Infected Tibial Nonunion: Ilizarov Fixator and Limb Reconstruction System

Amr Mohamed Eladawy [1], Tarek Abdelsamad Elhewala [1], Ezden Ellafe Ashore [2]*, Hosam Eldien fekry Abdel Aziz [1]

[1]Department of Orthopedic Surgery, Faculty of Medicine, Zagazig University, Egypt

[2]Department of Orthopedic Surgery, Faculty of Medicine, Sabha University, Libya

***Corresponding author:** Ezden Ellafe Ashore

E-mail: ellafeezden11@gmail.com

Accepted: 16.07.2023 **Revised:**04.07.2023 **Article History: Received:** 21.06.2023

Abstract:

Infected tibial non-union is a common orthopaedic problem. Ilizarov procedure is challenging and demand a high level of skills to excute correctly in order to lower the danger of nerve or vasculer damage extensively knowledge of human anatomy is necessary for surgeons are qualified to use this method because to bee along time to complete the appropriate trading in term of anatomy rail fixators are safer. The rail and ring fixators are quite versatile tools in the armamentarium of orthopaedic surgeons and can treat not only fractures but also bone gap/loss, limb length discrepancy and deformity simultaneously.

Keywords: Infected non-union of tibia, Ilizarov, LRS.

DOI: 10.53555/ecb/2023.12.1182

Introduction:

Most cases of infected nonunion have component of infection in soft tissue and bone ends. Both have to be debrided extensively. This creates gap in the soft tissue and bone as well. The management of infected non union is challenging for the orthopedic surgeon. However, distraction osteogenesis using some sort of external fixator is the only answer to bridge the defect. Ilizarov ring fixator (IRF) in infected NU achieves union, corrects deformities by the technique of bone transport, fragment deviation correction, re-establishes limb length, and maintains function. Unilateral rail fixator (RF) in infected NU maintains stability and restore length through distraction osteogenesis **(1).**

The choice of the external fixator is now generally determined by the experience and preference of the surgeon, the complexity of the problem, and the number of sites that need treatment. As a general rule, monolateral fixators may not be as well suited as ring fixators for the mechanical correction of deformities with angulations or rotation or for those that need more than two sites of treatment. Each type of external fixator exhibits individual mechanical characteristics that may affect osteogenesis and healing. The stiffness and stability of a fixator system are dependent on many variables, including the diameter of the wires, the number of wires used, the tension on each wire, the diameter of the rings, the number of rings used, and the spacing between the rings. As the use of half-pins results in half the number of sites of soft-tissue transfixation, they can decrease the number of pain-related and soft-tissue complications and can potentially improve the comfort of the patient and the tolerance to treatment **(2).**

The Ilizarov method is a comprehensive approach to all aspects of chronic tibial nonunion and simultaneously addresses the problems of deformity, shortening, defects, infection and osteoporosis. We found that the mean operating time was significantly less with a rail fixator than a ring fixator suggesting that the former is easier to apply. The Limb Reconstruction System (LRS Pitkar, Pune, India) is a uniplanar dynamised external fixator, which is lightweight and easy to construct. Unfortunately it is more difficult to correct a three-dimensional deformity with a uniplanar external fixator than with Ilizarov ring fixator. Circular frames also confer greater stability and more flexibility than uniaxial devices **(3).**

The current study showed that there was no significant differences between studied groups regarding the demographic characteristics which similar to **Shahid et al. (4)** who had patients with average age of 43.3 years with 10 males and two females. **Gupta et al. (5)** had patients in the age groups between 21 and 52 years, both male and female whereas. While **Bhardwaj et al., (1)** reported that all factors like age, sex, other associated injury, preoperative history, infection and nonunion were almost same in both groups which didn’t affect the results. The average age of patients was 39.48 years in Ilizarov ring fixator group and 36.96

years in group LRS. All the patients were male with right sided involvement in both the groups. No female patient was found in their study and this may be contributed to the fact that males being bread earners of the family in their study tend to be more involved in outdoor work and are, hence, more prone to severe injury than females. Majority of cases (20 in Ilizarov ring fixator group and 19 cases in rail fixator group) had been already operated once, and treated by tubular external fixator (12 in Ilizarov ring fixator group and 8 in rail fixator group), interlock nailing (2 in rail fixator group and none in other group), and ORIF (14 cases in Ilizarov ring fixator group and 11 in rail fixator group). Only three cases in Ilizarov ring fixator group and one case in rail fixator group were operated twice.

