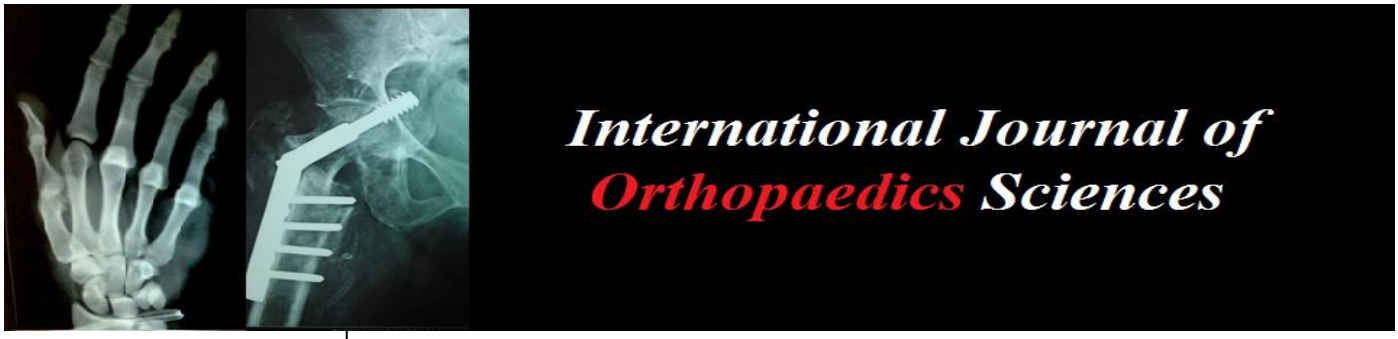

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Clinical outcome of limb reconstruction system (LRS) in the treatment of infected long bone shaft nonunion

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Abstract
Objective: To summarize the clinical and functional outcomes of infected non-union cases who have been treated with LRS.
Methods: Between January 2015 and September 2016, we treated 20 cases of infected nonunion of long bone with the LRS. 17 were males and 3 females.8 cases presented with infected implants while 7 cases were on external fixators. Initially we managed with implant removal and radical debridement followed by fixation with the LRS. Corticotomy and lengthening was done in 7 cases. The average duration for removal of LRS was 6.5 months. Distraction at the corticotomy site was done at the rate of 1 mm/day till lengthening was achieved and in those subjects where no corticotomy was done, acute docking and compression was given.
Results: Union occurred in 95% cases and eradication of infection in 90% cases. For 13 patients bone results were excellent, 5 patients good, 1 patient had fair result and 1 had poor result. Regarding functional results 8 had excellent score, 11 had good score and 1 had failure as the limb was amputated based on ASAMI scoring system.
Conclusion: LRS is an excellent alternative to Ilizarov fixation in the management of infected nonunion of long bones. It can be used to achieve union as well as to correct shortening in these cases. It is less cumbersome to the patient and more surgeon and patient friendly.

Keywords: Infected nonunion, limb reconstruction system, corticotomy, Ilizarov

Introduction
Injuries and fractures have become so common in the present day, main reason being population explosion, with increase in road traffic accidents, traffic congestion and urbanization, mechanization and agriculturization. Long bones femur, tibia and humerus being the most commonly fractured [1], their fracture management contributes significantly to the cost of orthopedic care being provided worldwide.
Treatment options for long bone fractures vary according to the type of fracture, age group, bone density, soft tissue status and associated complications. Conservative methods used are casting or bracing for stable closed fractures. Operative techniques used are fixation with plates and screws, intramedullary nailing and external fixation.
The most important complication following an open fracture is delayed union/nonunion. They contribute to about 10-20% of fracture treatment complication.
Today open fractures with infection are perhaps the most common causes of nonunion. [3]Infected non-union is associated with multiple problems like osteomyelitis, bone and soft tissue distortion and loss, sinuses, osteopenia, joint stiffness and multidrug-resistant and at times multibacterial infection. Various modalities of treatment for infected nonunion of long bones described are extensive debridement, microvascular soft tissue flaps, external fixation with bone graft, Ilizarov ring fixator, bone transport through external fixator over nail and limb reconstruction system (LRS) [2] Antibiotic-impregnated cement for control of infection is a common technique before union at the fracture site achieved.
In external fixation, fracture fragments can be realigned, compressed or distracted, without the need of opening fracture site. External fixators have the unique capability to stabilize bone and soft tissues at a distance from the operative or injury focus. If correctly applied, they provide unobstructed access to the relevant skeletal and soft tissue structures for their initial

assessment and also for those secondary interventions needed to restore bony continuity and a functional soft tissue sleeve. Patient can be mobilized almost immediately with more rigid external fixator.

