Aswan University Medical Journal, volume 5 / No.1/ March 2025 (9-22) Online ISSN: **2735-3117**

ORIGINAL ARTICLE

Evaluation of Using Limb Reconstruction System as A Primary And Definitive Fixation In Management Of Open Fracture Of Long Bone Lower Limb

Hesham Elrefae , Ahmed khaled* , Mohamed salman , Ebeed yasin

Department of Orthopedics, Faculty of medicine, Aswan University

ABSTRACT

Keyword: open fracture, long bone, Limb Reconstruction System

* **Corresponding author**: Ahmed khaled
Mobile: 01552207561
E-mail: akf.1281995@gmail.com

Background: Staged management of open fractures is challenging, time-consuming, and burdensome for surgeons and patients. The Limb Reconstruction System is an ideal one-stage surgery for managing open fractures in long bones in the lower limbs to avoid these difficulties. **Objective:** to assess the efficacy of the Limb Reconstruction System in treating open fractures in long bones of lower limbs regarding fracture stability and union. **Methodology:** This is a prospective study on 20 patients with open fractures tibia and femur. The patients were between 8 and 65 years old. All patients were treated with the Limb Reconstruction System. The assessment data included: joints (knee and ankle) range of motion, weight-bearing and fracture union. **Result:** The mean age in the study was 35.6 years with male predominance (93.3%). The union rate was 85% (17 cases) and the mean union time was 6.9 ± 1.9 months. pin tract infections rate 45% (9 cases), 2 (10%) patients with deep infections, Equinus in 1(5%) patient, infected non-union in 1(5%) patient, delayed union in 1(5%) patient, and mal-union in 1(5%). Regarding modified Anderson and Hutchinson's criteria; good in 11 patients, moderate in 6 patients, and poor in 3 patients. **Conclusion:** The Limb Reconstruction System is an effective method for the management of open fractures of long bones of the lower limbs, achieving early mobilization with minimal complications.

INTRODUCTION

Open fractures are daily challenging duties for the orthopedic surgeons. industrialization and mechanization increase rate of the high velocity trauma that lead to increase the open fracture rate[1,2]. open fractures are treating by The traditional method that include wound debridement , fracture stabilization by external fixator temporarily then definitive management after wound healing [3]. The disadvantages of this method is the requirement for multiple staged surgical procedures. Eventually end with high rate of infection , mal union , nonunion , shortening , deformity and consequently high cost. one staged definitive management of open fractures using Ilizarov or The Limb Reconstruction System(LRS)has been used as comprehensive solution in this situation[4]. LRS is more straightforward and accessible equipment for the surgeon and the

patient than ilizarov. LRS is more stiffer and stable than other conventional uniplaner external fixator. It is giving more access for soft tissue covering and its ability for compression and distraction at fracture site. We hypotheses in this current study that the LRS could be an effective definitive one staged method for management for open fracture of long bone lower limb. Our primary objective is assessment of the LRS efficacy as regards to radiological fracture union, while secondary objectives are evaluation of postoperative mobilization and complications

SUBJECT AND METHODS

This is a prospective study of 20 cases with open fractures of the long bone of the lower limb (tibia & femur) treated by LRS at the Orthopedic Department, Aswan University Hospital in the period between (January 2023 to January 2024). The included criteria were the Patients with open long bone fractures, regardless of the type or degree of fracture, their age was above 8 years. The degree of open fractures was classified according to the Gustillo- Anderson classification[5]. We excluded the patients with closed long bone fractures and patients with open fractures that were conservatively treated and open pathological fractures. All patients were evaluated according to the Advanced Trauma Life Support (ATLS) protocol. A detailed history is taken, a physical examination, assessment of the neurovascular, evaluation of skin condition, routine labs work up and good radiological examination was obtained.

Operative procedure

At the causality, the management of the open fracture had been included application of posterior splint and antibiotics and tetanus prophylaxis started immediately. At operative theater, The wounds were debrided and irrigated extensively, k-wire or small plate were hold Fracture reduction temporarily. The required length of rail of LRS was chosen with minimum one clamp on either side of fracture. According to site of the fracture, if fracture was distal in the long bone, one clamp on each fracture fragments but if the fracture site in the middle of long bone two clamps on each fracture fragments. In cases that the fracture site was distal third of the long bone , the distal fragment comprises one-third of the bone length so one clamps with three schanz pins were used, while in cases of more proximal the fracture site ,the distal fragment comprises two third of the long bone, we applied four schanz pins within two clamps in distal fragment of the fracture. The schanz pins were inserted into the proximal and distal fragments then securely fix to the clamps of the LRS. the clamps were connected to each other by the LRS rail then were tighten after confirmation of fracture reduction by the image intensifier, followed by removal of the temporary k-wires or small plate . The Schanz pins close to joint should be parallel to joint line. the stiffness of the frame and decreasing fracture site motion were achieved by expanding the pin distribution within each fragments and decreasing the gap between the bone and the LRS rail. The LRS should be applied in a manner that kept it distant from the wound site for subsequent soft tissue coverage procedure is necessary. The wounds were closed primary without tension if accessible or leaving open for other debridement , vacuum assisted closure (VAC) or skin coverage procedures.

