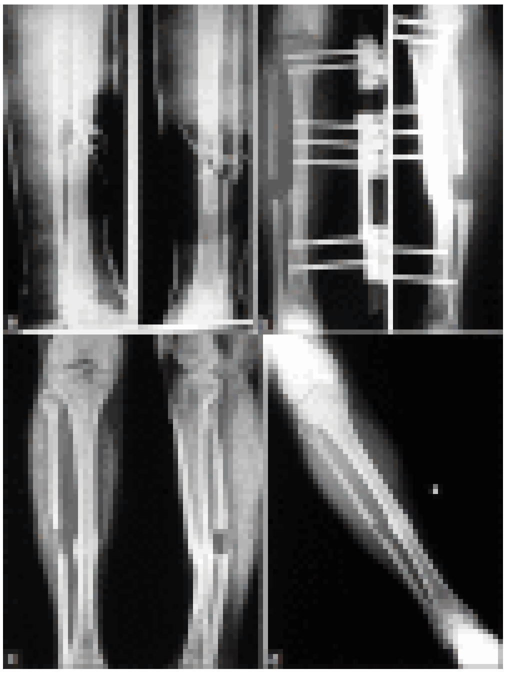

Fig 4: Infected nonunion of right tibia: Preoperative, postoperative, followup and at completion of treatment X-rays

Fig 1B: X-ray anteroposterior (a) and lateral view (b) of thigh at completion of treatment showing fracture has united well (c, d) clinical photographs showing range of motion

Fig 2A: (a, b) Anteroposterior and lateral views of humerus showing infected nonunion left humerus with implant in situ (c) Immediate postoperative anteroposterior X-ray of arm showing LRS in situ (d) Clinical photograph showing LRS in place (e, f) followup X-rays.

Fig 2B: (a, b) Anteroposterior and lateral X-rays shows union (c) Range of motion of elbow after removal of fixator

Fig 3: Anteroposterior (a) and lateral view (b) of leg bones showing infected nonunion left tibia (c, d) anteroposterior and lateral views followup X-rays showing union (e) Clinical photograph showing LRS in place. Patient standing single limb slance. (f) Anteroposterior.

Initially we managed with implant removal, radical debridement and fixed the nonunion with the LRS in operation theatre under all aseptic condition under suitable anesthesia under facility of an image intensifier [Figure 1]. In eight cases polymethyl methacrylate antibiotic cement beads were implanted. Commonly employed antibiotics were aminoglycosides (gentamicin), cephalosporins and vancomycin. Once there were no clinical signs of infection for 6-8 weeks, cement beads were removed. Twenty two cases presented with shortening (1-10 cm). Corticotomy and bone transport was done in 16 cases presenting with shortening ≥2 cm. Bifocal corticotomy was done in six cases presenting with shortening ≥7 cm. In cases of humerus, corticotomy and lengthening were not performed. We compressed the fracture site at the rate of 0.25 mm/day for 1-2 weeks and distracted corticotomy site at the rate of 1 mm/day, preferably in four increments a day. LRS was maintained till radiological sign of union was obtained (at least three out of four cortices united) [8]. The limb was protected with POP cast for 3-4 weeks in most of the cases after LRS removal. In our study, bone grafting was not done in any of the cases. Active and passive mobilization of adjacent joint was encouraged the day following operation. Ambulation and partial weight bearing was started on second or third postoperative day depending on patient's compliance, pain, local soft tissue condition and quality of bone. Compression at fracture site was started as early as third day postoperative day. Distraction at corticotomy site was started on the seventh postoperative day. Patients were discharged and asked to followup at 6, 12 and 14 weeks and at completion of treatment on the OPD basis. Patients were educated about pin tract hygiene, regular dressing, cleaning of external fixator and compression-distraction. At each followup appointment, problems of pin tract infection, loosening of pins, bolts, clamps were addressed. Check x-ray was taken at each followup appointment. Once radiological union of fracture site was visualized, 4 weeks were given for the consolidation and at the same time the corticotomy site was assessed. LRS was removed as office procedure in minor operation theatre under intravenous sedation. Average duration of treatment was less for humerus (mean 6.2 months), compared to femur (mean 9.3 months) and tibia (mean 10.2 months) [Figures [Figures11–4]. The details of patient, nonunion and treatments are summarized in Tables 11-3, respectively.