Singh et al., (6) reported that Most of the patients had multiple procedures before presentation as infected non-union. The main previous treatment was an external fixator in 17; an intramedullary nail in 5; plating in 4 and POP cast in 1. also, they reported that there was a predominance of the younger age group (average age 36.3 years; range 19-69 yrs.) the same trend as in other studies. In a study done by **Liu et al., (7)** (average 37.3 years, range 18-64 years); **Manish & Rabi (8)** (average 34.54 years, range 21-54 years); **Vignes et al. (9)** (average 36 years, range 24-51 years). The higher incidence in the younger population corresponds closely with the increased rate of road traffic accidents at this age.

The Singh et al showed that according to Paley's classification of non-union, 7 of the patient's post-debridement were in the B1 group having a bone gap > 1 cm with no bone shortening (4 in Ilizarov group versus 3 in Rail fixator group) while rest 5 patients were in the B3 group with both bone defect and shortening (2 in Ilizarov group versus 3 in Rail fixator group)with no significant differences between the studied groups. Which in agreement with the study of **Singh et al., (6)** who reported that According to Paley's classification of non-union, 16 of the patient's post-debridement were in the B1 group having a bone gap > 1 cm with no bone shortening while rest 11 patients were in the B3 group with both bone defect and shortening.

Bhardwaj et al., (1) reported that Type of infected NU in Ilizarov ring fixator, maximum cases were in the category of B2 (14 (52%)) and A2 (11 (44%)) and in rail fixator group, were in A2 (10 cases). During treatment, majority of cases underwent soft tissue removal by freshening the bony ends at the docking site (21 and 22 cases in Ilizarov ring fixator and rail fixator groups, respectively).

Various diagnostic classifications are available for nonunion and infected nonunion in the literature and are classified nonunion broadly into two types: Hypervascular (Hypertrophic) nonunion - the ends of the fragments are capable of biological reaction and Avascular (Atrophic) nonunion - the ends of the fragments are inert and are incapable of biological reaction **(10).**

Hyper vascular/Viable/Hypertrophic nonunion further subdivided into elephant

Foot type, horse hoof type and oligotrophic type **(1).**

Avascular/Nonviable/Atrophic nonunion further subdivided into torsion wedge, comminuted, defect and atrophic **(11).**

The above classification based on viability of the fracture ends with or without infection is a radiological classification **(11).**

PALEY classification:

It divided non-union clinically and radiologically into two major types:

- Type A (Bone loss <1 cm):
  1) A1- Nonunion with a mobile deformity.
  2) A2- Nonunion with a fixed deformity.
  3) A2-1 Stiff nonunion without deformity.
  4) A2-2 nonunion that is stiff with a fixed deformity.
- Type B (Bone loss>1 cm):
  1) B1-Nonunion with bony defect.
  2) B2-Nonunion with loss of bone length.
  3) B3-Nonunion with bony defect and loss of bone length.

