ORIGINAL ARTICLE

Functional and radiological outcome of ilizarov method for non-union of tibia and femur in pediatrics and adolescents

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Abstract

Objective: To review a single unit experience of functional and radiological outcome of ilizarov method for non-union of femur and tibia in pediatrics and adolescent patients.

Material and Methods: Femoral and tibial shaft fractures are severe injuries and challenging for both, the patient and surgeon. Un-eventful healing of both entities is expected in 8 to 12 weeks in about 90% of patients. However non-union rates of 2 to 12% for femoral and 60 to 80% for tibial shaft fractures have been reported even in the presence of advance surgical techniques. Non-union of femur and tibial shaft fractures can be managed by open reduction and internal fixation and bone grafting, external fixation and bone grafting, the Masquelet technique of induced-membrane formation. Distorted local anatomy, recipient site complication, graft failure, thrombosis, two stage surgery and re-fracture with induced-membrane technique are possible complications of trending treatment modalities. Ilizarov method has been reported in multiple studies to have been used successfully for the treatment of wide range of orthopaedic problems. There are few studies regarding the role of ilizarov in segmental bone transport for non-union of femur and tibia in pediatrics and adolescents internationally, no local studies. The study was an observational study where descriptive analysis was done at the Bolan Medical Complex Hospital Quetta, from February 2016 to February 2019.

Results: All the 30 patients (100.0%) which were included in the study had infected non-union of femur 11 (36.7%), infected non union tibia 8 (26.7 %), Non-union femur 9 (30.0 %), non union tibia 2 (6.7%). 8-patients (26.7) had no previous surgeries, 9 (30.0%) patients had only one surgery and 13 (43.3%) had 2-previous surgeries. Bone debridement and excision of seclerosed and necrosed bone was done in all 30 (100.0%) patients. The bone defect ranged from 1 to 5 cm. The most common previous surgery was ORIF with Narrow DCP/Ex Fix 8 (26.7%) and ORIF with LCP/ Ex Fix 8 (26.7%) Infection was eradicated in all 30 cases (100.0%) and union was achieved in all 30 patients (100.0%). The operative time ranged from 70 to 150 minutes mean+S.D 116.50(20.13). The most common complication was pin tract infection in 16(43.4%) with 5 patients (16.7%) superficial pin tract infection and 11 (36.7%) deep pin tract infection. The other complications were loosening of wires 3-patients (10.0%), loosening of Shan screws 6-patient (20.0%), Amputation 2-patients (6.7%), Refracture 4-patient (13.3%), poor regenerate 6-patients (20.0%). No severe limb oedema (0.00), loss of Knee mobility 9-patients (30.0%), loss of Hip mobility 2-patient (6.7%). The loose wires and schanz screws were removed and replaced by new ones in 5-patients (16.7.0%), shortening of less then 2 cm in 3-patients (10.0%).

Conclusion: The method of ilizarov which can reconstruct the bone is safe and effective method for treatment of non-union of femoral and tibial shaft fractures in pediatrics and adolescents. Despite the associated complications a detailed pre-operative plan, regular follow-up and timely management can help to achieve a satisfactory outcome. However our study lack direct comparison with any other treatment options therefore further randomized control trials are needed to draw more valuable conclusions.

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Keywords: Pediatrics and adoloscents patient, fracture of femur and tibia, Non-Union, Ilizarov, ORIF, Narrow DCP, Bone debridement, pin tract infection, corticocancellous bone graft

Introduction:

Femoral and tibial shaft fractures are severe injuries and challenging for both, the patient and surgeon. Un-eventful healing of both entities is

expected in 8 to 12 weeks in about 90% of patients.[1] However non-union rates of 2 to 12% for femoral and 60 to 80% for tibial shaft fractures have been reported even in the presence of advance surgical techniques.[2,3,4] Non-union of femur and tibial shaft fractures can be managed by open reduction and internal fixation and bone grafting, external fixation and bone grafting, the Masquelet technique of Induced-Membrane formation. Distorted local anatomy, recipient site complication, graft failure, thrombosis, 2-stage surgery and re-fracture with Induced-Membrane technique are possible complications of trending treatment modalities.[5]

