



International Journal of Orthopaedics Sciences

ISSN: 2395-1958
IJOS 2018; 4(2): 511-517
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www.orthopaper.com
Received: 19-02-2018
Accepted: 20-03-2018

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Establishing the efficacy of limb reconstruction system (LRS) in the management of complex long bone non-union: A prospective study

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DOI: <https://doi.org/10.22271/ortho.2018.v4.i2h.79>

Abstract

In an urban metropolitan city like Chennai, over the years there has been a steady increase of high velocity RTA's especially with the number of citizens using two wheelers. In these instances, it is common to encounter comminuted open long bone fractures of the humerus, tibia and femur. Despite the prompt redressal of these cases with adequate debridement and stabilisation, a significant percentage of these cases land up with recrudescence of infection leading to complex non-unions. Some of these cases end up being operated upon several times with an aim to eradicate the infection, the presence of infection leads to scarring of sub adjacent soft tissue and the repetitive surgical intervention leads to devitalisation of the surviving bone. These complex infective non-union presents with not only with problem of indolent infection but with associated deformity, limb length discrepancy, sub adjacent joint involvement, disuse osteoporosis and soft tissue atrophy, as a consequence they turn out to be a complex challenging orthopaedic situation. These complex non-unions have been over the decades been traditionally addressed by the ilizarov ring fixator systems. In comparison limb reconstruction system which are lighter, less cumbersome and structurally rigid and uniplanar, come in as a significantly suitable alternative. It further has the advantage of distraction at one level and compression at fracture site. It permits dynamization of fracture site which is an essential element in the treatment of any non-union. In this prospective case series done between March 2015 to October 2017, we have studied 34 cases of patients reporting with complex long bone non-unions by the application of limb reconstruction system. The present study establishes the efficacy of the limb reconstruction system (LRS) in the treatment of these complex non-unions fractures of the long bone. In our series all cases went in for sound union with only 5.72% (n = 4) requiring resurgery.

Keywords: Complex long bone non-union, limb reconstruction system (LRS), compression distraction, bone transport

1. Introduction

The Limb Reconstruction System (LRS) is a series of modular monolateral external fixators to be used in reconstructive procedures for the treatment of limb length discrepancy, bone loss, open fractures, non-union and angular deformities [1]. Many years of clinical experience have confirmed the efficacy of the device, providing good outcomes for the above indications [2]. The innovation in the Advanced LRS has produced improved efficiency; increasing its ease of application in deformity correction, joint contracture and bone transport with short segments. This has expanded the available choices for the surgeon as there is now a system of external fixation for the effective treatment of deformity and bone defects that is better tolerated by the patient [3].

Management of these complex nonunionised in the presence of infection, angular deformity, limb length discrepancy and also multiple previous surgery is a challenging orthopaedic task, that the surgeon faces [4]. This disadvantage of ilizarov ring fixator is that it has a poor patient compliance and require frequent surgeon monitoring. This limb reconstruction system (LRS) on the other hand are uniplanar, less bulky and cumbersome further it allows for distraction at one site and compression at the other site [5]. It further permits for dynamization of the fracture non-union site, which is the essence of the principle of treatment of non-union [6]. The present study incorporates non-union resulting from non-unions of long bone of tibia, femur and humerus, which are both of infective and non-infective.

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2. Material and Methods

2.1 Aim of the study: Evaluation of the efficacy, radiological and functional outcome by using limb reconstruction system (LRS) method in the treatment for the management of complex long bone non-union with or without segmental bone loss and with or without active indolent infection.

This is a prospective case series study of complex long bone non-union reporting at the Department of Orthopaedics at Sree Balaji Medical College and Hospital, Chromepet from March 2015 to December 2017. Recruitment of cases stopped in February 2017, so that the follow up time is for a minimum period of 10 months. Hence the study lasted 2 years and 10 months, while the recruitment of patients was for 24 months.