Ilizarov ring fixator and LRS are the implants that can serve the above purpose [4, 5] Ilizarov ring fixator and limb reconstruction system are common modalities and are single staged procedure. Correction of deformity and limb length discrepancy is possible with these along with excellent control of infection and facilitates bone union. Weight bearing can also be initiated during treatment. Compared to LRS, Ilizarov fixator is cumbersome to the patient, painful and relative difficult to mount.

Limb reconstruction system (LRS) is less bulky with better compliance, easy to apply and remove with advantage of being dynamic which is the most important principle in treatment of non-union [6, 7] It has the advantage of allowing distraction of osteotomy siteas well as compression at fracture site. It also allows dynamization of the fracture site, which is the essential principle in the treatment of nonunion [8]. This system is very effective, and offers rigid stabilization of fracture fragments and with an access to soft tissue care. Though, initially these fixators were expensive, on a long run they have become cheap, as these can be repeatedly used without any compromise. In our study we assess the union rates, infection control, lengthening and the complications associated with the LRS in the treatment of infected nonunion.

Objective

To assess the clinical and functional outcomes of infected non-union cases who have been treated with LRS

Regarding distraction histogenesis by Ilizarov technique,two types of fixators are in use: • Ilizarov ring fixator • Monorail fixator The greatest differences between the two types of fixators were the number of pin-track infections, problems of angulation and length of time for which patient cannot bear weight after application of fixator. Pin track infections are less with monorail fixator and angulation problems are more with it. Earlier it was considered that monorail fixator is a comparatively unstable construct and it does not allow early weight bearing. Early weight bearing with monorail fixator can cause problem of angulations, and refracture at the site of regenerate or docking site.

The major advantages of the Ilizarov method are that rotation and angulation can be corrected simultaneously, but knee motion loss is more with ilizarov and it is difficult to regain when compared with monolateral fixator. So a uniaxial deformity with subcutaneous bone like tibia monorail fixator is a good option.

Patient with Monorail fixator show better compliance as compared to Ilizarov fixator. The patient can wear clothes over the Monorail fixator (especially traditional Indian dresses) in a better way than Ilizarov system. The Monorail fixator technique is easier to learn than Ilizarov system. Furthermore no further major surgical procedures are needed after application of monorail fixator, though adjustments in alignment may be needed. Monorail fixator is low in cost as compared to ring fixator

Materials and Methods

A prospective study of the Clinical Outcome of Limb Reconstruction System (LRS) in infected long bone shaft nonunions was conducted at the Department of Orthopaedics, Government Medical College, Thiruvananthapuram. All patients with infected nonunion of long bones admitted in the study setting during the study period (Jan 2015 to Sep 2016) were included in the study. Sample size was calculated as 20.

Data were collected using a semi-structured questionnaire and clinical examination on serial follow up sessions in outpatient clinics. The final assessment part of the questionnaire was based on ASAMI Scoring System for assessing the outcome of fracture union.

Table 1: Ilizarov Bone Score

Bone Results	Description
Excellent	Union, no infection, deformity < 7, limb length discrepancy < 2.5 cm
Good	Union + any two of the following: absence of infection, < 7 deformity and limb length inequality of < 2.5 cm
Fair	Union + only one of the following: absence of infection, deformity < 7 and limb length inequality < 2.5 cm
Poor	Non union/refracture/union + infection + deformity > 7 + limb length inequality > 2.5cm

Table 2: Ilizarov Functional Score Follow Up

Functional	Description
Excellent	Active, no limp, minimum stiffness (loss of < 15 knee extension/ < 15 dorsiflexion of ankle), no reflex sympathetic dystrophy (RSD), insignificant pain
Good	Active, with one or two of the following: limp, stiffness, RSD [a], significant pain
Fair	Active, with 3 or all of the following: limp, stiffness, RSD [a], significant pain
Poor	Inactive (unemployment or inability to perform daily activities because of injury)
Failures	Amputation

Patients will be followed up at regular intervals of 4 weeks, 8 weeks, 4 months, 6 months and 1 year postoperatively.

Ethical approval was obtained from the institutional ethics committee prior to the study

Operative Technique –LRS Application In Infected Nonunion

Before the application of LRS external fixator, we should do thorough debridement of infected fracture site if there is sequestrum. We also have to know in which plane it has to be applied and why. The principle of applying instrumentation or implants is to apply at tensile force side. Whereas this instrumentation has to be applied only at compressive force side, that is medially or anteromedially because to nullify the compressive force of the muscles which are present at posterolaterally which is the side of tensile force.

