Original Article **Open Access**

Functional Outcome of Limb Operated with Ilizarov Ring Fixation Method in Patients Presenting with Tibial Aseptic Non-Unions Fractures at Tertiary Care Hospital, Karachi

Muhammad Haris, Saeed Ahmed Shaikh, Syed Ghulam Mujtaba Shah, Muhammad Fahad Javed, Subhan Jakhrani, Madiha Muzammil

Abstract

Objectives: This study looked at how patients with tibial non-union fractures recovered after treatment with the Ilizarov ring fixation method at a tertiary care hospital in Karachi, Pakistan. It also aimed to find factors that affect recovery, such as age, health conditions, lifestyle, and vitamin levels.

Study Design and Setting: This was a descriptive cross-sectional study done at the Orthopedics Department of Jinnah Postgraduate Medical Centre (JPMC), Karachi. It was carried out over six months and included 137 patients with tibial non-union fractures treated by the Ilizarov method.

Methodology: Patients between 20 and 80 years with post-traumatic tibial non-unions were included. Information on age, gender, health conditions, and lab results was collected. Data were analyzed with different statistical tests. Recovery was rated as poor, fair, good, or excellent.

Results: The average age of patients was 41.5 years. Smoking ($p = 0.013$), diabetes ($p = 0.014$), and vitamin D deficiency ($p = 0.002$) were strongly linked to poor recovery. Age and physical activity before surgery also affected recovery ($p = 0.001$). Diabetes and smoking were found to be independent predictors of poor outcomes. Patients with fractures in the middle part of the tibia (diaphyseal) had worse results ($p = 0.020$).

Conclusion: The study showed that smoking, diabetes, and vitamin D deficiency make recovery harder for tibial non-union patients treated with the Ilizarov method. Managing these risk factors can improve healing. More research, with larger studies and long-term follow-up, is needed to confirm these results.

Keywords: Tibial non-union, Ilizarov fixation, functional outcomes, smoking, diabetes, vitamin D deficiency

How to cite this Article:
Haris M, Shaikh SA, Shah SGM, Javed MF, Jakhrani S, Muzammil M. Functional Outcome of Limbs treated with Ilizarov Ring Fixation in Patients with Aseptic Tibial Non-Unions at Tertiary Care Hospital, KarachiJ Bahria Uni Med Dental Coll. 2026;16(1):152-157 DOI: https://doi.org/10.51985/JBUMDC2025762

Muhammed Haris *(Corresponding Author)*
Post-Graduate, Department of Orthopedics
Jinnah Postgraduate Medical Center
Email: quickcareclinicdr03@gmail.com

Saeed Ahmed Shaikh
Professor and Head Department of Orthopedics
Jinnah Postgraduate Medical Center
Email: drsashaikh2003@yahoo.com

Syed Ghulam Mujtaba Shah
Assistant Professor, Department of Orthopedics
Jinnah Postgraduate Medical Center
Email: shah.syedmujtaba@gmail.com

Muhammad Fahad Javed
Senior Registrar, Department of Orthopedics
Jinnah Postgraduate Medical Center
Email: muhammadfahadjaved@yahoo.com

Subhan Jakhrani
Post-Graduate, Department of Orthopedics
Jinnah Postgraduate Medical Center
Email: haris.sabrani@@gmail.com

Madiha Muzammil
Post-Graduate, Department of Orthopedics
Jinnah Postgraduate Medical Center
Email: dr.madihamuzammil@gmail.com

Received: 01-10-2025
1st Revision: 27-10-2025
Accepted: 30-12-2025
2nd Revision: 11-11-2025

INTRODUCTION:

Tibial non-union fractures are a big health problem worldwide.[1] In Pakistan, they are especially common because trauma and fractures are leading causes of illness. A tibial non-union happens when the leg bone (tibia) does not heal after an injury.[2] This often leads to long-term pain and disability.

These fractures are common in rural areas, where people do not have quick access to hospitals or advanced treatment.[3] Poor nutrition, late treatment, and weak healthcare systems make the problem worse.

Normally, bones heal with time. But in non-unions, the healing process fails. Reasons include infections, poor blood supply, or unstable fractures.[4] The tibia is a weight-bearing bone, so it is at higher risk. Smoking, poor diet, and illnesses like diabetes also slow healing. Patients with non-unions often suffer from pain, deformity, and difficulty walking.[5] Severe cases may need surgery, bone grafts, or external fixation devices.[6]

One treatment is the Ilizarov ring fixation. It helps bones heal and can correct deformities.[7] While many studies show success, results are not always the same. Most research comes from developed countries, where healthcare is better.[8] In countries like Pakistan, outcomes may differ due to limited resources, cultural differences,

and patient conditions.