2.2 Inclusion criteria

- Both men and women in age group of 20 to 50 years were included in the study.
- Non-union of humerus, femur and tibia both non-infective and infective, with any associated limb length discrepancy or angular deformity, were included in the study.

2.3 Exclusion criteria

- Patients not fulfilling the above inclusion criteria were excluded.
- Tuberculous non-unions were excluded.
- Pathological fracture non-unions arising out of skeletal metastasis, were excluded.
- Congenital causes of non-union of fracture were excluded.
- Fracture non-unions resulting from metabolic bone diseases were excluded.

2.4 Operative Management

Patient was worked up for surgery by doing all pre-surgical investigations. Anaesthetic fitness for surgery was obtained. Each case was planned depending on radiological diagnosis, soft tissue condition, infective or non-infective status. Patients with bone loss, dead sclerotic or sequestered bone and limb-length discrepancy were planned for excision of the devitalized tissues and the gap was managed by bone transport after a corticotomy at a proximal metaphyseal or metaphyseal – diaphyseal zone, after acute docking at the debrided fracture site. Segmental resection of fibula was done in leg to allow for acute docking. Attention was paid to preserving the periosteum at the corticotomy site because it has a major role in distraction osteogenesis. Sinus tract if any were surgically excised.

Patient was taken under spinal anaesthesia for lower limb non-union fractures and for upper limb non-union fractures, general anaesthesia or suitable regional anaesthesia was adopted. Wound debridement at the fracture non-union site was done meticulously and the bone ends were freshened until active bleeding could be visualised. Necrotic and fibrotic soft tissues in the vicinity of the fracture site were excised. In the presence of active or indolent infection, an antibiotic lavage with metrogyl and gentamycin was given which was followed up with a lavage with povidone iodine solution. Prior to lavage, swab was taken for culture and sensitivity.

Monolateral external fixator was applied following this. In cases requiring bone transport the designated site of corticotomy was addressed first before the surgical exploration of the non-union site. The most distal and the proximal schanz screws were applied first and tightened after making sure that the limb is in proper axial and rotational

alignment. The remaining schanz screws were secured subsequently. In all the cases acute docking was done at the non-union site and compression given. A C ARM image was taken at the end of the surgery to reconfirm the bony alignment and the bicortical purchase of the schanz screws. Corticotomy for bone transport was opted for only when the expected limb length discrepancy exceeded to 2 cm. In our series of 34 cases, 25 cases had shortening comprising of the designated limit. Shortening is an issue from the functional view point only in the lower limb bones. Shortening of even up to 3 cm are forgiving in the upper limb arm bone. The operative field was thoroughly irrigated and wound closed by stay suture.

2.5 Post-op protocol

2.5.1 First phase

During this first phase care is taken to meticulously do the pin tract dressing. IV antibiotics which were initiated on the day of surgery were continued for 5 days. In instances where gross or indolent infection were detected intra-operatively and sample was sent for culture and sensitivity, depending on the sensitivity report appropriate IV antibiotics were initiated and continued for a period of 3 weeks. The period of distraction is dependent on the extent of shortening present. In our series of 34 cases, 25 cases had a shortening in excess of 2 cm necessitating a corticotomy at a proximal site and then a subsequent distraction. Shortening of a few cm of humeral bone were over looked as they had no functional bearing on the outcome. In our series of 25 cases, which required lengthening, 19 cases were of tibia and 6 cases were of femur.