Post-operative care

All patients were instructed for limb elevation and good analgesics and antibiotics were given. to avoid joint contracture and muscle atrophy we advised the patients to perform quadriceps and

hamstring strengthening exercises and straight leg raising exercises. repeated debridement and VAC dressing is planned according to wound status. partial weight-bearing walking (PWB) with a walker or crutches was informed to patients depending upon fracture type. Wound coverage was planned after the eradication of the infection. assessment of the outcome included evaluation of the wound, joints (knee and ankle) range of motion (ROM), fracture union, and modified

Table1(1) Modified Anderson's and Hutchin's criteria

Results	**Shortening**	**Grade of deformity in Angulation (Malunion)**
Good	< 1 cm	**Upto 5□varus / valgus Upto 10□ Anterior /Posterior**
Moderate	1-2 cm	**5-10□ varus / valgus** **10-20□ Anterior / Posterior**
Poor	**> 2 cm**	**> 10□ varus / valgus** **> 20□ Anterior / posterior Angulation**

Anderson and Hutchinson's criteria[6] (Table 1).

RESULTS:

This study included 20 patients**,** the mean age of all studied patients was 36.3 ± 15.1 years with minimum age of 9 years and maximum age of 65 years. There were 17 (85%) male and 3 (15%) females in the studied patients. There were 14(70%) smoker patients and 6 (30%) non-smoker patients, there were 6 (30%) patients with comorbidities. The Tibia was affected in 15 (75%) patients, while the femur in 5(25%) patients. As regards the Gustillo classification**,** there were 12(60%) type II patients and 8 (40%) type III patients in the studied patients. The most recorded modes of trauma are fall from height in 5 patients, firearm injury in 2 (10) patients, gunshot in 1 (5%) patient, and road traffic accident (RTA) in 12 (60%) patients. The right side was affected in 15 patients and the left side was affected in 5(25%).The fracture site was distal in 4(20%) patients, where one clamp on each fracture fragment are used, middle in 11(55%) patients where two clamp are used in both fragment , proximal in 3(15%) patients where distal fragment has two clamp and segmental in 2(10%) patients. The open fractures were an isolated injury in 13(65%) patients and associated injury in 7(35%) patients**.** The time between injury and application of LRS was the mean application time in all studied patients was 10.05 ± 8.2 (ranged from 1 to 28) days.

Affected bone	Femur	5	25%
	Tibia	15	75%

		Studied patients (N = 20)	
Sex	Male	17	85%
	Female	3	15%
Age (years)	Mean ±SD	36.3 ± 15.1	
	Min – Max	9 – 65	
Smoking	No	6	30%
	Yes	14	70%
Comorbidities	No	14	70%
	Yes	6	30%
Classification	Type II	12	60%
	Type III	8	40%
Mode of trauma	Fall from height	5	25%
	Firearm	2	10%
	Gun shot	1	5%
	RTA	12	60%
Affected side	Right	15	75%
	Left	5	25%
Affected site	Distal	4	20%
	Middle	11	55%

	Proximal	3	15%
	Segmental	2	10%
Type of injury	Isolated injury	13	65%
	Associated injuries	7	35%
Time of application	mean ±SD	10.05 ± 8.2	
	Min – Max	1 – 28	

(Table 2) shows Clinical and demographic data

Regarding postoperative mobilization, the mean patient starting partial weight bearing **(**PWB) was 7.2 ± 1.9 (ranged from 4 to 10) days. The mean Full Weight Bearing (FWP) was 4 ± 1.5 (ranged from 2 to 7) months**.** post-operative ROM, the mean ankle dorsiflexion (DF) is 9.2 ± 2.5 (ranged from 0 to 10) degrees. The mean ankle plantar flexion (PF) was 41.1 ± 7.2 (ranged from 20 to 45) degrees. The mean knee flexion in all studied patients was 113.2 ± 8.2 (ranged from 100 to 120) degrees. Knee extension was 0 in all studied patients. The mean follow-up duration was 9.25 ± 2.5 (ranged from 4 to 13) months**,** regarding complications: (a) pin tract infections in 9 (45%) patients who healed on suitable parenteral antibiotics after culture and sensitivity. Of these 9 patients, 1 patient needed secondary surgical debridement and changing one Schanz site and finally completely healed, (b) 2 (10%) patients who suffered from deep infections underwent secondary debridement that completely healed, (c) Equinus in 1(5%) patient that was treated by aggressive physiotherapy, (d) chronic infection of the fracture site reported in 1(5%) patient, that underwent debridement, sequestrectomy, and cement spacer for 6 weeks till infection resided then later bone graft was done and finally united, (e) delayed union in 1(5%) patient, underwent fibuloectomy for dynamization of the fracture site and finally united. (f) mal-union in 1(5%). At the final follow-up, the union rate was 85% (17 cases), where the non-union was reported in 3 (15%) cases that were treated with removal of the LRS and internal fixation with bone graft after a 3 week holiday period. LRS is removed after the complete union. The mean complete radiological union time was 6.9 ± 1.9 months. According to modified Anderson and Hutchinson's criteria, the results were poor in 3(15%) patients (15%), moderate in 6 (30%) patients and good in 11(55%) patients

