REVIEW of LITERATURE

Raschke MJ et al in 1992,[20]reported the new fixation method and the primary clinical experience. Four patients who previously sustained Grades II-IIIb open tibial fractures had an average bony defect of 9 cm. Two patients had previous bony infections. All patients had serial debridement and myocutaneous flaps were required in three patients. An unreamed IM nail was inserted, and the transport device was applied. After an osteotomy, segmental transport was carried out until docking was attained. The external fixator was removed after interlocking of the transported segment. The mean duration of external fixation was 17.9 days/cm and the mean period until roentgenographic consolidation of the distraction and non-union site was 41.2 days/cm. There were two pin-tract infections but no IM infections. One nail broke after osseous consolidation of the regenerate at the distal interlocking site and required exchange.

Yongu WT et al in 2009,[21] have conducted a study on bone gap management using linear rail system. They have selected the femur bone fracture patients for the study. They have found the linear rail system as a simpler, less challenging and cosmetically accepted procedure.

Wani N et al in 2011,[22]assessed the results of patients with Gustilo types II, IIIA and IIIB open tibial fractures managed early with the Ilizarov external fixator (IEF). Sixty patients (51 males, nine females; age range 20–62 years; mean age 32.8 years) with type II (11 patients), type IIIA (13) and type IIIB (36) tibial diaphyseal fractures underwent emergency debridement and minimal bone fixation (with external fixator), followed by definite fixation with the IEF after three to five days. Average duration of the hospital stay was 8.6 days. All fractures united with an average union time of 21.1 weeks

(standard deviation [SD] 3.18) in type II, 21.7 weeks (SD 3.57) in IIIA and 24. 9 weeks (SD 5.14) in IIIB fractures. The difference between union time in type II and IIIA was not significant ($p > 0.05$), but that between IIIA (and also type II) and IIIB was significant ($p < 0.05$). The healing index in patients who underwent lengthening was 1.5 months/cm. The wounds in 27 patients were managed by delayed primary closure, in 19 patients with second intent (all IIIB), in 11 patients with skin grafting (mostly type IIIB fractures) and in three patients with musculocutaneous flaps. The most common complications of the procedure were pin tract infection and pain at the fracture site. Most of the patients were able to achieve good knee and ankle range of motion. Early application of the Ilizarov fixator constitutes an excellent management of open tibial fractures, especially types II, IIIA and IIIB, due to good functional and radiological results.

Lakhani A et al in 2014,[23] assessed the outcome of rail fixator system in reconstructing bone gap. 20 patients (17 males and 3 females with mean age 30.5 years) who suffered bone loss due to open fracture and chronic osteomyelitis leading to infected gap non-union. Ten patients suffered an open fracture (Gustilo type II and type III) and 10 patients suffered bone gap following excision of necrotic bone after infected nonunion. There were 19 cases of tibia and one case of humerus. All patients were treated with debridement and stabilization of fracture with a rail fixator. Further treatment involved reconstructing bone defect by corticotomy at an appropriate level and distraction by rail fixator. They achieved union in all cases. The average bone gap reconstructed was 7.72 cm (range 3.5-15.5 cm) in 9 months (range 6-14 months). Normal range of motion in nearby joint was achieved in 80% cases. They had excellent to good limb function in 85% of cases as per the association for the study and application of the method of ilizarov scoring system [ASAMI] score. All patients well tolerated rail fixator with good functional results and gap reconstruction. Easy application of rail fixator and

comfortable distraction procedure suggest rail fixator a good alternative for gap reconstruction of limbs.