2.5.2 Second phase

Distraction was initiated on POD 7. The fixator was always applied to the lateral aspect for femur and the tibia. The distraction procedure was taught by the surgeon to the patient. The aim was to achieve a distraction of 1mm per day and this was accomplished by making a quarter of a turn of the distraction nut at fourth hourly intervals, during the waking hours (viz: 8.00 am, 12.00 pm, 4.00 pm and 8.00 pm). Thus a 360 degrees rotation of the distraction nut translates into a 1mm distraction at the corticotomy site. Patient is also taught to do pin tract dressings. Toe touch walking with walker support is also initiated from POD 7 or as early as the patients pain tolerance may permit. Thus prior to discharge the patient is ambulant, knowledgeable about the distraction method and also is trained on self-care of the pin tracts which is usually done with sterillum. Usually the patients are discharged by POD 12 with the advise that should there be abnormal pain, numbness or tingling distal to the fixator, the distraction procedure should be stopped forthwith and resumed after 48 hours in increments of two turns, 3 turns and 4 turns over a period of 7 days. Should upon resumption of distraction, if there be any recrudescence of pain or numbness, patient is advised to report immediately to the hospital.

3. Results

Table 1: Based on the age and sex of the patients.

Age (In Years)	Male 'N' (Percentage)	Female 'N' (Percentage)
20-24	2	1
25-29	3	2
30-34	4	1
35-39	7	1
40-44	5	0
45-50	5	3
Total	26(76.47%)	8(23.53%)

Table 2: Patient’s particulars.

Charecteristics		“n”	Percentage %
Gender	Male	26	76.47
	Female	8	23.53
Sidedness Of Fracture	Left	14	41.18
	Right	20	58.82
Nature Of Fracture	Closed	6	17.65
	Open	28	82.35
Mode Of Injury	Rta	26	76.47
	Fall From Height	6	17.65
	Fall From Ladder	2	5.88

Table 3: Nature and anatomical site of the complex non-union.

Chrecteristics		“n”	Percentage %
Level of Non Union	Upper 1/3 rd	3	8.82
	Middle 1/3 rd	25	73.53
	Lower 1/3 rd	6	17.65
Nature of Complex Non Union	Infected Non-Union With Draining Sinus	23	67.64
	Infected Non-Union Without Sinus	5	14.72
	Non-Infected Bone Defect Non Union	3	8.82
	Elephant Foot Non-Union	2	5.88
	Oligotrophic Non-Union	1	2.94

Table 4: Characteristics.

Particulars	In Months	“N”	Percentage %
Mean Duration Of Non Union	6-7	4	11.76
	7-8	5	14.70
	8-9	9	26.49
	9-10	16	47.05
Long Bone Involvement	Tibia	24	70.58
	Humerus	4	11.77
	Femur	6	17.65
Lrs Usage Mode	Compression	6	17.64
	Compression Distraction	3	8.82
	Compression And Bone Transport	25	73.54

Table 5: Complication.

Problem	“N”	Percentage %
Pin Tract Infection	22	31.88
Pin Loosening	10	14.49
Joint Stiffness	17	24.63
Angulation	7	10.14
Premature Union Of Corticotomy Site	2	2.89
Persistant Discharge	2	2.89
Equinus	9	13.04
Refracture	2	2.89

Table 6: Mean distraction done over the long bones.

Shortening In Mm	Mean Distraction				Total	
	Femur (N)	(Days)	Tibia (N)	(Days)	N	%
2 - 2.4	1	35	3	38	4	37.25
2.5 - 2.9	1	42	2	46	3	44.66
3 - 3.4	2	51	3	58	5	55.2
3.5 - 3.9	1	59	5	64	6	63.16
4 - 4.4	1	70	6	75	7	74.28
Total	6		19		25	

Table 7: Mean period taken for fracture healing for lower limb bone.

Time Taken In Weeks	Tibia	Femur
35-37	1	0
38-40	3	1
41-43	9	1
44-46	7	3
47-49	4	1
Total	24	6

Table 8: Mean period of fracture healing for upper limb bone.

Time In Weeks	Humerus
25-26	1
26-27	2
27-28	1
Total	4

In the 24 months of recruitment we could enrol 34 patients who satisfied our inclusion criteria. Of these 34 patients, there were 76.47% (n = 26) males and 23.53% (n = 8) females. There was a preponderance of right sidedness of the fracture nonunions at 58.82% (n = 20) among these 34 cases the primary fracture was a open fracture in 82.35% (n =28). Again majority of the injuries 76.47% (n=26) were as a result of road traffic accident.