		Studied patients (N = 20)	
Post-operative complications	Pin tract infection	9	45%
	Deep infection	2	10%
	Equinus	1	5%
	Infected fracture site	1	5%
	Delayed union	1	5%
	Mal-union	1	5%
	Non-union	3	15%
Follow up duration (months)	Mean ±SD	9.25 ± 2.5	
	Min – Max	4 – 13	
PWB (days)	Mean ±SD	7.2 ± 1.9	
	Min – Max	4 – 10	
FWB (months)	Mean ±SD	5 ± 1.5	
	Min – Max	2 – 7	
Union time (months)	Mean ±SD	6.9 ± 1.9	
	Min – Max	3 – 10	
Fracture union	Full union	17	85%
	Nonunion	3	15%
Ankle DF	Mean ±SD	9.2 ± 2.5^0	
	Min – Max	$0 – 10^0$	
Ankle PF	Mean ±SD	41.1 ± 7.2^0	
	Min – Max	$20 – 45^0$	

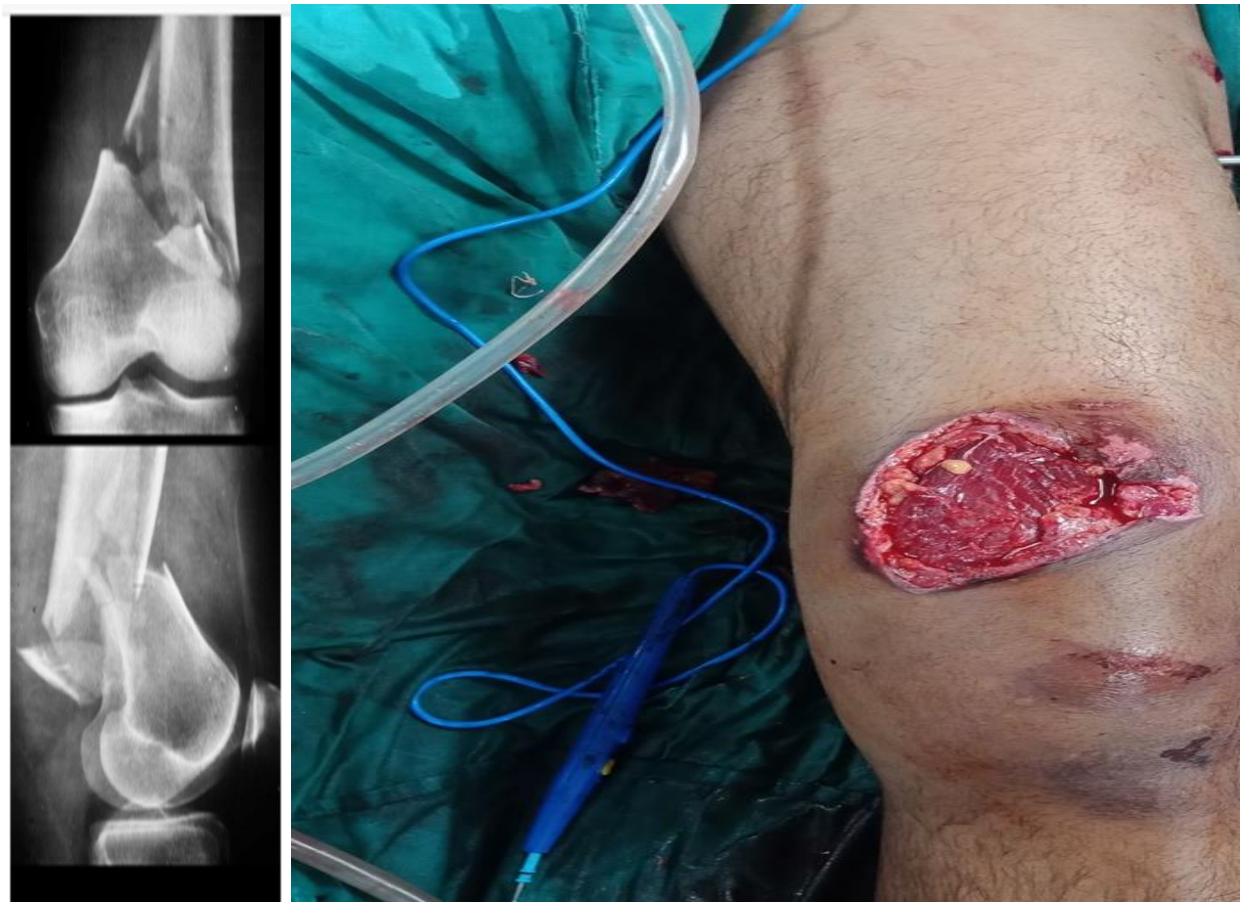
Knee flexion	Mean ±SD	113.2 ± 8.2^0	
	Min – Max	$100 – 120^0$	
modified Anderson and Hutchinson's criteria	Poor	3	15%
	Moderate	6	30%
	Good	11	55%