This classification system is further modified by the presence or absence of infection **(1).**

MAURIZIO CATAGNI'S classification:

- A1 - Noninfected mobile nonunion.
- A2 - Noninfected stiff hypertrophic nonunion without deformity.
- A3 - Noninfected Hypertrophic nonunion with deformity.
- B1 - Noninfective nonunion with bone defect of up to 5 cms.
- B2 - Noninfective nonunion with bone defect exceeding 5 cms.
- B3 - Noninfective nonunion exceeding 10 cms with local scarring.
- C1 - Infected nonunion with atrophy.
- C2 - Infected nonunion with hypertrophy without deformity.
- C3 - Infected nonunion with hypertrophy and deformity.
- C4 - Infected nonunion with bone gap of less than 5 cms.
- C5 - Infected nonunion with bone gap between 5 and 10 cms.
- C6 - Infected nonunion with bone gap exceeding 10 cms **(12).**

THE UNIVERSITY OF TEXAS classification:

Based on the location of infection:

- Type 1: Intramedullary.
- Type 2: Superficial.
- Type 3: Local.
- Type 4: Diffuse with segmental bone loss **(11).**

Based on modification by immune competence of the host:

- Type A: Healthy immune system.
- Type B: Local / Systemic compromise of immune system.
- Type C: Severe compromise of immune system **(10).**

WIELAND classification:

Chronic osteomyelitis according to this classification is a wound with open fractures, positive wound culture, and pus discharge for more than 6 months.

- Type I: open, bone exposed and with no features of bone infection but with soft tissue infection.
- Type II: Presence of Circumferential, cortical and endosteal infection.
- Type III: Presence of Cortical and endosteal infection together with segmental bone loss **(12).**

AO classification:

- Infected non-draining nonunion. (Active/Quiescent).
- Infected draining nonunion **(13).**

Etiology and pathogenesis of infected non-union of tibia:

Various virulent factors are released by the bacteria that react to the host's attempts at eradication. Glycocalyx (slime), a hydrated mucopolysaccharide, which protects the bacterium and allows the bacterium to cling itself to metal hardware making it harder to eradicate deep infections**(13).**

So, it is always necessary to remove the hardware device if eradication of wound infection is to be obtained. This slime protects the bacteria in a sessile state increasing their resistance to destruction by a factor of 500. This layer protects the bacteria from the effects of antibiotics, antibodies, and immune directed phagocytosis **(10).**

Osteomyelitis after plating:

Poor handling of tissues during exposure and fracture reduction, unnecessary stripping of periosteum at the fracture focus causes additional damage to the vascularity of bone fragments. Contamination at the fracture site leads to infection which spreads along the exposed bones and implants. Necrotic and infected bone fragments will eventually be demarcated and sequestrated with further loss of stability **(11).**

Osteomyelitis after nailing:

Mostly occurs following open nailing, in open nailing with surgical exposure of the fracture site, additional periosteal stripping, and potential contamination must also be taken into account. Blunt reamers and too large reamers can produce excessive heat and necrosis in turn can jeopardize the endosteal blood supply **(1).**

Figure (1): Oblique view of leg bones with knee showing (a) upper tibial infected nonunion (b) After infection control (c) Ilizarov apparatus in situ (d). If vertical compression is given, it causes vertical displacement of nonunion ends. With the help of washers, horizontal compression is achieved perpendicular to plane of nonunion (e) Good union. No loss of length (14).

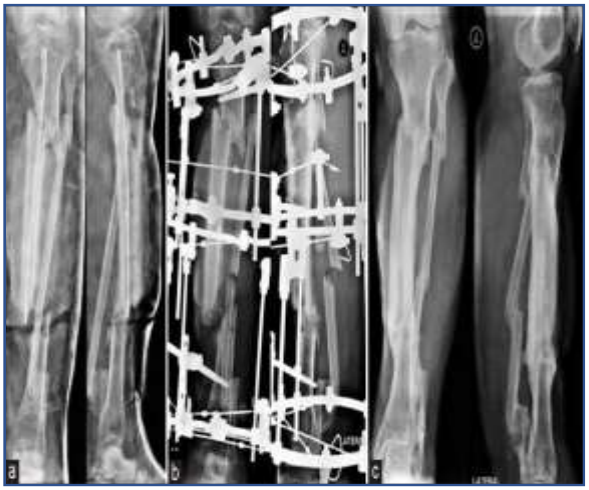

Figure (2): X-ray leg bones with knee and ankle joint showing (a) Infected segmental nonunion after cure of infection with rods and beads (b) Ilizarov fixator in situ to achieve horizontal compression perpendicular to plane of nonunion (c) achieved union at both levels. Fibulaectomy done. No lengthening (14).