Table 1: Details of patient

Table 1

Details of patient

Variable	Numbers
Fracture side	
Left	16
Right	14
Fracture characteristic	
Open	27
Closed	03
Injury mechanism	
Road traffic accident	25
Work place injury	03
Domestic injury	02

Table 3: Details of treatment

Table 3

Details of treatment

Variable	Number
Mean time of union (months)	9.68 (6-18)
Mean time as in patients (days)	44 (30-62)
Mean number of followup appointments	14 (4-22)
Mean number of major operation following application of frame	2.3 (1-4)
Mean number of minor operation following application of frame	2.1 (1-3)
Mode of treatment	
Compression	12
Compression-distraction	02
[illegible]	[illegible]

Table 2: Details of nonunion

Variable	Numbers
Mean duration of nonunion (months)	24.3 (10 months to 19 years)
Level of nonunion	
Upper one-third	06
Middle one-third	13
Lower one-third	11
Type of nonunion	
Infected nonunion	26
Infected draining nonunion	20
Infected non draining nonunion	06
Noninfected nonunion	04

Paired t-test was used to compare the preoperative and post-treatment limb length discrepancy and range of movements of joints proximal and distal to the nonunion site. $P < 0.05$ was considered as significant.

Results

The final outcome was calculated in 28 cases for which final followup was available. Out of 28 cases, we were able to achieve complete union in 25 cases (89.28%) and eradication of infection in 91.66% of cases. Three cases failed to unite and two were lost to followup. 16 cases underwent lengthening. Average lengthening achieved was 4.57 cm (range 3-8 cm). Mean residual limb length discrepancy was 1.36 cm [Figure 5]. Finally there was no limb length discrepancy in 61% of cases, in 25% of cases it was 0.1-1 cm and in 14% of cases it was 1.1-2 cm. There was no significant difference in preoperative and post-treatment joint movements ($P > 0.05$). Results were calculated and graded as excellent, good, fair and poor based on ASAMI Scoring System [9].

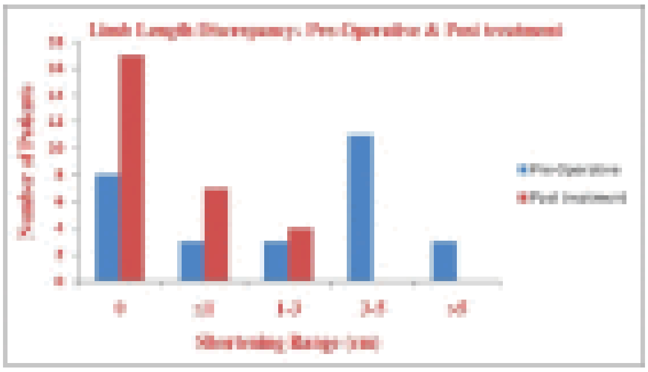

Fig 5: A bar diagram showing preoperative and postoperative limb length discrepancy*

Complications

Complications were classified according to Paley classification as problem, obstacle or true complication. Problem represented difficulties that required no operative intervention to resolve. Obstacles represented difficulties that required an operative intervention. All intraoperative injuries and difficulties during limb lengthening that were not resolved before the end of treatment were considered true complications.

Pin tract infection (n = 22, 78%) was the most common problem, pin loosening (n = 8, 29%) was the most common obstacle and joint stiffness (n = 13, 46%) was most common true complication. Other complications were angulation (n = 5), premature union of corticotomy (n = 1), equinus (n = 7), persistent discharge (n = 2) and refracture (n = 1) In our study at completion of treatment, there was no significant angular deviation (>15 degree) in any case. Twenty four cases (86%) had no angulation, while two cases (7%) had angulation less than 5 degree and in other two cases it was 7 degree. Final results of our study is shown in [Table 4] [9]. They are based on Ilizarov scoring system [Table 5] [9].

Table 4: Results

Results	No.	Percentage
Bone		
Excellent	22	79
Good	03	11
Fair	-	-
Poor	03	10
Functional		
Excellent	11	40
Good	14	50
Fair	-	-
Poor	-	-

Table 5: Ilizarov scoring system

	Bone results	Functional results
Excellent	Union, no infection, deformity <7 degree, limb length discrepancy <2.5 cm	Active, no limp, minimum stiffness (loss of < degree dorsiflexion of ankle), no reflex sym
Good	Union + any two of the following: Absence of infection, <7 degree, deformity and limb length inequality of <2.5 cm	Active with one or two of the following: Limp, stiffness, RSD, significant pain
Fair	Union + Only one of the following: Absence of infection, deformity <7 degree, limb-length inequality of <2.5 cm	Active with three or all of the following: Limp, stiffness, RSD, significant pain
Poor	Nonunion/re-fracture/union + infection + deformity >7 degree + limb-length inequality >2.5 cm	Inactive (unemployment or inability to return because of injury)
Failures	-	Amputation

RSD = reflex sympathetic dystrophy

Discussion

Traditionally, Ilizarov distraction osteogenesis is commonly used for managing complex non-union of long bone fractures associated with large defect and infection [1, 10, 11, 12]. But Ilizarov technique has been tempered by its complexity and technical difficulty, the commitment of time and resources required for good result and the potential for numerous complications [5]. LRS is uniplanar dynamized external fixator that is light weight, easy to construct frame with short learning curve and based on same basic principle of Ilizarov. It provides stable external fixation with the capacity to change the stiffness of fixation, and therefore, the fracture environment can be more precisely controlled. Limb lengthening can be achieved by bone transport. LRS is mechanically very stable because of the robust construct and variable spread of fixation by the use of sliding clamps. But it is difficult to correct three-dimensional deformities with uniplanar external fixator LRS unlike Ilizarov fixator.