Table (3) shows postoperative complications and complications**.**

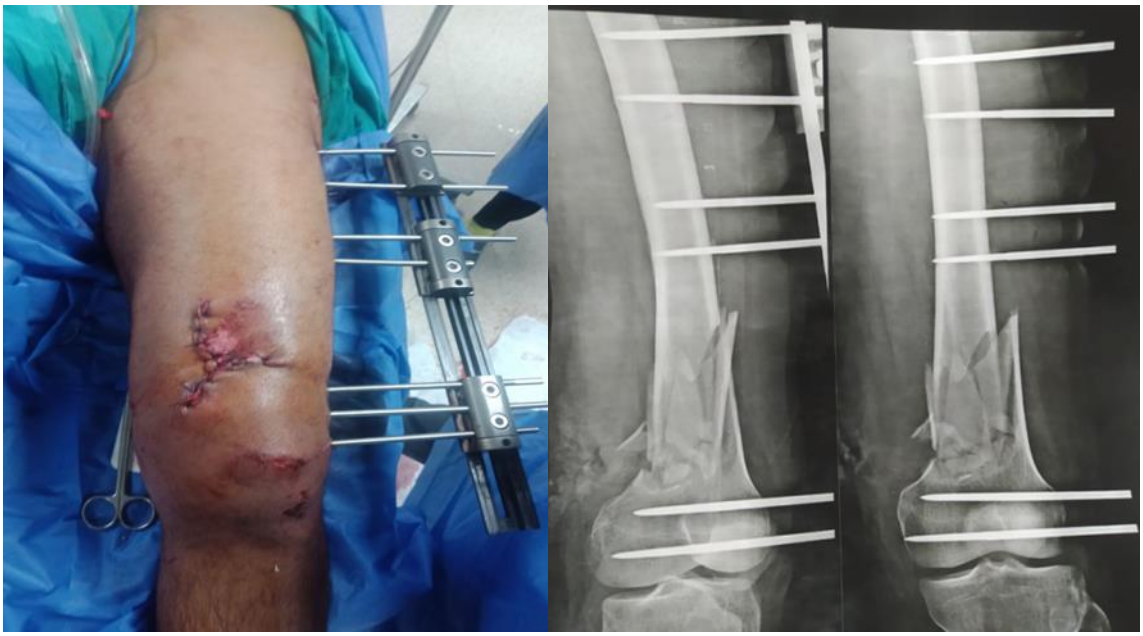
Illustrative cases

We presented 2 illustrative cases of open fracture femur and tibia fixed by LRS and final radiological and clinical outcomes. (Figures 1- 2)

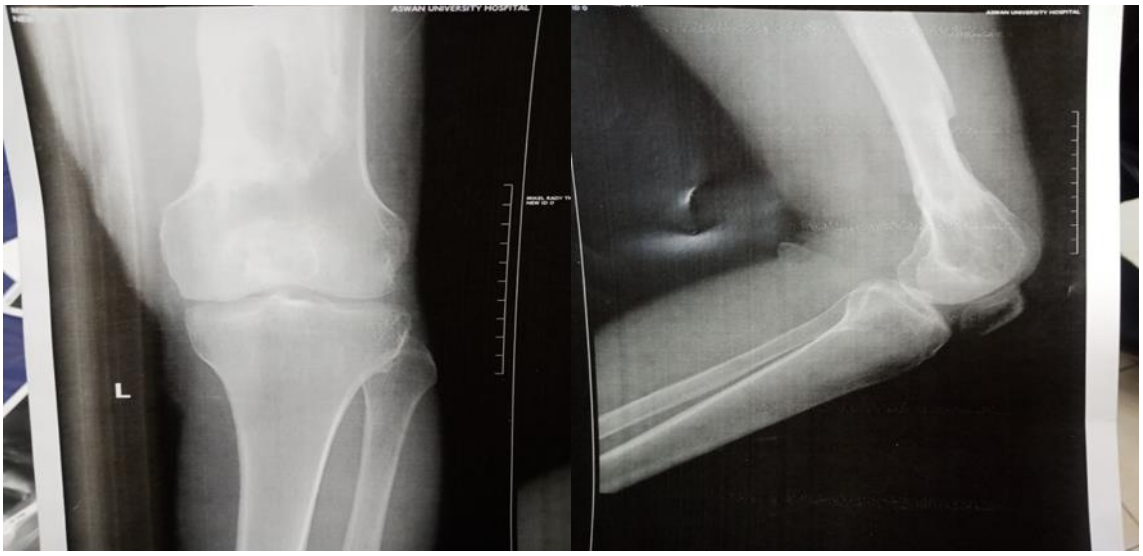
Case (1) Male patient 38 y, motor car accident, with left comminuted open (OGII) extra-articular distal femur fracture neurovascular bundle intact.