Most of the non-unions treated in this series involved the middle 1/3rd of the long bone at 73.53% (n = 25) followed by fracture of the lower 1/3rd at 17.65% (n=6). Majority of these non-unions 82.36% (n=28) were those with indolent or frank infection at the non-union site with or without sinus only 17.64% (n=6) were of the noninfective type.

Majority of the non-unions in our series 70.58% (n=24) were of tibia, 17.35% (n=6) were of femur and 11.77% (n=4) were of the humerus. The mean time lapse of the non-unions dealt with this series were 8.6 months (range: 6 months to 10 months). The LRS usage mode was 73.54% (n=25) as a compression and bone transport mode. In the remaining 26.46% (n=9) the LRS usage mode was either in pure compression mode or in the compression distraction mode.

Among the complications encountered the highest were in the form of pin tract infection at 31.88% (n=22), this was followed at 24.63% (n=17) as joint stiffness and another 14.49% (n=10) as pin loosening. We had 2.89% (n=2) of premature union of coticotomy site where distraction had been withheld for about 4 weeks due to nerve palsy, which required surgical refreshment of the coticotomy site. We also had 2.8% (n=2) of refracture at the distracted site because of early weight bearing by the patient after fixator removal. These 2 cases however could be managed conservatively by the application of PTB cast.

In our series majority of the patients 58.80% (n=20) where in the age group of 35-50 years. The remaining 41.20% (n= 12) where in the age group of 20-34 years. In cases requiring coticotomy and bone transport the number of days were proportionate to the amount of shortening. The mean number of days were maximum at 74.28% for a shortening of 4 to 4.4cm. Our series included cases where the shortening ranged from 2 to 4.4 cm, of these 19 involved that of tibia and 6 involved that of femur.

4. Case illustration



Fig 1a: Fracture of lower 1/3rd of femur right side.



Fig 1b: Showing failed plating system resulting in non union.



Fig 1c: Showing 6 months after distraction with LRS in situ.



Fig 1d: Showing adequate callus formation at 9 months.



Fig 1e: Showing fracture union at 10 months.

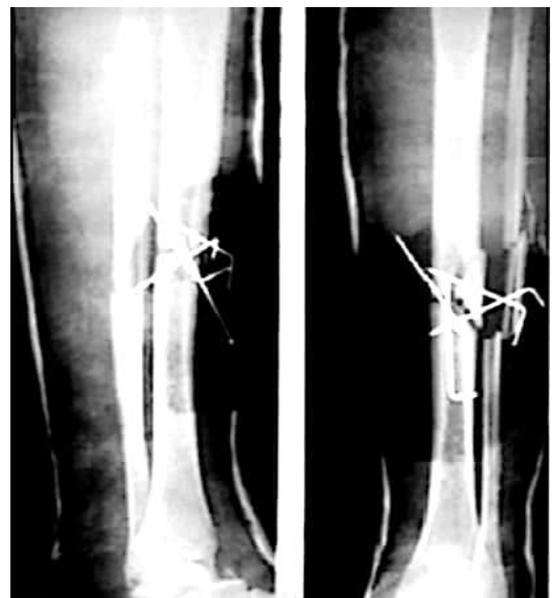


Fig 2a: Showing fracture of both bone of right leg with implant failure and non-union.