In this study incidence of complex nonunion was most common in the third (40%) decade with male predominance (93%), and RTA (83%) was most common mechanism of injury. This is probably due to people of this age group are more prone for open fractures of long bones secondary to high velocity trauma (RTA). This study shows that tibia (54%) was the most common bone going for complex nonunion. Probable cause for this is one-third of tibia being subcutaneous is more prone to fracture, particularly open fracture. Intramedullary nailing was the most common mode of previous surgery (33%). Most of fracture united between 37-48 weeks (57%). The duration of treatment was less in cases of humeral complex nonunions (mean 6.2 months), where corticotomy and bone transport was not done. There was no major complications like radial nerve palsy and joint stiffness, Furthermore, the monolateral axial external fixator was tolerated well and allowed movements of shoulder and elbow throughout the period of treatment. It was more in cases with defect nonunions and fracture nonunions at ends of long bones, which needed additional prolonged period for enhancement of union.

In this study the union rate was 89.2%. Among them, 32% was by primary union, 50% by bone transport and 7% by callus distraction. It is in contrast of study done by Patil *et al*. (95%) [7] and Hashmi *et al*. (90%) [13] where bone grafting was done to achieve union. We were not able to achieve union in three cases (10.72%). Among these failed cases, one presented after 19 years of injury (distal one-fourth tibia) and underwent multiple earlier procedures. Distal fragment was very small with very poor bone quality and there was long standing infection with soft tissue atrophy. This case finally underwent for below knee amputation. Other two cases were infected nonunion of femur. Both cases presented after 3-4 years with multiple earlier procedures and bone stock was not good. One of them re-fractured after removal of frame, but infection was eradicated. In this case intramedullary nailing was done. In other case, we were neither able to control infection, nor achieve union. This patient refused further treatment.

Pin tract infection resolved with regular dressing before removal of frame. Pin loosening was managed by pin reinsertion and intravenous antibiotics. Other obstacles were premature union of corticotomy site in one case (3%) and refracture (3%) in another case. In the case of premature union of corticotomy site, we were not able to achieve normal limb length and there was 2 cm final shortening. Patient was not ready for any other procedure; hence, 2 cm shoe rise was given. While in case of refracture, which occurred in a case of 4-year-old infected nonunion femur, we were able to control infection and after one year of no signs of infection, intramedullary nailing was done. Joint stiffness was mainly pre-existing before applying LRS. We tried to improve it by passive and active exercises including physiotherapy, but there was no satisfactory improvement. The infection appeared to have been eradicated in most of our patients (91.66%). However, since we could not certainly exclude the possible future reactivation of infection, absence of discharging sinus for a minimum of 12 months was considered as success. This rule applied to all our patients. In our patients the outcome of bony consolidation was better than functional results. Excellent bony results of treatment accompanied by resolution of infection does not guarantee a good functional result. The functional result depends primarily on the existing damage of nerves, muscles, vessels, joints and to a lessor extent bones [Table 6].

Table 6: Comparison of our results with other studies

Results	Present study (LRS)		Hashmi et al.,[13] (LRS)		Patil et al.,[7] (ILIZAROV)		Rose et al.,[14] (ILIZAROV)	
	No.	%	No.	%	No.	%	No.	%
Bone								
Excellent	22	79	67	61	17	41	1	17
Good	03	11	38	35	14	34	3	50
Fair	-	-	04	3	4	10	1	17
Poor	03	10	-	-	6	15	1	17
Functional								
Excellent	11	40	46	42	14	39	1	17
Good	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Active involvement and participation of the patients is necessary for successful LRS treatment. Patient should be involved in daily adjustment of the apparatus. The co-operation of the physical therapist and patient is also important, since the patient must exercise the limb and joints. Nearly all of our patients were able to stand and walk with partial weight bearing immediately after LRS application. This is considered the most essential part of this method of treatment.

Limitation of our study includes the lack of a control group or a comparison treatment group that does not allow the development of true evidence based guidelines for the optimal treatment of this group of patients. Additionally, our study included more men than women. Female reproductive hormones have been shown to influence the inflammatory response and outcome after trauma [15, 16]. Finally, we included patients between 17 to 66 years in our study. The immune system is known to deteriorate with advanced age, rendering older patients less able to mount an appropriate immune response after infection or traumatic challenges [17, 18, 19]. Nevertheless, our study represents a large prospective group of patients in which complex nonunion of long bones treated successfully.

To conclude, the complex nonunion are managed satisfactorily with LRS. It is an alternative to Ilizarov fixation in management of complex nonunion of long bones.

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