Figure(1A) shows preoperative x-ray and clinical photo of the wound



Figure(1B) shows clinical intraoperative of LRS femur and post-operative x-ray



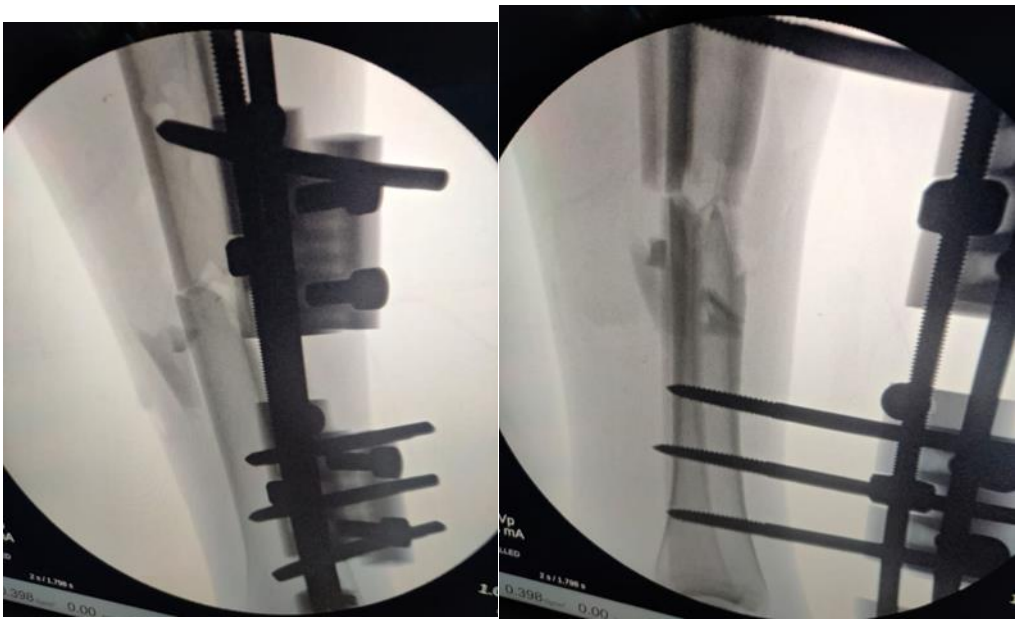
Figure(1C) shows full fracture union after 1 year

Figure (1D) shows clinical outcome after one year

Case (2)

Male patient 26 y, road traffic accident with left open (OGII) mid-shaft tibia and fibula fracture ,neurovascular bundle intact.