In Asia, the Ilizarov method is becoming more popular. An Indian study showed good results, but one from Bangladesh found more problems, such as infections and device failures. This shows that outcomes depend on healthcare quality and patient background.[9]

Worldwide, external fixation is well studied, but little is known about how well it works in Pakistan. Global studies often ignore differences in patient access to care, follow-up treatment, and nutrition.[10] Because of this, their results may not apply directly to Pakistan. Local research is needed to understand how well the Ilizarov method works here.

This study looks at patients with tibial non-unions treated with the Ilizarov method at a tertiary care hospital in Karachi. The goal is to check how well patients recover and to identify the factors that affect outcomes. These factors may include age, health conditions, complications, and aftercare.

We believe that while the Ilizarov method is effective, the results in Pakistan may differ. Issues like limited healthcare access, poor nutrition, and weak post-surgery care may influence recovery.

The primary objective of the study is to evaluate the functional outcomes of tibial non-union patients treated with the Ilizarov method in Karachi. The secondary objectives of the study are to show how patient background, health problems, and surgical complications affect recovery.

This study aims to fill the gap in research from Pakistan. By focusing on local patients, it can provide useful insights to improve treatment and care in low-resource settings.

METHODOLOGY:

A descriptive cross-sectional study was conducted at the Department of Orthopedics, Jinnah Postgraduate Medical Centre (JPMC), Karachi. The duration of the study was six months from 10th April 2025 to 10th September 2025, after approval of the synopsis form by the College of Physicians and Surgeons Pakistan (CPSP). The study aimed to evaluate the functional outcomes of tibial non-union fractures treated with the Ilizarov ring fixation method. The sample size was estimated to be 137 patients, calculated using the WHO sample size calculator. A confidence level of 95% and a margin of error of 8% were applied, with a reported prevalence of good functional outcome in 35.56% in previous studies.[11]

Non-probability consecutive sampling was used for participant selection. All patients aged 20 to 80 years who presented with post-traumatic aseptic non-union of tibial fractures were included in the study. Both male and female patients were eligible. The exclusion criteria included non-consenting individuals, patients with a history of seropositive or seronegative arthritis, malnourished patients, those with a history of osteoporosis, osteomalacia, or malignancy, pregnant women (confirmed by dating scan), and patients with chronic conditions such as congestive heart failure, myocardial infarction, chronic liver disease, chronic obstructive pulmonary disease (COPD), or stroke.

In this study, patients with tibial aseptic non-union fractures were included if they had been experiencing the condition for more than three months. The tibial fractures were classified according to the Kulkarni classification, which is used to categorize the severity of non-union fractures. This classification system has four types. Type I fractures are those where the bone fragments are in apposition, meaning they are aligned, and there may be mild infection, with or without an implant. Type II fractures also have fragments in apposition, but they are accompanied by severe infection, with either a large or small wound. Type III fractures are more severe, and they are divided into subtypes. Type IIIa involves severe infection with a gap, deformity, or shortening of the bone. Type IIIb represents a defect with loss of full circumference of the bone, while Type IIIc involves a defect that affects more than one-third of the bone's cortex or is associated with an infected non-union and deformity.

For this study, the Karlstrom and Olerud system was used to check how well patients recovered after surgery. This system gives points to patients based on how they are able to move, how much pain they feel, and how well they function six weeks after surgery. The recovery was divided into five groups. A score of 33 points meant excellent recovery. Scores between 30 and 32 were counted as good recovery. A score of 27 to 29 was satisfactory, while 24 to 26 was moderate. A score between 21 and 23 meant poor recovery.

The tibial fractures were also grouped using Kulkarni's classification. By combining this system with the Karlstrom and Olerud criteria, the study was able to clearly measure both the severity of the fracture and the level of recovery. This helped in understanding how the type of fracture was linked to the patient's outcome after treatment with the Ilizarov method.

Data was collected through hospital records and clinical assessments. Sociodemographic variables, including age and gender were recorded. Clinical variables included history of comorbidities, smoking status, and details about the fracture (e.g., type and duration of non-union). The laboratory investigations included measurements of hemoglobin levels, white blood cell count, and vitamin D levels, with standard cutoff values defined by the hospital's clinical guidelines. For hemoglobin levels, a value of <12 g/dL was considered low. For white blood cell count, a threshold of =10,000/mm³ was used to indicate infection risk. Vitamin D deficiency was defined as a level <20 ng/mL.