Analysis and Observation

Majority of the cases were in the age group of 25-50 years (60.0%). 85% of the study subjects were males.

Most common primary treatment done was External Fixation (35%).

Tibia was the commonest long bone presented with nonunion. 77.8% of the cases had closed injury pattern. 53.3% of cases were Gustilo-Anderson type 3.

45% of the study subjects were diabetic. Only 30% of the study subjects were hypertensive in 60% of the cases, vancobead was inserted at the time of surgery. In 35% of the cases, corticotomy was done at the time of surgery. In only 30% of the cases, bone graft was done at the time of surgery.

In 35% of the cases, pin tract infection was present. In 40% patients, there was loosening of at least one pin. In 30% of subjects, mild to moderate joint stiffness was seen. Out of 20 subjects 1 subject had persisting infection after treatment. 80 percentage of subjects had no limping. Out of 20 patients 4 developed Reflex Sympathetic Dystrophy.

In 95% subjects, the treated limb was functionally active

Out of 19 patients 73.7% patients had shortening less than 2.5 cm (1 patient was amputated). Out of 19 subjects 3 subjects had deformity more than 7 degrees after treatment.

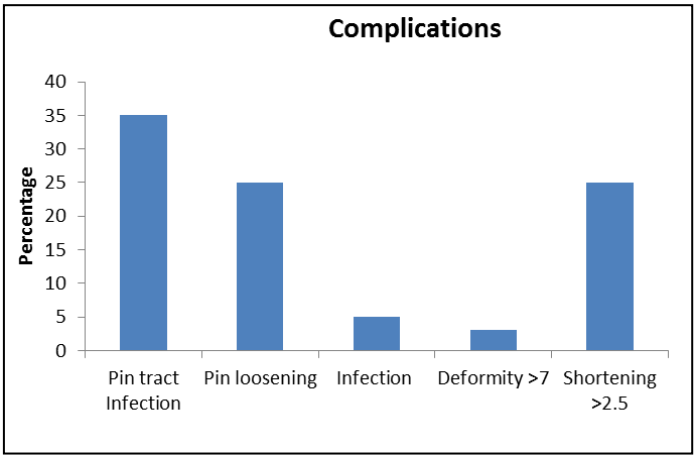

Fig 1: Complications

Most common complication seen during treatment was pin tract infection.

Table 3: Ilizarov Bone Score

Ilizarov Bone Score	Frequency	Percent
Excellent	13	65.0
Good	5	25.0
Fair	1	5.0
Poor	1	5.0
Total	20	100.0

In 65% subjects the results were excellent and 25% subjects the results were good.

Table 4: Ilizarov Functional Score

Functional Ilizarov Score	Frequency	Percent
Excellent	8	40.0
Good	11	55.0
Failure	1	5.0
Total	20	100.0

In 40% subjects the functional results were excellent and 55% subjects the results were good.

*48 yr old male patient presented with infected ILN tibia and nonunion 7 month post op treated by debridement and acute docking

Fig 2: Pre-Op Xray-Infected Non-union with ILN insitu

Fig 3: Nail removed and LRS applied

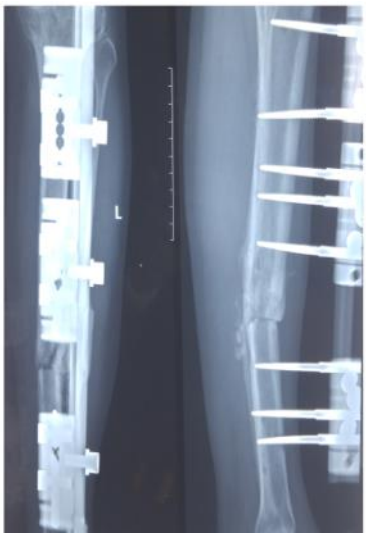

Fig 4: 4 Months Follow-up Xray

Fig 5: 1 year Follow-up Xray

Fig 6: Functional results

******46 year old female case of fracture humerus, treated by open reduction and internal fixation presented with infected non-union. Implant removal, debridement and LRS applied.