Figure (2A) shows preoperative clinical photo and x-ray



Figure(2B) shows intraoperative c-arm image intensifier image

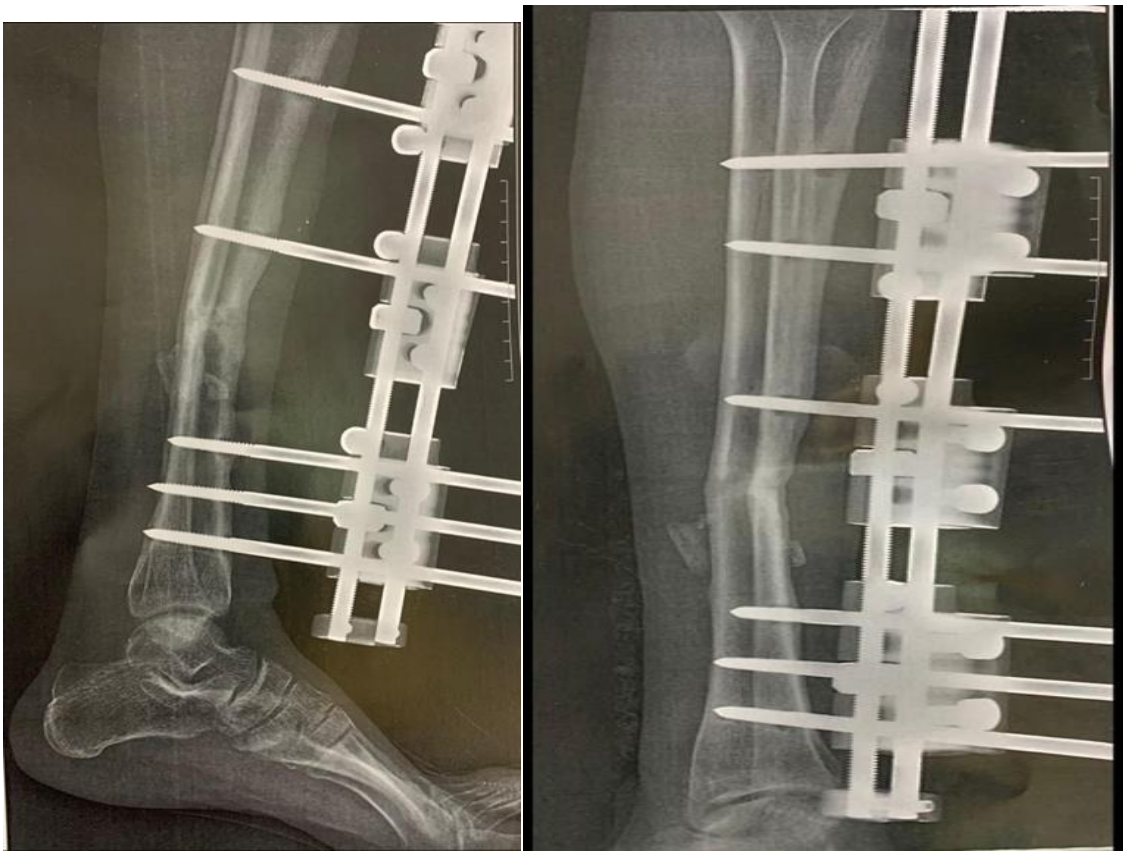


Figure (2C) shows the full fracture union of LRS open mid-shaft tibia fracture

DISCUSSION

The objective of treatment for open fractures is to maximize function and maintain the quality of life for the patient. Treatment options include minimally invasive osteosynthesis, intramedullary nailing, biological fixation, and external fixation[7-10].

External fixators are the standard procedures for treating comminuted, faulty, and contaminated open fractures, such as Gustilo-Anderson types IIIB and IIIC[11,12]. Yokoyama K warns that intramedullary nailing for treating grade IIIB and IIIC is dangerous due to deep infection and nonunion in 20.3% of cases[13] External fixators are preferred due to their simplicity and soft tissue treatment, but they also pose risks like extended immobilization and revision surgery.

The LRS is a minimally invasive approach that enables efficient wound care, fracture stability, and bone lengthening[14]. LRS fixation allows complete weight bearing immediately after surgery, preserving the leg and avoiding amputation, promoting early fracture healing and reducing financial load, but has issues like pin loosening and infection[15].

Staged management of open fractures is associated with serious complications: shortening, soft tissue healing problems, higher morbidity, multiple surgeries, prolonged hospitalization, and its consequences such as nosocomial infection, deep vein thrombosis (DVT), and bed sores, all of which lead to an increased risk of union problems, as well as higher cost[16]. In a 1988 research, Edward treated Grade III open tibial fractures with external fixation, and 93% of the fractures united satisfactorily, with 89% of patients having good clinical function [17]. Infection is more likely in patients treated with secondary intramedullary nail after primary external fixator or postponed primary nailing [18].

The Ilizarov ring fixator is an effective treatment method, however it is more inconvenient for the patient and difficult for the surgeon to master when compared to LRS. According to a study conducted by Ajmera et al., LRS demonstrated to be an efficient mode of treatment in cases with open fractures of the tibia with bone loss as a defined modality of treatment for damage management as well as union and lengthening[19].

The purpose of the study is to evaluate the efficacy of the LRS in the treatment of 20 patients with open tibia and femur fractures, and we found that the LRS could be an effective primary and definitive therapy for lower limb open fractures, producing equivalent fracture union with early mobility and a low risk of complication. We initially managed our patients in the causality with splintage , and intravenous antibiotics and prepared for the surgery. According to Gustillo-Anderson classification[5], 12 type II patients (60%) and 8 type III patients (40%) were in the studied patients. Unlike Jaña Neto et al [20], who recorded type III (45%) and Type II (55%). We recorded the mean of the time interval between the time of injury and application of LRS was 10.05 ± 8.2 days. Long travel times from remote locations to a tertiary care facility caused the surgery delay. post-operative complications recorded in our study, pin tract infection in 9 (45%) patients, deep infection in 2 (10%) patients, Equinus in 1(5%) patient, chronic infection in 1(5%) patient, delayed union in 1(5%) patient and mal-union in 1 (5%). All of these complications were treated according to their nature without any residual disability. The most important factor for preventing and eradicating infection of the wound is good debridement and starting antibiotics as early as possible, as reported in most literature [21,22]. In our study, this protocol resulted in success in 18 (90%) cases success with only 2 (10%) cases of deep infection.