Pintract infection:

Pin site complications include pin site inflammation, chronic infection, loosening, and metal fatigue failure. Most authors agree that infection rates from external fixation pins have steadily decreased as pin technology has improved but are still very far from zero. The most common pin site complications are now graded by many classifications **(12).**

Drilling with blunt drill bits at excessive speed and power causes heat necrosis of the cortical bone. Necrotic bone area may also result from forced insertion of Schanz screw or insertion of Steinmann pins into inadequate holes or without predrilling **(13).**

Necrotic fragments in the form of ring sequestrum provide an excellent medium for bacteria, which migrate along the inserted implant into the wound. Bone resorption can be seen on X-ray, which is a sign of pin loosening. Occasionally chronic osteomyelitis reaching into the medullary canal may develop **(10).**

Preoperative planning for schanz screws

Tapered Bone conical Screws are "Designed for Increased Holding Power" and better purchase of screws in the bone. Reverse turn is not allowed in the screws, because once reverse turn allowed makes the screw loosened because of tapering ends **(15).**

Successful external fixator requires a good pin-bone interface; Pin loosening occurs due to the following reasons,

- ❖ Bending of LRS screws.
- ❖ Loading which is unequal.
- ❖ Pre-tensioning of LRS pins.
- ❖ Infection of pin site **(16).**

All these causes loosening around the pin hole which ultimately results in pin loosening. The features of the Limb reconstruction system tapered screw helps in getting a better purchase in the bone and for stable fixation. Higher resistance offered by Tapered screw to bending where it is most needed i.e., at the near cortex **(17).**

Unilateral fixator exerts maximum load on the near cortex (i.e.,60-70%). The greater screw diameter ensures a higher resistance to bending force at near cortex. On insertion of tapered screw, each screw thread creates a new and larger track in the bone. Pre-drilling helps in reducing the amount of force required to insert a screw thereby ensuring distribution of loads evenly **(18).**

The tapered screw design, peculiar geometry produces efficient radial Preload and helps to provide excellent bone purchase. It has been shown that dynamization in the LRS reduces the stress on the screws and improved screw fixation stability. Even partial backup of screw results in loss of bone grip is the main disadvantage of this system **(18).**

The ''Non-Orthofix' uniform diameter screw or schanz pin screws:

During insertion, grooves cut by the previous threads will be occupied by each successive thread of the screw. This causes sustained & repeated erosion of the grooves in the bone. While encountering the far cortex, difficult bone penetration. The surgeon has to apply extra force to insert the screw and during the procedure, when done rapidly, the screw may advance into the bone like a wedge & the cortex may be ruptured **(16).**

Purchase may also be less than ideal, as the flute interrupts continuity of the thread. While encountering the near cortex, the screw may damage the grooves , so that the screw tract may get enlarged, which may lead to uneven weight distribution and failure of pins i.e., loosening **(18).**