Ajmera A et al in 2015,[24]evaluated the outcome of the limb reconstruction system (LRS) in the treatment of open fractures of tibial diaphysis with bone loss as a definitive mode of treatment to achieve union, as well as limb lengthening, simultaneously. Thirty open fractures of tibial diaphysis with bone loss of at least 4 cm or more with a mean age 32.5 years were treated by using the LRS after debridement. Mean followup period was 15 months. The mean bone loss was 5.5 cm (range 4-9 cm). The mean duration of bone transport was 13 weeks (range 8-30 weeks) with a mean time for LRS in place was 44 weeks (range 24-51 weeks). The mean implant index was 56.4 days/cm. Mean union time was 52 weeks (range 31-60 weeks) with mean union index of 74.5 days/cm. Bony results as per the ASAMI scoring were excellent in 76% (19/25), good in 12% (3/25) and fair in 4% (1/25) with union in all except 2 patients, which showed poor results (8%) with only 2 patients having leg length discrepancy more than 2.5 cm. Functional results were excellent in 84% (21/25), good in 8% (2/25), fair in 8% (2/25). Pin tract infection was seen in 5 cases, out of which 4 being superficial, which healed to dressings and antibiotics. One patient had a deep infection which required frame removal. Limb reconstruction system proved to be an effective modality of treatment in cases of open fractures of the tibia with bone loss as definite modality of treatment for damage control as well as for achieving union and lengthening, simultaneously, with the advantage of early union with attainment of limb length, simple surgical technique, minimal invasive, high patient compliance, easy wound management, lesser hospitalization and the lower rate of complications like infection, deformity or shortening.

Pal P C et al in 2015,[25]have conducted a study on 32 cases of selected compound fracture of tibia. There were 26 males and 6 females and the average age was 40 years. Patients

were randomly divided into two groups (n=16 for each): one underwent Ilizarov fixation and the other received LRS fixation. Cases were followed up for 3-24 months, 6 months on average. Functional and radiological outcomes were assessed using the Association for the Study and Application of Methods of Ilizarov (ASAMI) criteria for both rail and ring fixator. Radiological outcome was found excellent in 68.75%, good in 18.75% and fair in 12.50% of cases treated by rail fixators whereas it was excellent in 56.25%, good in 18.75%, fair in 12.50% and poor in 12.50% of cases treated by ring fixators. Functional result was satisfactory in 75.00% of cases treated by rail fixator and 68.75% of cases treated by ring fixators whereas the corresponding rate of unsatisfactory was 25.00% vs. 31.25%.

Rohilla R et al in 2016,[26]compared the radiological and functional outcomes of ring and rail fixators in patients with an infected gap (> 3 cm) non-union of the tibia. 70 patients were treated for a posttraumatic osseocutaneous defect of the tibia measuring at least 3 cm. These were randomised into two groups of 35 patients using the lottery method. Group I patients were treated with a ring fixator and group II patients with a rail fixator. The mean age was 33.2 years (18 to 64) in group I and 29.3 years (18 to 65) in group II. The mean bone gap was 5.84 cm in group I and 5.78 cm in group II. The mean follow-up was 33.8 months in group I and 32.6 months in group II. Bone and functional results were assessed using the classification of the Association for the Study and Application of the Method of Ilizarov (ASAMI). Functional results were also assessed at six months using the short musculoskeletal functional assessment (SMFA) score. The result was excellent, good, fair and poor in 21, 12, 0 and 2 in group I; and 14, 15, 3, and 3 in group II, respectively. The functional results were excellent, good, fair, and poor and failure in 16, 17, 1, 0 and 1 in group I; and 22, 10, 0, 3 and 0 in group II, respectively. Both fixator systems achieved comparable rates of union and functional outcomes. The rate of deep pin-tract infection was

significantly higher in the rail fixator group but patients found it more comfortable. They recommend the use of a ring fixator in patients with a bone gap of more than 6 cm. Patients with a bone gap up to 6 cm can be managed with either a ring or rail fixator.