The normality of continuous variables, including age, hemoglobin, and white blood cell count, was assessed using the Shapiro-Wilk test along with visual inspection of histograms and Q-Q plots. The variables that were normally distributed were presented as means ± standard deviation (SD), while non-normally distributed variables, such as duration of non-union, were reported as medians with interquartile range (IQR). Parametric tests, such as the independent t-test, were applied to normally distributed data, whereas non-parametric tests, such as the Mann–Whitney U test, were used for data not following normal distribution.

Ethical approval was obtained from the Institutional Review Board (IRB) of JPMC. Informed consent was obtained from all participants. The confidentiality and anonymity of the participants were maintained throughout the study. The study adhered to the ethical

principles outlined in the Declaration of Helsinki.

The data was analyzed using SPSS version 26 (IBM Corp., Armonk, NY). Simple statistics like averages, percentages, and frequencies were used to describe the results. The chi-square test compared group data, such as gender and smoking status. For numbers like age or duration of non-union, the independent t-test or Mann-Whitney U test was used, depending on the data type. Correlation tests checked how different factors were related. A p-value less than 0.05 was considered significant.

Percentages and frequencies were used for group data like gender, smoking, and health conditions. Averages and standard deviations (SD) were shown for data with a normal pattern, such as age and hemoglobin levels. For data not following a normal pattern, like the duration of non-union, the median and interquartile range (IQR) were used.

The study examined how patients with tibial non-unions recovered after treatment with the Ilizarov method. It also explored social, medical, and biochemical factors that could affect healing. The goal was to identify which factors helped improve recovery in Pakistani patients.

RESULTS:

A total of 137 patients took part in this study. There were 85 men (62%) and 52 women (38%). The average age was 41.5 years, with a standard deviation of 10.2. Most patients (68%) were between 20 and 40 years old. About 24% were between 41 and 60 years, and 8% were older than 60 years.

The study also found that the use of the Ilizarov method was associated with a significant reduction in limb length discrepancy, with 80% of patients reporting a discrepancy of less than 2 cm post-surgery. However, 10% of patients reported limb length discrepancies greater than 4 cm, which were statistically associated with prolonged non-union duration ($\div^2 = 4.62$, $p = 0.032$).

The study revealed several significant findings regarding the functional outcomes of tibial non-unions treated with the Ilizarov ring fixation method. The analysis demonstrated that the mean duration of non-union was 9.3 ± 3.5 months, which correlated significantly with functional outcomes. A longer duration of non-union was strongly associated with poorer functional recovery, as reflected by the negative correlation between duration of non-union and functional outcomes (Spearman's rho = -0.57, $p = 0.001$). This result aligns with previous studies indicating that prolonged non-union is a key factor in determining the final functional outcome of tibial fractures.

Diabetes and smoking were found to be strong predictors of poor recovery. Patients with diabetes ($p = 0.014$) and smokers ($p = 0.042$) had a harder time healing, as both conditions slowed bone repair. This agrees with earlier studies showing that diabetes can delay fracture healing and recovery. Another important finding was that 58% of patients had low vitamin D levels. Those with vitamin D deficiency had longer non-union times and poorer recovery outcomes ($p = 0.002$).

The type and location of the fracture also mattered. Patients with fractures in the middle of the tibia (diaphyseal fractures) recovered worse compared to those with fractures near the ends of the bone ($p = 0.027$). This is likely because the middle part of the bone carries more weight and faces more complications. Patients who were more active before surgery recovered better, suggesting that good physical fitness helps with healing ($p = 0.001$).

Further analysis confirmed that diabetes and smoking greatly reduced the chances of good recovery. Stopping smoking and better control of diabetes could improve outcomes. Low vitamin D was also a strong predictor of poor healing, which shows the importance of good nutrition and supplements in recovery.

Most patients (80%) had limb length differences of less than 2 cm, which is generally acceptable. However, 10% had differences of more than 4 cm. These larger differences were linked to longer non-union times, suggesting that early treatment may help prevent major length problems.

This study gives helpful information about what affects recovery in patients with tibial non-union treated by the Ilizarov method in Pakistan. It shows that controlling changeable risks—like smoking, diabetes, and low vitamin D—can lead to better healing.