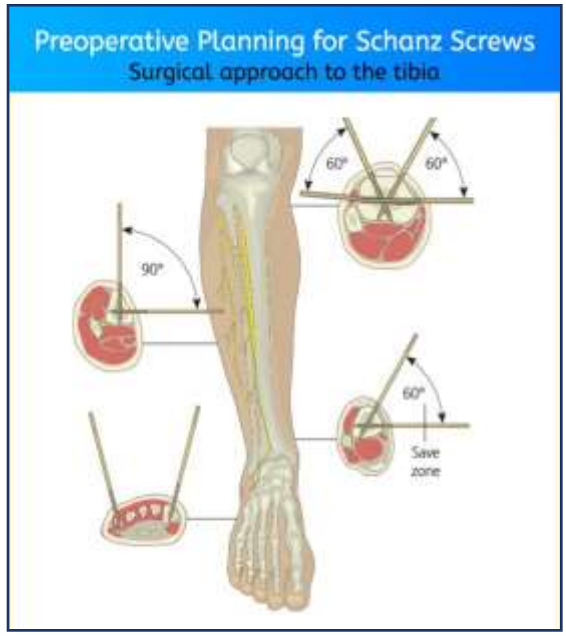

Figure (3): Surgical approach to the tibia with Schanz Screw. The soft tissue zone through which Schanz Screws can be inserted without damaging important structures (vessels, nerves, muscles, and tendons) is anteromedial to the tibia. The angles of this safe zone vary. If the lateral surface of the distal third of the tibia is avoided, damage to the anterior tibial artery can be avoided. If the ventral zone of the distal tibia is avoided, interference with the tendons can also be avoided (19).

The advantage of conical tapered screws:

They can be removed without any hassles in the outpatient department. The tapered pins are easy to remove in the clinic because all of the threads become loose after the initial turn **(17).**

Good purches ,less pin tract infection and stable fixation.

Limb reconstruction system screws:

The various types of screws used in LRS are cortical screws, cancellous screws and "cutting edge" screws for lengthening and bone transport procedures. Standardized screw introduction technique designed to ensure with negligible trauma to surrounding soft tissues **(20).**

Hydroxyapatite coated pins can be used in osteoporotic bone, which has the ability to improve the interface between bone and implant. Postoperative care of the pins is essential for the trouble-free pin sites, which is necessary for the successful external fixation procedure so that the infections can be reduced **(21).**

During pin placement the soft tissue tension should be avoided to minimize pin-tract infection .The fundamental principle for pin placement especially when distraction osteogenesis is attempted is that the pins should be parallel to the adjacent joint in all planes. The nuts on the Limb reconstruction system apparatus are tightened with a torque wrench (Allen key) that is provided **(22).**

Reusage:

The apparatus includes various clamps, made of hard anodized Aluminium alloy. Once the limb reconstruction system apparatus has been completely used, the entire apparatus is disassembled; discard the tapered pins because they should not be reused **(17).**

Immerse the dissembled parts of LRS apparatus in 36 volume of Hydrogen peroxide for more than 12 hrs, any residue remaining are brushed in running water, then soaped in distilled water, as this will remove traces of hard water. After the above treatment the apparatus is dried and sent for resterilization for the next usage **(16).**

References:

1. **Bhardwaj, R., Singh, J., Kapila, R., & Boparai, R. S. (2019).** Comparison of Ilizarov ring fixator and rail fixator in infected nonunion of long bones: a retrospective followup study. Indian journal of orthopaedics, 53, 82-88.
2. **Kundu, Z. S., Gupta, V., Sangwan, S. S., & Kamboj, P. (2012).** Gap nonunion of tibia treated by Huntington's procedure. Indian Journal of Orthopaedics, 46(6), 653.
3. **Rohilla, R., Wadhwani, J., Devgan, A., Singh, R., & Khanna, M. (2016).** Prospective randomised comparison of ring versus rail fixator in infected gap nonunion of tibia treated with distraction osteogenesis. The bone & joint journal, 98(10), 1399-1405.
4. **Shahid, M., Hussain, A., Bridgeman, P., & Bose, D. (2013).** Clinical outcomes of the Ilizarov method after an infected tibial non union. Archives of trauma research, 2(2), 71.
5. **Gupta, S. V., Govindappa, C. V. S., & Reddy, M. R. (2014).** Treatment of infective non-union of diaphyseal fractures with Ilizarov fixation. OA Orthopaedics, 2(1), 4-8.
6. **Singh, A. K., Parihar, M., & Bokhari, S. (2019).** The Evaluation of the Radiological and Functional Outcome of Distraction Osteogenesis in Patients with Infected Gap Nonunions of Tibia Treated by Bone Transport. Open Access Macedonian Journal of Medical Sciences, 7(4), 559.