Tekin AÇ et al in 2016,[27]evaluated functional and radiological results following treatment with the single-plane external fixator limb reconstruction system (LRS) for open tibial diaphyseal fractures resulting from high-energy trauma. 50 tibias from 49 patients (males: 32, females: 17) were classified as type 3 according to the Gustilo-Anderson open fracture classification, and definitive treatment was applied with the LRS. The patients ranged in age from 20 to 36 years. Time to union, time of external fixator usage, complications and functional results according to the Johner-Wruhs criteria were recorded. The mean follow-up period was 23 ± 12 months (range: 1144). Of the 50 tibias, full union was achieved with the LRS in 48 (96%). No shortness or deformity was observed in any patient. Knee and ankle range of movement were measured as full in all patients at the final follow-up examination after removal of the LRS. The mean time to union was 20.4 ± 4 weeks (range: 16-24). The mean time of external fixator use was 20 weeks (range: 16-24 weeks). For the definitive treatment of open tibia diaphyseal fractures, the LRS was an optimal and safe choice that offered single-stage surgery.

Patil MY et al in 2016,[28]determined the efficacy of Limb Reconstruction System for treatment of compound tibia fractures. A prospective study was carried out where 54 cases out of 412 compound tibia fractures having Modified Gustilo Anderson Type IIIA and IIIB with a mean age of 42±5 years were treated using LRS over a period of 26 months. Bony and functional assessment was done by Association for the Study and Application of the Methods of Illizarov (ASAMI) criteria. Among 54 patients, bony results as per ASAMI score were

excellent in 36, good in 14, fair in 2 and poor in 2 patients. Functional results were excellent in 43, good in 7, fair in 4 patients. The average fracture union time was 8 months. Post-surgery patient satisfaction was excellent since fixation allowed weight bearing immediately. Average hospital stay was 7 days and financial burden was reduced by 40% as compared to multi staged surgery. The average time of return to work was 20 days. LRS is an easy, simple and definitive surgical procedure that allows immediate full weight bearing walking. It reduces hospital stay, is cost effective with excellent patient compliance and can also be used for bone lengthening/transportation

Dabkana TM et al in 2016,[29]assessed the effectiveness bone transport/distraction technique using the Linear Rail System for the treatment of segmental bone loss following trauma. There were 10 patients involve in study,8 males and 2 females, age between 22 and 48 years. All patients with segmental bone loss of more than 4 cm following RTA were included in the study. All our ten patients achieved adequate defect correction of up to 80% to 100%. H.S. Pitkar LRS System when used properly is good for management of segmental bone loss following trauma.

Patil NVP et al in 2016,[30]compared the outcome of the unreamed intramedullary nailing and limb reconstruction system (LRS, Orthofix) in the treatment of type IIIA Gustilo-Anderson open fractures of tibial diaphysis. 80 cases were treated with orthofix were labelled as group A and 80 cases treated with unreamed intramedullary nailing were labelled as group B. Average time of union in group A was an average 35 weeks (30-40 weeks) in 64 cases (80%) with 16 cases (20%) of non-union which were subsequently treated with bone grafting and showed union at an average 40 weeks (38-44 weeks). Group B showed average time of union at an average 29 weeks (2438 weeks) in 66 cases (82.5%) with 10 cases(12.5 %) of infective non-union at which subsequently treated with

external fixator and showed union at average 36 weeks (34-38 weeks). 4 cases which showed delayed union were dynamised and bone grafted and showed union at an average 32 weeks. Intramedullary nailing can be used in the management of type IIIA fractures as it allows early union and primary closure with the avoidance of secondary procedures with the risk of higher rate of deep infection.

Nath RG et al in 2017,[31]evaluated outcome of the open tibial fractures treated with Orthofix. The study was prospective study involving 30 patients with open Tibial fractures. The patients were treated with wound debridement and stabilisation with Orthofix and followed up. Then the patients were followed up to evaluate clinically, functionally by Lower Extremity Functional Score (LEFS) and radiologically by Radiographic union scale in Tibial fractures (RUST). All the 30 patients included in our study had achieved bone union (100%). One patient (3.33%) had delayed union and required bone grafting and fibulectomy. The mean follow up period is 32.6 weeks. The average period taken for fracture union is 24.4 weeks. The mean LEFS score for the 30 patients at the end of follow up is 88.75%. The mean RUST score at the end of follow up is 2.6. Orthofix serves as external fixator and definitive fixation device as it allows dynamization. Hence Orthofix is a very good device in Open tibial fracture management if proper rehabilitation measures and proper timing of dynamization is followed.