The mean follow-up duration in all studied patients was 9.25 ± 2.5 months. the mean union time in our study was 6.9 ± 1.9 months, which is similar to the reported study of Ajmera et al,[19] Thakur et al,[23] and Pal, C. P et al, [24] which was 6, 5, and 5.5 months respectively. In the current study; The knee and ankle ROM was satisfactory, where the mean ankle DF was 9.2 ± 2.5 while the ankle PF was 41.1 ± 7.2. The mean knee flexion was 113.2 ± 8.2 with no loss of Knee extension. According to modified Anderson and Hutchinson's criteria, our results were good in 11(55%) patients (15%), moderate in 6 (30%) patients, and poor in 3(15%) patients. Kale AB et al[25], reported in their study , a good result in 80%, moderate in 17% and poor in 3% of patients. In a study conducted by et al [26] on the care of open tibial fractures with LRS rail external fixators, 90% of the fractures united well: excellent to good results in 72%, fair in 18%, and bad in 10% of instances, according to the modified Anderson and Hutchin's criteria. Lakhaniet al [27] employed a rail fixator system to rebuild bone gaps and found that union was accomplished in all cases. In 80% of cases, adjacent joints were restored to their normal range of motion. Functional outcomes were excellent to good in 85% of cases using ASAMI criteria.

Chandra Prakash et al [28]., reported in their short-term prospective investigation on 32 patients with open fractures of the tibial shaft, 40 years was the average age. Patients were divided equally into 2 groups: group A underwent an Ilizarov fixator and group B was fixed with LRS fixator. The average follow-up was 6 (ranged from 3 to24) months, and radiographic findings with LRS were excellent in 68.75% and good in 18.75%, and fair in 12.50%, while in the Ilizarov group; 56.25% of cases were excellent, 18.75% good, 12.50% fair, and 12.50% poor. In the LRS group,75.00% of cases were satisfactory regarding the functional outcome, comparable to 68.75% of cases fixed by Ilizarov fixators.

CONCLUSION

LRS is an effective primary and definitive method for the management of open fractures of lower limb long bone, with minimal rates of complications and advantages of early mobilization and easy access for wound care.

LIMITATIONS

This study's limitations included a lack of a comparison group or a control group and a smaller sample size. Considering the study's optimistic results, further multicentric studies and randomized control trials are suggested before establishing it as an effective modality of treatment in cases of open fractures.

RECOMMENDATION

We recommend LRS for lower limb long bone open fracture. Further trials with longer follow-ups and comparison of LRS with other methods, such as Ilizarov external fixator, in the long bone open fracture in the lower limb are warranted. Further studies should be conducted with more subjects and using further classification scores. Therefore, we recommend further multi-centric prospective studies are required to confirm our findings.

Disclosure of interest

The authors declare that they have no competing interest

REFERENCE

1. *Patil, M. Y., Gupta, S. M., KuruPati, S. K. C., Agarwal, S., & Chandarana, V. (2016).* Definitive management of open tibia fractures using limb reconstruction system. *Journal of Clinical and Diagnostic Research: JCDR*, *10*(7), RC01.
2. *Atef, A., & El-Tantawy, A. (2014).* Management of open infected comminuted tibial fractures using Ilizarov concept. *European Journal of Orthopaedic Surgery & Traumatology*, *24*, 403-408.
3. *Elbeshry, S. S., & Alabd, K. A. (2019)*. Management of open tibial fractures type IIIB by segment transfer using limb reconstruction system fixator. *The Egyptian Orthopaedic Journal*, *54*(2), 110-115.
4. *Hu, R., Ren, Y. J., Yan, L., Yi, X. C., Ding, F., Han, Q., & Cheng, W. J. (2018).* Analysis of staged treatment for Gustilo Anderson IIIB/C open tibial fractures. *Indian journal of orthopaedics*, *52*, 411-417.
5. Gustilo, R. B., Mendoza, R. M., & Williams, D. N. (1984). Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *Journal of Trauma and Acute Care Surgery*, *24*(8), 742-746
6. *Anderson, L. D., Hutchins, W. C., Wright, P. E., & Disney, J. M. (1974).* Fractures of the tibia and fibula treated by casts and transfixing pins. *Clinical Orthopaedics and Related Research (1976-2007)*, *105*, 179-191.
7. *McGraw JM, Lim EV. Treatment of open tibial-shaft fractures. External fixation and secondary intramedullary nailing. J Bone Joint Surg Am. 1988 Jul;70(6):900-11. PMID: 3392088.*
8. Batta V, Dwyer AJ, Gulati A, Prakash J, Mam MK, John B. No difference in the long term final functional outcome after nailing or cast bracing of high energy displaced tibial shaft fractures. *J Trauma Manag Outcomes*. 2012;6:5.
9. Agˇ us¸ H, Kıranyaz Y, Mavi E, Reisogˇ lu A, Eryanılmaz G. Treatment of open Tibial Fractures with early biological internal fixation. *Eklem Hastalık Cerrahisi*. 2000; 11:24–31.
10. Rajasekaran S, Dheenadhayalan J, Babu JN, Sundararajan SR, Venkatramani H, Sabapathy SR. Immediate primary skin closure in type-III A and B open fractures: results after a minimum of five years. *J Bone Joint Surg Br*. 2009;91-B(2):217-24.
11. McKee MD, Yoo DJ, Zdero R, Dupere M, Wild L, Schemitsch EH, et al. Combined single-stage osseous and soft tissue reconstruction of the tibia with the Ilizarov method and tissue transfer. *J Orthop Trauma*. 2008;22(3):183-89.
12. Kataria H, Sharma N, Kanojia RK. Small wire external fixation for high-energy tibial plateau fractures. *J Orthop Surg*. 2007;15(2):137-43.
13. Yokoyama K, Itoman M, Uchino M, Fukushima K, Nitta H, Kojima Y. Immediate versus delayed intramedullary nailing for open fractures of the tibial shaft: a multivariate analysis of factors affecting deep infection and fracture healing. Indian J Orthop. 2008 Oct;42(4):410-9. doi: 10.4103/0019-5413.43385. PMID: 19753228; PMCID: PMC2740339.
14. *Mangukiya, H. J., Mahajan, N. P., Pawar, E. D., Mane, A., & Manna, J. (2018).* Functional and radiological outcome in management of compound tibia diaphyseal fracture with AO monolateral fixator versus Limb
15. Mahantesh Yellangouda Patil, Srinath Gupta, Sri Krishna Chaitanya Kurapati, Saumya Agarwal, Vishal Chandarana: Definitive Management of Open Tibia Fractures Using