7. **Liu, T., Yu, X., Zhang, X., Li, Z., & Zeng, W. (2012).** One-stage management of post-traumatic tibial infected nonunion using bone transport after debridement. Turkish Journal of Medical Sciences, 42(6), 1111-1120.
8. **Manish, K., & Rabi, J. (2012).** Bone transport in tibial gap non-union—A series of 25 cases. Open Journal of Orthopedics, 2012.
9. **Vignes, G. S., Arumugam, S., & Ramabadranof, P. (2014).** Functional outcome of infected non-union tibia fracture treated by Ilizarov fixation. INTERNATIONAL JOURNAL OF SCIENTIFIC STUDY, 2(7), 87-92.
10. **Sharma, B., Shakunt, R. K., Patel, J., & Pal, C. P. (2021).** Outcome of limb reconstruction system in tibial infected non-union and open tibial diaphysial fracture with bone loss. Journal of Clinical Orthopaedics and Trauma, 15, 136-138.
11. **Xie, J., Zhao, G., Yasheng, T., Chen, H., Amuti, N., Maimaitirexiati, M., et al. (2021).** Ilizarov bone transport to treat infected nonunion of long bones: a multicenter retrospective cohort study. Journal of International Medical Research, 49(3), 03000605211002701.
12. **Chalak, A., Singh, S., Shetty, S., Kale, S., Singh, P., & Ghodke, A. (2021).** A Novel technique of three-ring Ilizarov fixator frame in gap non-union of tibia. Journal of Clinical Orthopaedics and Trauma, 23, 101639.
13. **Fahad, S., Habib, A. A., Awais, M. B., Umer, M., & Rashid, H. U. (2019).** Infected non-union of tibia treated with ilizarov external fixator: our experience. Malaysian orthopaedic journal, 13(1), 36.
14. **Chaudhary, M. M. (2017).** Infected nonunion of tibia. Indian journal of orthopaedics, 51(3), 256-268.
15. **Zhao, Z., Zhang, Z., & Guo, H. (2023).** Tibial Plateau Fractures. In Orthopaedic Trauma Surgery: Volume 2: Lower Extremity Fractures and Dislocation (pp. 237-284). Singapore: Springer Nature Singapore.
16. **Gathen, M., Ploeger, M. M., Jaenisch, M., Koob, S., Cucchi, D., Kasapovic, A., et al. (2019).** Outcome evaluation of new calcium titanate schanz-screws for external fixators. First clinical results and cadaver studies. Journal of Materials Science: Materials in Medicine, 30, 1-8
17. **Khan, Q., Zeb, J., Khan, I., & Khan, M. A. (2021).** Comparison of infection rate in Ilizarov between Schanz screws and wires. Rawal Med J, 46(3), 572-575.
18. **Buza, J. A., & Gum, J. L. (2021).** Cortical Screw Fixation. In Advanced Robotic Spine Surgery (pp. 1-12). CRC Press.
19. **Vastortho. (2023).** Schanz Screw Specification, Uses, Sizes and Surgical Techniques. Available at: https://www.vastortho.com/schanz-screw/ Accessed at 29/05/2023.

20. **Fernando, P. L. N., Abeygunawardane, A., Wijesinghe, P. C. I., Dharmaratne, P., & Silva, P. (2021).** An engineering review of external fixators. Medical Engineering & Physics, 98, 91-103.
21. **Martins, A., Fátima Paulino, M., Manuel Roseiro, L., & Augusta Neto, M. (2019).** The effect of external fixator configurations on the dynamic compression load: an experimental and numerical study. applied sciences, 10(1), 3.
22. **Fragomen, A. T., Livingston, K. S., & Sabharwal, S. (2020).** External Fixators for Deformity Correction. Essential Biomechanics for Orthopedic Trauma: A Case-Based Guide, 107-126.