Pangavane S et al in 2017,[32]conducted a study on 20 compound tibia and femur fractures treated by the limb reconstruction system (LRS). 10 cases of compound tibia IIIa and 10 cases 0f IIIb were included in study. Status of wound was classified by Gustilo -Anderson open wound criteria, comorbidies were noted additional procedure if any were noted. Radiological union was defined as minimum of 3 cortical continuity in views of X-Ray. Time duration was recorded in which knee Range of motion was assessed by

'hand goniometry during treatment. Average age of patient was 37.9 years, fracture tibia showed total 100% union. Average time for tibial union was 10.2 month. Average time for tibial LRS in situ was 10.6 month. 6 patients required corticotomy with lengthening Average lengthening was 2.5 cm in 7 no cases (1.5-5 cm range). Average knee ROM are 100 degree of flexion (range90130). Complication noted were pin tract infection, Delayed or Non-union, multiple surgeries, patient's co-operation.

Mahajan NP et al in 2017,[33]evaluated the outcome of limb reconstruction system in 20 patients for management of compound tibia diaphyseal fracture. The mean time of partial weight bearing was 3.5±2.97 weeks, full weight bearing was 8.55± 4.14 weeks and bone union time was 20.22±5.22 weeks. The pin tract infection was found in 5 (25%) cases. Delayed union was observed 06 (30%) cases. Shortening of more than 2 cm were recorded in 3 (15%) patients. Joint (knee or ankle) stiffness was observed in 6 (30%) cases. Loosening of pin was observed in 3 (15%) cases. Chronic osteomyelitis was observed in 3 (15%) cases. Secondary procedures were done in 11 (55%) cases. Bone marrow aspiration was done in 5 (25%) cases, iliac bone grafting in 5 (25%) cases. LRS is found to be wonderful tool in management of compound tibia fractures as primary and definitive mode because of its safety, versatile nature, patient friendly and cost effectiveness.

Mangukiya HT et al in 2018,[34]did a prospective study comprising 40 patients with compound tibia diaphyseal fracture managed with AO monolateral external fixator (Group 1) (n = 20) and Limb reconstruction system (Group 2) (n = 20) as primary and definitive tool. In their study bony outcome by ASAMI score shows 6 (30%) patients had Excellent, 5 (25%) patients had Good and 9 (45%) had Poor bony outcome from Group I. In group II, 12 (60%) patients had Excellent, 4 (20%) patients had Good, 2 (10%) patients had Fair, and 2 (10%) had Poor bony outcome. The functional

outcome by ASAMI score shows 3 (15%) patients had Excellent, 8 (40%) patients had Good, 5 (25%) patients had Fair, 3 (15%) had Poor bony outcome from Group I. In group II, 9 (45%) patients had Excellent, 7 (35%) patients had Good, 2 (10%) patients had Fair, and 2 (10%) had Poor functional outcome. Limb reconstruction system (LRS) offers several advantage over AO monolateral external fixator such as ease of application, versatility, stronger fixation, less fixator related complications, early weight bearing and early bony union for management of compound tibia diaphyseal fracture as primary and definitive tool.