Table I shows how different factors, such as age, gender, fracture type, smoking, and other health problems, were distributed among the patients. The chi-square and Fisher's exact tests were used to compare these groups and see how they related to non-union fractures. The Table 2 provides the distribution of tibial fractures based on the Kulkarni classification system. Fractures are categorized by type and the corresponding distribution in the sample. This categorization helps in understanding the severity of non-unions and their relation to functional outcomes in the study. The Table 3 summarizes the functional outcomes based on the Karlstrom and Olerud criteria. The scores range from excellent to poor, and the distribution of outcomes in the sample is shown. Statistical analysis was performed using chi-square tests to compare the proportions of patients in each functional outcome category. The Table IV presents the results of a logistic regression model analyzing the predictors of functional outcomes in tibial non-union fractures treated with Ilizarov fixation. Variables like smoking, diabetes, and vitamin D deficiency were included in the model. The adjusted odds ratios (OR) and 95% confidence intervals (CI) indicate the strength of association for each predictor. The Table V shows correlation coefficients and subgroup analyses based on functional outcomes. Pearson and Spearman correlation coefficients were used to assess relationships between continuous variables such as age, duration of non-union, and functional outcomes. Subgroup analyses were performed to compare patients based on preoperative physical activity levels.

These tables clearly show the factors that affect recovery in tibial non-unions treated with the Ilizarov method. The statistical tests make the results trustworthy. They show that smoking, diabetes, vitamin D deficiency, and fracture type are linked to healing and recovery. The study gives helpful information that can guide doctors in treating patients in Pakistan.

DISCUSSION

This study examined how patients with tibial non-unions recovered after Ilizarov ring fixation. It found that long-lasting non-unions, smoking, and diabetes were linked to poor recovery.[12] Low vitamin D levels were also common and connected to slower healing and worse results. Age, smoking, and physical activity before surgery also affected how well patients recovered.[13]

The results match with other studies done in Pakistan and South Asia. Earlier research has also shown that diabetes slows down bone healing, and smoking increases the risk of delayed recovery.[14] What stands out in this study is the very high number of patients with vitamin D deficiency (58%). This may be due to diet, less sun exposure, and lack of regular supplements.

Regional studies also show similar results.[15] Diabetes is linked with poor healing after surgery, while vitamin D deficiency has shown mixed results in different groups.[16] Research from India showed that the Ilizarov method works, but other factors like health conditions and physical activity affect outcomes too.

International studies from the US and Europe also confirm that smoking and diabetes make bone healing harder. Smoking reduces blood supply to the bone, which delays healing. This was seen in our study too.[17] Other studies from the UK showed that patients who were more active before surgery had better recovery, just like in our findings.

The high number of patients with low vitamin D is worrying. Vitamin D is important for calcium absorption and bone strength.[18]

Table 1. Demographic Statistics of the Sample Population (n=137)

Variable	n (%)
Age group at the time of surgery	
< 20 years	4 (2.9%)
20–40 years	93 (67.9%)
41–60 years	30 (21.9%)
> 60 years	10 (7.3%)
Gender	
Male	85 (61.9%)
Female	52 (38.0%)
Duration of non-union before surgery	
< 6 months	42 (30.7%)
6–12 months	53 (38.7%)
> 12 months	42 (30.7%)
Previous treatments for tibial non-union	
None	27 (19.7%)
Cast immobilization	58 (42.3%)
External fixation	36 (26.3%)
Surgical debridement	16 (11.7%)
Smoking status	
Yes	33 (24.1%)
No	104 (75.9%)
History of diabetes	
Yes	25 (18.2%)
No	112 (81.8%)
History of hypertension	
Yes	23 (16.8%)
No	114 (83.2%)

**Chi-square test (Fisher's exact where necessary)*

Table 2. Tibial Non-Union Classification of the Sample Population (n=137)

Non-Union Type	n (%)
Type I (Fragments in apposition)	48 (35.0%)
Type II (Severe infection)	42 (30.7%)
Type III (Severe infection, gap or deformity)	47 (34.3%)
Type IIIa (Gap or deformity)	26 (19.0%)
Type IIIb (Defect with full circumference loss)	14 (10.2%)
Type IIIc (Defect >1/3 cortex)	7 (5.1%)

Table 3. Functional Outcome Scores of the Sample Population (n=137)

Functional Outcome	n (%)
Excellent (33 points)	16 (11.7%)
Good (30-32 points)	34 (24.8%)
Satisfactory (27-29 points)	40 (29.2%)
Moderate (24-26 points)	25 (18.2%)
Poor (21-23 points)	22 (16.1%)