Fig 7: Initial Injury

Fig 8: Infected Non-union after 3 months

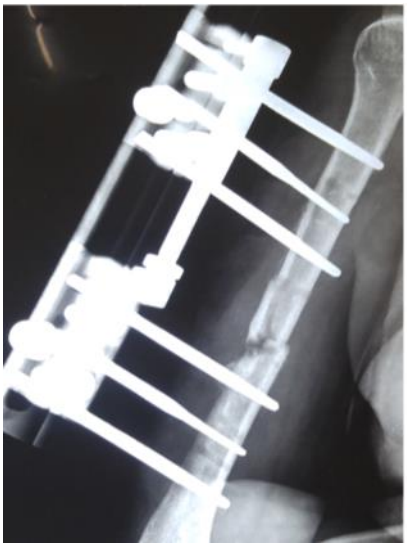

Fig 9: Post-operative X ray

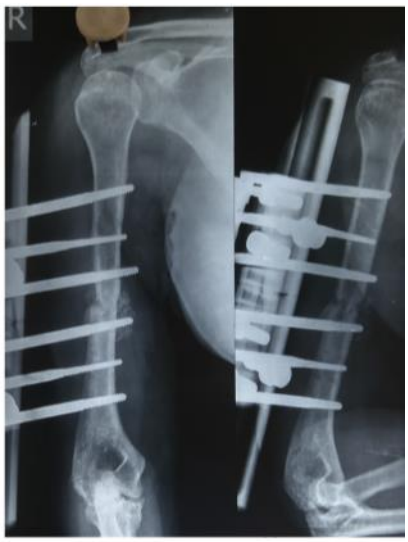

Fig 10: 2 months follow up

Fig 11: 4 months followup

Fig 12: 6 months followup

Discussion

Non-union is a difficult clinical problem often arising from severe injury to the limb. It may have a devastating effect on patient's social and financial state. These patients are usually operated upon several times either to gain stabilisation and healing or to eradicate infection, which in turn produces scarring of the soft tissues and devitalisation of any surviving bone. Traditionally, Ilizarov distraction osteogenesis is commonly used for managing complex non-union of long bone fractures associated with large defect and infection [31]. 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 [32]. LRS is uniplanar dynamic external fixator that is light weight, has short learning curve and is based on same basic principle of Ilizarov [9]. It provides stable external fixation with ability to do limb lengthening by bone transport. Major drawback is difficulty to correct three-dimensional deformities unlike Ilizarov fixator.

Our study outcome was assessed with ASAMI scoring system. For 13 patients bone results were excellent, 5 patients good, 1 patient had fair result and 1 patient had poor result. Regarding functional outcome 8 had excellent score, 11 good score and 1 had failure as the limb was amputated. Comparisons of present study with other studies in the literature are given in table below.

Table 5: Bone Results Outcome Comparison with Other Studies (in%)

Bone results	Present Study	Hashmi *et al.* [9]	Hiranya *et al.* [15]	Patil *et al.* [32]
Excellent	65.0	61	79	41
Good	25.0	35	11	34
Fair	5.0	-	-	10
Poor	5.0	4	10	15

Table 6: Functional Results Outcome Comparison with Other Studies (in%)

Functional results	Present Study	Hashmi *et al.* [9]	Hiranya *et al.* [15]	Patil *et al.* [32]
Excellent	40	42	40	39
Good	55	50	50	39
Fair	-	3	-	5
Poor	-	-	-	5
Failure	5	5	10	12

Summary and Conclusions

With the increase in high velocity injuries and open fractures, infection is becoming one of the common cause of nonunion. External fixators are the choice of treatment when the nonunion is associated with soft tissue loss and bone loss along with infection at the nonunion site. LRS is a type of advanced monoplanar external fixator with many benefits. Soft tissue procedures like skin grafting, myocutaneous, muscle pedicle flap repair can be easily accompanied with external fixator in position.

Resection of devitalized bone, simultaneous compression of the fracture gap or site and secondary limb lengthening by proximal corticotomy and compression and distraction techniques can be accompanied with the LRS external fixator to achieve union and eradication of infection. Complications are minimal, with good range of movements at knee and ankle.

20 cases of infected nonunion of long bones were managed with LRS (Limb Reconstruction System) external fixator. Most of the fractures were treated initially by external fixation. Static quadriceps exercise was begun during immediate postoperative period. Knee and ankle motion was allowed immediately from the first postoperative day.

To conclude, though this study was a prospective study, randomized control design was not used. It included only 20 patients with follow up of one year. We are of the opinion that in infected nonunion with bone loss and in cases with extensive soft tissue damage, limb reconstruction system is a good choice to save the limb, achieve union and restore limb length. Patient can be allowed early weight bearing without any adverse effect on bone union, alignment and quality of regenerate. It is an alternative to Ilizarov fixation in management of complex nonunion of long bones.

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