Ilizarov method has been reported in multiple studies to have been used successfully for the treatment of wide range of orthopaedic problems like congenital short stature, deformity correction caused by traumatic injuries, infections, metabolic bone diseases and limb length discrepancy, nonunions and bone defects.[6]

The method of ilizarov segmental bone transport has several advantages like limited surgical exposure and less blood loss. These factors make this approach especially applicable to patients with pre-existing soft tissue and bone infections and poor skin condition. Femoral and tibial reconstructions using the ilizarov method offers the surgeon a comprehensive way to avoid a variety of complications and address many femoral pathologies to the ability to perform limb lengthening, deformity correction and bone transport at the same time.[7] So we can say that our technique of segmental bone transport with ilizarov method offers a safe and effective method to combat one of the most difficult orthopaedic problems.

Objectives: To review a single unit experience of functional and radiological outcome of ilizarov method for non-union of femur and tibia in pediatrics and adolescent.

We included all non-unions of femur and tibial shafts in pediatric and adolescents age group presented or referred to our department during the study period. We excluded femur and tibial shaft fractures due to some pathological condition, like tumor, bone cyst or any metabolic bone condition and the patients that were lost follow up.

Material and Methods:

The surgical techniques for external fixation of pediatric femur fractures has been previously reported.[7] Patient was positioned supine on radiolucent operating table with entire lower limb for tibial fractures and entire lower limb and abdomen for femoral fractures was included in the sterile field.

For femur fracture, the fracture non-union site was opened and bone debridement was done up to the paprica sign. If the created bone defect was less then 2 cm, docking was done initially. For larger defects segmental bone transport was done. 2-3 arches were applied for the proximal femur. Complete rings were applied in the distal femur. In some cases arches were also used in the distal femur when needed. If the distal femoral segment was short a complete ring was applied on proximal metaphyseal area of the tibia and the knee joint was spained. 2-3 half pins were used in each arch. In each ilizarov ring 2-3 wires were applied.

For non-union of the tibia fracture site was opened and bone debridement was done upto the paprica sign. If the created bone defect was less than 2 cm, docking was done initially. For larger bone defects segmental bone transport was done. Two complete rings were applied in the proximal fregment and two complete rings were applied in the distal fregment, with two to four ilizarov wires in each rings. If the distal fragment was very short and stibility was not achieved with one ring in the distal fragment, the ankle was spained and a half ring was applied in the foot which was removed after docking was achieved.

The width of the underline bone determined the diameter of the half pin (no greater than ⅓ the diameter of the underline bone), and hydroxyappatite-coated pins were preferred.

Table 1*: Demographics Characteristics*

Variables	N (%)	
Age	Mean ± S.D	12.07 ± 2.16
Gender	7	
Male	5(16.7)	
Female	25(83.3)	
Diagnosis		
Infected Non Union Femur	11(36.7)	
Infected Non Union Tibia	8(26.7)	
Non Union Femur	9(30.0)	
Non Union Tibia	2(6.7)	
No of Previous Surgeries		
1 surgery	9 (30.0)	
2 surgery	13(43.3)	
No Surgery	8(26.7)	

Table 2*: Clinical Characteristics*

Variables	N (%)	
Type of Previous Fixation		
Ex Fix	7(23.3)	
Ex Fix/ Ex Fix	1(3.3)	
I/M Nail	1(3.3)	
N/A	8 (26.7)	
ORIF with LCP/ Ex Fix	8 (26.7)	
ORIF with NDCP/Ex Fix	2(6.7)	
Rush Pin	1(3.3)	
Rush Pin / Ex Fix	2(6.6)	
Bone Defect		
Yes	30(100.0)	
Bone debridement and excision of scleroses bone		
Yes	30(100.0)	
Length of Bone defect		
1 cm	4(13.3)	
2 cm	7(23.3)	
3 cm	9(30.0)	
4 cm	6(20.0)	
5 cm	4(13.3)	
Time frame in days	Mean ± S.D	165.0 ± 52.5
Infection Eradicated		
Yes	29(96.7)	
Union achieved		
Yes	30(100)	
Operative time	Mean ± S.D	116.50(20.13)
Pain		
Yes	11(36.7)	
Analgesia		
Yes	11(36.7)	

To avoid thermal necrosis of the underline bone, hand insertion of pre-drilled half pins was preferred. To confirm the overall alignment of the limb elctrocautry cord under fluoroscopy was used to assess the mechanical axis of the entire limb.