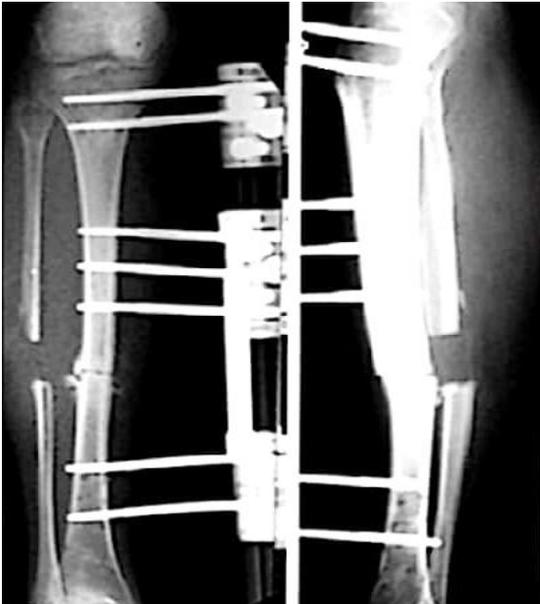


Fig 2b: Showing LRS over right tibia with fibulectomy.



Fig 2c: Showing fracture union of right tibia after LRS is removed at 6 months.



Fig 3a: Showing fracture mid shaft of right humerus.

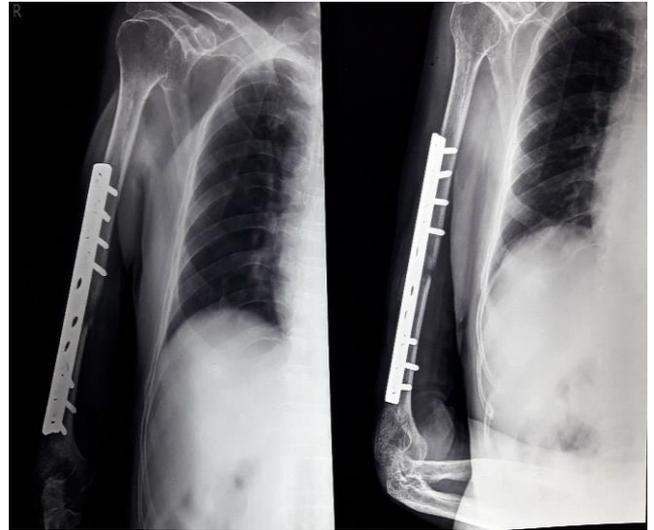


Fig 3b: Showing non union fracture shaft of right humerus with infected implant in situ.



Fig 3c: Showing patient after LRS fixator application.

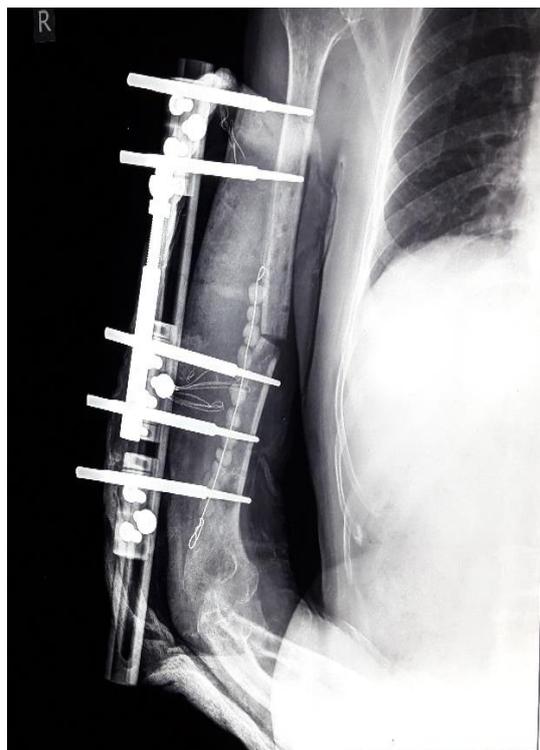


Fig 3d: Showing fracture shaft of humerus after implant removal with antibiotic beads and LRS fixator in situ.



Fig 3e: X ray Showing united fracture shaft of right humerus at 6 months.