Sandhu KS et al in 2018,[35]compared the role of Ilizarov (group1) and Rail fixator devices (group 2) in their study of 15 patients each under both groups. 15 patients of non-union long bones in each group from 21 to 60 years with mean age of 37.6 year in group A and 40.5 years in group B. 90% of the patients were male. Most of the patients had non-union of tibia and further the middle one third was more commonly involved in either group. Nine out of 15 patients in both the groups had infected type of non-union. Average shortening was 2.9 cm in group A and 2.86 cm in group B. Maximum number of patients had undergone about two previous surgeries. 12 patients underwent acute docking or compression in group A compared to 13 in group B. Three and two patients underwent compression – distraction for treatment of non-union in group A & B respectively. Patients were followed up at 6, 12 and 24 week intervals. Union was seen in 13 cases in group A and 14 cases in group B. The duration for union was average 8.8 months and 8.1 months in respective groups. Normal range of motion in nearby joint was achieved in 80% cases. They had excellent to good limb function in 80% of the cases in Group A and 86% of cases in group B as per ASAMI scoring system. Bone results were more or less similar in both the groups. Functional results were a bit better in rail fixator group.

Anand VK et al in 2018,[36]assessed the union rates, infection control and complications associated with LRS. 42 patients with complex nonunion of long bones managed with application of rail fixators were enrolled. Fixation was performed using a monolateral external fixator. Patients were followed up regularly in OPD every two weeks for the first two months and thereafter every month till docking of the fracture fragments was achieved. Majority of the patients had an external fixator or infected implant at the time of presentation. No special investigations were required in our study except for frequent X-Rays and pus culture and sensitivity. Corticotomy was done in almost half (55%) of the patients. Two patients required additional bone grafting and one patient required freshening of bone ends as secondary procedures. Another secondary procedure adopted was PRPP injection in 1 patient at the docking site to achieve union but it ultimately failed to unite. Out of 42 patients, 22 patients are while remaining 18 patients are still undergoing treatment and one patient lost to follow up. Mean treatment duration was 7.9 months ranging from 4 months to 14 months. Complex nonunion can be managed satisfactorily with rail fixators.

Singh AK et al in 2019,[37]studied the Functional outcome of performing distraction osteogenesis in cases of infected non-union of tibia treated with Ilizarov and Limb Reconstruction System. The study was done with 27 patients of infected gap nonunions of the tibia. After implant removal, if required radical resection of necrotic tissue and fractures were stabilised with Ilizarov or mono-lateral fixator depending on non-union site. Corticotomy was either done proximally or distally. Patients were followed up at monthly intervals for a minimum of 6 months. The ASAMI-Bone healing score was excellent or good in 86% patients and Functional score was excellent or good in 89% of patients. The commonest problems were of pin tract infection, wire loosening and angulation of the transported segment. Elderly age, persistent infection, sensory loss in the foot, the stiffness of the knee, and above all

the patient's reluctance to go any further given the protracted treatment besides, systemic disorders such as diabetes are all pointers for considering amputation as an alternative.

Singh P et al in 2020,[38]analysed the efficacy, functional and radiological outcome of Limb Reconstruction System (LRS) in management of open fractures of tibia with or without bone loss as a primary and definitive tool. They treated 20 patients with compound injuries of tibia with Limb Reconstruction System (LRS) as a primary and definitive tool. 15 males & 05 females were included. Average follow up period was 36.45±4.7 weeks ranging from 06 – 18 months. There was sound bony union in all of the cases with resolution of infection. The mean time of full weight bearing was 10.45±2.25 weeks and bone union time was 23.26±6.33 weeks. ASAMI score (Association for the Study and Application of the Method of Ilizarov) for bony outcome was Excellent in 13 (65%) patients, good in 5 (25%) patients, fair in 1 (5%) patient and Poor in 1 (5%) patient. ASAMI score for functional outcome was Excellent in 14 (70%) patients, Good in 4 (20%) patients, fair in 1 (5%) patient and Poor in 1 (5%) patient. Rail external fixator was sufficient enough for wound healing & bony union. Limb Reconstruction System (LRS) offers an alternative option to treat compound fractures of tibia because of simplicity of application, its good fracture stability, adjustable geometry, light weight, affordable cost, and patient friendly and can induce/enhance fracture healing by compression and distraction osteogenesis.