Statistical analysis: Data was stored and analysed using IBM-SPSS version 23-0, decriptive anlaysis done using count, percentages of base line characteristics, diagnosis, clinical characteristics and complications. Table(I) showing the descriptive outcome.

Initially there were 40-patients in the study. The 10-patients that were lost in the follow-up either they have changed their residence or phone numbers so they were not included in the study.

A total of 30-patients were included in this descriptive study with an age range of 8 to 15 years (mean: 12.7±2.16 years) with 25-male (83.33%) and 5-female patients (16.67%).

Patients were encouraged partial weight bearing mobilization with assistive devices on the next day of the operation. Physiotherapy was advised for knee, hip and ankle (range of motion exercises). Daily pin care with half-strength hydrogen peroxide and pyodine solution was recommended. Intravenious antibiotics were given according to the culture and sensitivity tests.

Distraction-osteogenesis was started on the 7th post-operative day. The rate was 1 mm per day and the rhythm was 0.25 mm 4-times a day. If early consolidation was suspected on the radiographs the distraction rate was increased accordingly. When the docking was achieved compression was done (0.25 twice weekly until union was achieved or patient complaint pain).

When radiological union was achieved at the fracture site and consolidation of the regenerate was appreciated, the ilizarov fixator was often dynamized by loosening the longitudinal connections between the proximal and distal pin clusters at the fracture site and also the threaded rods across the regenerate. Generally the fixator was removed when at least three cortices were

Table 2*: Clinical Characteristics (continued)*

Variables	N (%)
Refracture	
Yes	5(16.7)
Poor Regenerate	
Yes	6(20.0)
Re-fracture in the consolidate	
Yes	4(13.3)
Amputation	
Yes	2(6.7)
Loosening of shanz screws	
Yes	6(20.0)
Loosening of wires	
Yes	3(10.0)
Neurological symptoms	
Nil	30(100.0)
Severe limb oedema	
Nil	30(100.0)
Loss of knee mobility	
Yes	9(30.0)
Loss of Hip mobility	
Yes	2(6.7)
Superficial pin tract infection	
Yes	11(36.7)
Deep pin tract infection	
Yes	5(6.7)
Removal of wire or shawnz screw	
Yes	5(16.7)
Shortening of less than 2cm	
Yes	3(10.0)

Table 3*: Results of femoral non union using the criteria of association for the study and application of the method of ilizarov (ASAMI) scoring system*

Bone results		
Excellent	Union, no infection, deformity <7°, limb-length discrepancy <2.5 cm	16
Good	Union + any two of the following:	2
	Absence of infection, < 7° deformity and limb-length inequality < 2.5 cm	
Fair	Union + only one of the following:	1
	Absence of infection, deformity < 7° and limb-length inequality <2.5 cm	
Poor	Nonunion/re-fracture/union + infection + deformity > 7° + limb-length	1
	Inequality > 2.5 cm	
Functional results		
Excellent	Active, no limp, minimum stiffness (loss of < 15° knee extension /< 15°	10
	dorsiflexion of ankle), no reflex sympathetic dystrophy (RSD) insignificant pain.	
Good	Active, with 1 or 2 of the following: Limp, stiffness, RSD, significant pain	5
Fair	Active, with 3 or all of the following: Limp, stiffness, RSD, significant pain	3
Poor	Inactive (inability to return to daily activities because Of injury)	1
Failures	Amputation	1

radio graphically healed on two orthogonal radiographs. The ilizarov was removed under General Anesthesia in the routine operation list.