Limb Reconstruction System .Journal of Clinical and Diagnostic Research. 2016 Jul, Vol-10(7): RC01-RC04

16. Korkala O, Antti-Poika I, Karaharju EO. External fixation in open fractures of leg. Analysis of traps and complications of the method. *Rev Chir Orthop Reparatrice Appar Mot*. 1987;73:637–42.
17. Edwards CC, Simmons SC, Browner BD, Weigel MC. Severe open tibial fractures. Results treating 202 injuries with external fixation. *Clin Orthop Relat Res*. 1988;230:98-115.
18. Blachut PA, Meek RN, O'Brien PJ. External fixation and delayed intramedullary nailing of open fractures of the tibial shaft. A sequential protocol. *J Bone Joint Surg Am*. 1990;72(5):729-35.
19. Ajmera A, Verma A, Agrawal M, Jain S, Mukherjee A. Outcome of limb reconstruction system in open tibial diaphyseal fractures. *Indian J Orthop*. 2015;49: 429-35.
20. Jaña Neto FC, de Paula Canal M, Alves BA, Ferreira PM, Ayres JC, Alves R. Analysis of the characteristics of patients with open tibial fractures of Gustilo and Anderson type III. Rev Bras Ortop. 2016 Jan 29;51(2):143-9. doi: 10.1016/j.rboe.2016.01.002.
21. Naique, S. B., Pearse, M., & Nanchahal, J. (2006). Management of severe open tibial fractures: the need for combined orthopaedic and plastic surgical treatment in specialist centres. *The Journal of Bone & Joint Surgery British Volume*, *88*(3), 351-357.
22. Harley, B. J., Beaupre, L. A., Jones, C. A., Dulai, S. K., & Weber, D. W. (2002). The effect of time to definitive treatment on the rate of nonunion and infection in open fractures. Journal of orthopaedic trauma, 16(7), 484-490
23. Thakur, A. J., & Patankar, J. (1991). Open tibial fractures. Treatment by uniplanar external fixation and early bone grafting. *The Journal of Bone & Joint Surgery British Volume*, *73*(3), 448-451.
24. Pal, C. P., Kumar, H., Kumar, D., Dinkar, K. S., Mittal, V., & Singh, N. K. (2015). Comparative study of the results of compound tibial shaft fractures treated by Ilizarov ring fixators and limb reconstruction system fixators. *Chinese Journal of Traumatology*, *18*(06), 347-351.
25. Kale, A. B., Patole, V. V., Argekar, H. G., Sharan, S., & Goregaonkar, A. B. (2017). Limb reconstruction system as a primary and definitive mode of fixation in open fractures of long bones. *International Journal of Research in Orthopaedics*, *3*(2), 167
26. Vijay C, MahendraKumarK L, ManjappaC N; Management Of Open Type IIIA And Type IIIB Fractures Tibia With LRS External Fixator. The Internet J Ortho Surg, 18 (2011). DOI:10.5580/23a
27. Lakhani A, Singh D, Singh R: Outcome of rail fixator system in reconstructing bone gap Indian J Orthop, 48 (2014), pp. 612-616
28. Chandra Prakash Pal, Harish Kumar, Deepak Kumar, K.S. Dinkar, Vivek Mittal, Naveen Kumar Singh: Comparative study of the results of compound tibial shaft fractures treated by Ilizarov ring fixators and limb reconstruction system fixators, Chinese Journal of Traumatology,Volume 18, Issue 6,2015. 347-351, https://doi.org/10.1016/j.cjtee.2015.08.006.