5. Discussion

In the present day scenario incidence of long bone fractures have increased due to rise in road traffic accidents. These fractures in many an instances, go in for complex non-unions, some requiring prolonged treatment and sometimes even multiple surgeries. In the instance of the original fracture being open, the chances are that we have to deal with an infective non-union. Repetitive surgeries and the presence of infection produces scaring of soft tissues and devitalization of the remaining bone. Indolent infection are almost invariably present also with other complications such as deformity, limb shortening, adjacent joint stiffness, disuse atrophy of the muscles and disuse osteoporosis of the injured bone [7]. All these problems make it a challenging task for the orthopaedic surgeon [8]. It is in managing this herculean task, that the

external fixators come as a boon, as they are able to address all these problems simultaneously [9, 10]. From the 90's onwards complex, non-unions, whether infected or otherwise were managed surgically with ilizarov external ring fixator system. But the disadvantages in it lies with the fact that they are cumbersome heavy and complicated, from the patients point of view [11]. The limb reconstruction system on the other hand are uniplanar and therefore less bulky. These have an added advantage of allowing for distraction at coticotomy site and compression at fracture site, which allows for correction of any limb length discrepancy simultaneously.

The limb reconstruction system allows also for dynamization of the fracture site with micro motion which is the essential component in the treatment of fracture non unions [12]. LRS is mechanically a stable construct and the presence of sliding clamps allows for a variable spread of fixation. In our series of 34 patients there was a male preponderance of 76.47% (n=26). This compares well with the study of Hiranya Kumar Seenappa *et al.*, who reported a male preponderance of 93%. Our incidence of 76.47% compares well with that of Seenappa's study of 83% as RTA being the predominant mechanism of injury. In our series majority of the non-unions 70.58% were of the tibia, which when compared to Seenappa's was 54%. Tibial bone being a subcutaneous bone for more than half its length, is more prone for open fracture. Most of our humeral fractures healed by a mean of 5.8 months which compares well with the series of Seenappa's where it was reported as 6.2 months. In our series tibial non-unions took a mean of 9.9 months and femoral non-unions took a mean of 10.4 months. There was 1 case of radial nerve palsy which recovered in 6 weeks and hence was not recorded as a complication. In view of the monolateral axial fixator, in the shoulder series, mobilization of the shoulder and elbow was possible as early as two weeks and hence there were no significant residual joint stiffness. However there were 10 cases of ankle stiffness and 7 cases of knee stiffness in the lower limb series, but a majority of these cases had the stiffness prior to LRS fixation.

In our series union rate was 100%. Among them 17.46% was by primary union, 8.82% was by callus distraction compression and 73.54% by bone transport. In cases of shortening of less than 2 cm, in which coticotomy and bone transport was not performed in the lower limb series, for them a shoe rise was given.

Table 9: Comparison of our results with other studies. (Based on ASAMI scoring system) [13].

Result	Our Study LRS		Hiranya Kumar Seenappa <i>et al.</i> , LRS [14]		Hashmi <i>et al.</i> , LRS [15]	
	N	%	N	%	N	%
Bony Results						
Excellent	12	35.29	22	79	67	61
Good	17	50	03	11	38	35
Fair	5	14.70	0		04	03
Poor	0		03	10	0	0
Functional Results						
Excellent	15	44.11	11	40	46	42
Good	17	50	14	50	55	55
Fair	2	5.88	0		4	3
Poor	0		0		0	
Failure	0		03	10	5	5

Our bony results as per ASAMI scoring did not match with neither Hiranya *et al.*, [14] nor that of Hasmi *et al.*, [15] but surprisingly the functional results are a near perfect match in all the three studies. This proves the point that in the ASAMI scoring system [13] the bony results do not reflect the functional results and hence needs to be taken cognisance of.

6. Conclusion

Limitation of our study is in the fact that we did not have a control group or a comparison study with ilizarov technique. Also the ratio of male to female cases was grossly tilted in favour of the former at 3:1. With the above given limitations and the relatively small number of cases (n = 34), our

experience with LRS has been gratifying for complex long bone nonunions which are either infected or not by achieving a union rate of 100%. Patient satisfaction and compliance during the entire course of treatment was excellent.

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