Results:

All the 30-patients (100%) which were included in the study had infected non-union femur 11(36.7%), infected non-union tibia 8 (26.7%), Non-union femur 9 (30.0 %), non-union tibia 2(6.7%). 8-patients (26.7) had no previous surgeries, 9 (30.0%) patients had only one surgery and 13 (43.3%) had 2-previous surgeries.

Bone debridement and excision of seclerosed and necrosed bone was done in all 30 (100%) patients. The bone defect ranged from 1 to 5 cm. The most common previous surgery was ORIF with Narrow DCP/Ex Fix 8 (26.7%) and ORIF with LCP/Ex Fix 8 (26.7%) Infection was eradicated in all 30-cases (100.0%) and union was achieved in all 30-patients (100.0%). The operative time ranged from 70 to 150 minutes mean±S.D 116.50.

The most common complication was pin tract infection in 16 (43.4%) with 5-patients (16.7%) superficial pin tract infection and 11 (36.7%) deep pin tract infection. Patients with post-operative pain 11 (36.7%) patients, all these patients needed analgesia to relieve the pain.

The other complications were loosening of wires 3-patients (10.0%), loosening of Shan screws 6-patient (20.0%), Amputation 2 patients (6.7%), refracture 4-patient (13.3%), poor regeneration 6-patients (20.0%), No severe limb oedema (0.00), loss of Knee mobility 9-patients (30.0% loss of Hip mobility 2-patient (6.7%). The loose wires and schanz screws were removed and replaced by new ones in 5-patients (16.7.0%), shortening of less then 2 cm in 3-patients (10.0%). Table I & II

The bone and the functional results for femur were assessed according to the protocol laid down by the association for the study and application of the method of Ilizarov (ASAMI).[6] Table: III. The bone and the functional results for tibia were assessed according to the protocol

Table 4: *Results of tibial non union using the criteria of association for the study and application of the method of ilizarov (ASAMI) scoring system*

Bone results		
Excellent	Union, no infection, deformity <7°, limb-length discrepancy <2.5 cm	6
Good	Union + any two of the following:	2
	Absence of infection, < 7° deformity and limb-length inequality < 2.5 cm	
Fair	Union + only one of the following:	1
	Absence of infection, deformity < 7° and limb-length inequality <2.5 cm	
Poor	Nonunion/re-fracture/union + infection + deformity > 7° + limb-length	1
	Inequality > 2.5 cm	
Functional results		
Excellent	Active, no limp, minimum stiffness (loss of < 15° knee extension /< 15°	5
	dorsiflexion of ankle), no reflex sympathetic dystrophy (RSD) insignificant pain.	
Good	Active, with 1 or 2 of the following: Limp, stiffness, RSD, significant pain	2
Fair	Active, with 3 or all of the following: Limp, stiffness, RSD, significant pain	2
Poor	Inactive (inability to return to daily activities because Of injury)	1
Failures	Amputation	0

Case 1 Figure:1

Case 1 Figure:2

Case 1 Figure:3

Case 2 Figure:1

Case 2 Figure:2

Case 2 Figure:3

laid down by the association for the study and application of the method of Ilizarov (ASAMI).[6] Table: IV. The bone and functional results were not always the same. In 7-patients the functional outcome was better than the bone outcome, where as in 5-patients the bone outcome was better than the functional outcome.

Evaluations and outcomes: We prospectively followed the patient who had under gone ilizarov treatment for non-union of the femur and tibia in pediatrics and adolescents. Bone transport time, external fixation time, external fixation complications were all recorded. Radio graphs were reviewed every two weeks during the distraction period and monthly during the consolidation period. Ilizarov external fixator was removed when radiograph showed solid docking site union and the regenerate area had a minimum of three complete cortices. Functional and bone results were evaluated according to ASAMI classification.[4]

Discussion:

The purpose of this study was to assess the functional and radiological outcome of ilizarov method in non-union of femur and tibial fractures in pediatric and adolescents patients. Based on the review of 30 such cases we believe that this approach yields good to excellent functional results with a minimal rate of complications .This conclusion is also supported by literature showing successful results in other centers.[7-11]

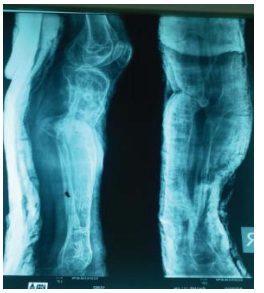
Radical debridement including excision of necrotic soft tissue and sequestractomy usually results in bone and soft tissue defects which increase the complexity of the subsequent reconstruction.