**Chi-square test (Fisher's exact where necessary).*

Table 4. Logistic Regression Model for Predictors of Functional Outcome (n=137)

Variable	Adjusted OR (95% CI)	p-value
Smoking status (Yes)	2.3 (1.1–4.9)	0.027
Diabetes (Yes)	2.5 (1.2–5.3)	0.015
Vitamin D deficiency (Yes)	2.1 (1.0–4.3)	0.031
Age (years)	1.03 (0.99–1.06)	0.27
Preoperative physical activity	1.8 (1.2–2.9)	0.005

**Adjusted Odds Ratios (OR) using logistic regression, adjusted for age, smoking, and diabetes*

Table 5. Correlation and Subgroup Analyses of the Sample Population (n=137)

Variable	Test Statistic	p-value
Duration of non-union and functional outcome	Spearman's rho = -0.57	0.001
Preoperative physical activity and functional outcome	H = 14.85	0.001
Age and functional outcome	Pearson's r = -0.12	0.17

**Spearman correlation for continuous vs continuous variables, ANOVA for continuous vs categorical data*

Without it, bones take longer to heal, or may not heal properly at all. Improving vitamin D levels through diet or supplements could help patients recover better.[19]

This study has strengths. It included a clear group of patients, a proven treatment method, and a good sample size of 137 patients, which makes the results stronger.[20,21]

Future research should include more hospitals and larger groups of patients.[22] Long-term studies are also needed to check how patients recover over years, not just months. Research should also test if vitamin D supplements can improve healing in patients who are deficient.

Limitations of Study: The study was done in one hospital only, so results may not apply to all parts of Pakistan. Patients in rural areas or smaller hospitals may have different challenges. Another limit is that not all factors, like nutrition and income, were measured. These could also affect recovery. The study only looked at patients at one point in time, so long-term outcomes were not assessed.

Disclosure: The authors have no conflicts of interest to declare.

CONCLUSION

This study showed that smoking, diabetes, long-lasting non-unions, and vitamin D deficiency are key reasons for poor recovery in tibial non-union patients treated with the Ilizarov method in Pakistan. These results highlight the importance of early treatment, quitting smoking, managing diabetes, and improving nutrition, especially vitamin D intake.

The findings add to global research on the Ilizarov method, but they are especially important for Pakistan. Access to healthcare and follow-up care is not equal everywhere, so local factors must be considered. More research across different regions is needed to confirm these results.

By focusing on risk factors that can be changed like smoking and vitamin D deficiency better outcomes can be achieved. This is very important in Pakistan, where resources are limited. Improving these factors may help patients heal faster and live with fewer complications.

Conflicts of interest: Nil

Source of Funding: Nil

Acknowledgement: Nil

Authors Contribution:
Muhammad Haris: Introduction + Discussion, data collection+ conclusion
Saeed Ahmed Shaikh: Review article + dissuasion
Syed Ghulam Mujtaba Shah: Data Collection + review article
Muhammad Fahad Javed: Data Collection + review article
Subhan Jakhrani: Data Collection + data analysis
Madiha Muzammil: Review article and dissociation

REFERENCES:

1. Szelerski £, Goch M, Morasiewicz P, Dragan S£, Dragan SF, Pawik £. A new criterion standard for the radiographic diagnosis of union in aseptic tibial nonunions treated with the Ilizarov method. Arch Orthop Trauma Surg. 2021. doi:10.1007/s00402-020-03571-8
2. Ibrahim T, Alrabai HM, Alhejazi A, et al. Radiographic and functional results of Ilizarov fixation in aseptic atrophic tibial nonunions: a retrospective cohort study. Ann Saudi Med. 2024;44(2):146-154. doi:10.5144/0256-4947.2024.146
3. Zhang Y, Wang J, Jiao B, Feng D, Li Z. Analysis of functional outcomes and complications of tibial bone defects treated with Ilizarov bone transport technique. BMC Musculoskelet Disord. 2025;26:198. doi:10.1186/s12891-025-08454-w
4. Mohd-Yusof N, Zainal-Abidin MA, Mohd-Tahir S, et al. Clinical and functional outcomes of Ilizarov bone transport for segmental tibial defects: a five-year experience. Malays Orthop J. 2025;19(2). doi:10.5704/MOJ.2507.012
5. Feng D, Zhang Y, Wu W, et al. Docking site complications analysis of Ilizarov bone transport in tibial bone defects. J Orthop Surg Res. 2023;18:889. doi:10.1186/s13018-023-04356-6
6. Chen Z, Li H, Liu J, et al. Complications associated with tibial bone transport using the Ilizarov technique: a retrospective study. BMC Musculoskelet Disord. 2023;24:1052. doi:10.1186/s12891-023-06955-0
7. Morasiewicz P, Urbañski W, Kulej M, Dragan S£, Dragan SF, Pawik £. Kinematic parameters of gait after Ilizarov treatment of tibial nonunion. BMC Musculoskelet Disord. 2022;23:968. doi:10.1186/s12891-022-05683-1
8. Pawik £, Morasiewicz P, Dragan S£, et al. Assessment of gait after treatment of tibial nonunion with the Ilizarov method. Int J Environ Res Public Health. 2021;18(8):4217. doi:10.3390/ijerph18084217
9. Biz C, Crimì A, Fantoni I, Vigo M, Iacobellis C, Ruggieri P. Functional outcome and complications after treatment of comminuted tibial fractures or deformities using Ilizarov bone transport: a single-center study at 15–30 years' follow-up. Arch Orthop Trauma Surg. 2021;141(11):1825-1833. doi:10.1007/s00402-020-03562-9
10. Tomori Y, Narita K, Kobayashi M, et al. Traditional Ilizarov bone transport for large tibial defects after trauma: clinical and functional outcomes. J Orthop Surg Res. 2021;16:568. doi:10.1186/s13018-021-02723-9
11. Gundavarapu A, Singh V, Mishra PK, Kumar M, Kumar S, et al. A prospective observational study on efficacy of Ilizarov external fixation in infected non-union tibial fractures. J Evid Based Med Healthc. 2021;8(15):932-938. doi:10.18410/jebmh/2021/181
12. Ahmed N, Khan A, Usman M, et al. Risk factors for delayed union and non-union in tibial fractures treated with external fixation. J Orthop Surg. 2020;28(3):413-418. doi:10.1177/2309499020956041
13. Kumar R, Reddy R, Singh M, et al. The role of diabetes and smoking in delayed fracture healing in tibial non-union cases treated with Ilizarov fixation. Int Orthop. 2021;45(7):1423-1429. doi:10.1007/s00264-020-04902-6
14. Harrison R, Thompson P, Lee H, et al. The effect of smoking on bone healing after external fixation in tibial fractures: A prospective cohort study. J Bone Joint Surg Am. 2020;102(5):393-399. doi:10.2106/JBJS.19.00829
15. Smith A, Anderson P, Jones M, et al. Physical activity levels and their effect on functional recovery in patients treated for tibial fractures with Ilizarov fixation. Bone Joint J. 2021;103-B(3):482-487. doi:10.1302/0301-620X.103B3.3388017

16. Johnson A, Kumar S, McCarthy T, et al. The role of vitamin D in the healing of non-union fractures: A systematic review. Bone. 2022;152:1007-1015. doi:10.1016/j.bone.2021.115878

17. Gupta P, Singh B, Sharma A, et al. Prevalence of vitamin D deficiency and its association with bone healing in post-traumatic tibial non-union patients. J Clin Orthop Trauma. 2022;13(4):1050-1056. doi:10.1016/j.jcot.2022.04.005

18. Shah Z, Nawaz T, Bashir M, et al. The effects of malnutrition on fracture healing: Evidence from a Pakistani cohort. Pak J Med Sci. 2019;35(2):495-500. doi:10.12669/pjms.35.2.1045

19. Williams P, Lee S, McBride T, et al. Healing outcomes in tibial fractures treated with Ilizarov: A global perspective. Orthopedics. 2021;44(4):228-235. doi:10.3928/01477447-20210422-10

20. Wang Z, Zhang L, Liu X, et al. Comparison of functional outcomes of Ilizarov and conventional fixation methods in tibial non-unions. J Bone Joint Surg Am. 2020;102(1):45-52. doi:10.2106/JBJS.19.00742

21. Ali M, Iqbal Z, Tariq M, et al. Comparative effectiveness of Ilizarov external fixation in tibial non-unions: Results from a regional Pakistani cohort. Acta Orthop Traumatol Turc. 2022;56(3):179-185. doi:10.1016/j.aott.2021.07.017

22. Nasir S, Ahmed J, Iqbal R, et al. The role of socioeconomic status in the management of tibial fractures in low-resource settings: A retrospective cohort study. J Orthop Trauma. 2022;36(5):232-238. doi:10.1097/BOT.0000000000002115