Several methods can be adopted for the management of bone defects, such as cortico-cancellous bone graft, vasucularised autogenous bone graft, Masquelet-induced membrane technique and ilizarov bone transport. Cortico-cancellous bone graft is ideal for patient with a small defect and no infection and there are limited options for autogenous bone graft in pediatrics and adolescents patients. Vasucularised autogenous bone graft usually vasucularise fibular graft is associated with high rate of refracture, donor site morbidity, and complexity of the operation and usually is not a good option for femoral and tibial defects because of its thinner size.[11] Masquelet-induced membrane technique needs a large amount of bone graft with consequent donor site morbidity and at least 2 operating procedures are required for a successful

Case 3 Figure:1

Case 3 Figure:2

Case 3 Figure:3



Case 3 Figure:4

surgery. The other option to take a large amount of bone graft for Masquelet-induced membrane technique is reamer–Irrigator-Aspirator which is not available in most centers including our centre. So far there are no recommendations of reamer– irrigator-aspirator in pediatrics and adolescents. Here are few studies available on Masuelet-induced membrane technique in pediatrics and adolescents patients.[12] Allograft requires challenging preparations and preservations. Furthermore the involvements and the extension of the defect limit the chance of using the previous methods unless the soft tissue is treated first which is time consuming.[13]

Ilizarov method has gained popularity for the treatment of non-union of femur and tibial fractures because it has no such dificulties which are present in other reconstructions. The technique is based on a biological principle which has been termed the tension stress effect by Professor Ilizarov. It entails a segmental bone transport in which corticotomy is performed in the proximal or distal metaphysis and the bone is gradually distracted.

Ilizarov external fixation device is strongly recommended in the treatment of non-union of femur and tibial fractures in adults which is also applicable with some modification in pediatrics and adolescents.[14]

The following basic principles of this philosophy were stated by the Professor Ilizarov.[15,16]

The principles of Professor Ilizarov are adequacy of blood supply and loading tension stress effect that stimulates the bio-synthetic activity in tissues, possibility of full-time control of callus formation, gradual lengthening and correction and erly limb functioning and loading.

The surgical techniques applying the ilizarov techniques are not aggressive, spare tissue and involve little blood loss. They do not require massive intensive care measures post-operatively. [1518]

In our study, the patients that were included had multiple previous failed surgeries and mostly complicated by non-union or infection. Despite the fact that our series was relatively small, it's note worthy that the external fixator time reflected the extent of bone restoration required, the number of previous interventions and the nature of initial stabilization of the fracture.

One important observation that needs to be mentioned in our study is that we had low pin tract infection (43.4%) which is very high in other studies (sometimes 100%)[9-11,13,14] The reason for this successful outcome is meticulous pin tract care in our patients.

Conclusion:

The Ilizarov method which can reconstruct the bone is safe and effective method for treatment of non-union of femoral and tibial shaft fractures in pediatrics and adolescents.

Despite the associated complications a detailed pre-operative plan, regular follow-up and timely management can help to achieve a satisfactory outcome. However our study lack direct comparison with any other treatment options therefore further randomized control trials are needed to draw more valuable conclusions.

Level of evidence:III

Conflict of interest: None

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Role and contribution of authors:

Dr Karim Bakhsh, collected the data, references and did initial writeup

Dr Hamidullah Khan, collected the data and helped in discussion writing

Dr Eid Mohammad, collected the references and helped in interpretation of data

Dr Attiq Ur Rehman, collected the references and helped in result writing

Dr Amanullah, collected the data references and helped in introduction writing.

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