

Reliability of the Radiographic Union Scale for Tibial Fractures (RUST) in Assessing Fracture Healing Following Intramedullary Interlocking Nailing: A Prospective Observational Study

Aditya Sharma¹, Apser Khan², Sanjay Gupta³, Devansh Agarwal⁴,
Harshvardhan Buddhist⁵

¹⁻⁵Department of Orthopaedics, Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.

Corresponding Author: Apser Khan

DOI: <https://doi.org/10.52403/ijhsr.20260726>

ABSTRACT

Assessment of fracture union following intramedullary interlocking nailing is essential for guiding rehabilitation and clinical decision-making. Conventional radiographic evaluation is subjective and associated with considerable inter-observer variability. The Radiographic Union Scale for Tibial fractures (RUST) was developed to provide a standardized and objective method for assessing radiographic fracture healing.

Objective: To evaluate the inter-observer reliability of the Radiographic Union Scale for Tibial fractures (RUST) in assessing fracture healing after intramedullary interlocking nailing.

Materials and Methods: A prospective observational study was conducted in the Department of Orthopaedics at Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, India, between April 2024 and September 2025. Thirty-seven adult patients with tibial shaft fractures treated with intramedullary interlocking nailing were included. Standardized anteroposterior and lateral radiographs obtained at 6, 12, and 24 weeks postoperatively were independently assessed by five orthopedic surgeons and two orthopedic senior residents and one radiologist using the RUST scoring system. Inter-observer reliability was evaluated using the Intraclass Correlation Coefficient (ICC) with 95% confidence intervals (CI).

Results: The mean age of the participants was 38.03 ± 15.01 years, and 86.5% were males. Mean RUST scores increased progressively during follow-up, ranging from 5.27–5.51 at 6 weeks, 7.49–8.35 at 12 weeks, and 11.08–11.32 at 24 weeks. Inter-observer reliability improved over time, with an ICC of 0.800 (95% CI: 0.668–0.887) at 6 weeks, 0.945 (95% CI: 0.910–0.969) at 12 weeks, and 0.977 (95% CI: 0.961–0.987) at 24 weeks. The overall inter-observer reliability was excellent (ICC = 0.953; 95% CI: 0.928–0.973).

Conclusion: The Radiographic Union Scale for Tibial fractures demonstrated excellent inter-observer reliability in assessing fracture healing following intramedullary interlocking nailing. Observer agreement improved with advancing fracture healing, supporting the use of RUST as a simple, objective, and reproducible tool for routine clinical practice and orthopedic research.

Keywords: Tibial shaft fracture; Radiographic Union Scale for Tibial fractures (RUST); Intramedullary interlocking nailing; Fracture healing; Inter-observer reliability; Intraclass correlation coefficient.

INTRODUCTION

Tibial shaft fractures are among the most common long-bone injuries, accounting for approximately 1–2% of all fractures and 36–43% of long-bone fractures. These injuries predominantly affect young, economically active individuals and are usually caused by high-energy trauma such as road traffic accidents, industrial accidents, and falls from height. Owing to the subcutaneous location of the tibia and its limited soft-tissue coverage, these fractures are associated with delayed union, non-union, infection, and other complications, making accurate assessment of fracture healing an essential component of patient management.¹⁻³

Intramedullary interlocking nailing (IMN) has become the gold standard treatment for displaced tibial shaft fractures because it provides stable fixation while preserving fracture biology and soft-tissue integrity. It allows early mobilization, promotes biological healing, and has demonstrated excellent clinical outcomes. Nevertheless, successful postoperative management depends largely on accurate assessment of fracture union to guide weight-bearing, rehabilitation, and the need for secondary intervention.⁴⁻⁶

Although clinical findings such as pain on weight bearing and tenderness at the fracture site are useful indicators of healing, radiographic evaluation remains the most commonly used method for assessing fracture union. Conventional radiographic interpretation, however, is subjective and exhibits considerable variability among orthopedic surgeons.

Previous studies have demonstrated poor agreement regarding the interpretation of callus formation, cortical bridging, and fracture line disappearance, resulting in inconsistent clinical decision-making.⁷⁻⁹ To overcome these limitations, Whelan et al. developed the Radiographic Union Scale for

Tibial fractures (RUST), a standardized radiographic scoring system that evaluates healing of each of the four cortices visible on anteroposterior and lateral radiographs. Each cortex is assigned a score based on callus formation and fracture-line visibility, generating a total score ranging from 4 to 12, with higher scores indicating greater fracture union. The RUST score transforms subjective radiographic interpretation into an objective, reproducible numerical assessment of fracture healing.¹⁰

Subsequent validation studies have demonstrated substantial to excellent inter-observer and intra-observer reliability of the RUST scoring system. Stephen et al. reported excellent inter-observer (ICC = 0.86) and intra-observer (ICC = 0.88) agreement, supporting its use in both clinical practice and research.¹¹ Leow et al. further confirmed strong reproducibility of RUST scoring in an independent cohort, while Cekiç et al. demonstrated significant correlations between RUST scores and clinical outcomes following intramedullary nailing.^{12,13} Despite these encouraging findings, observer variability continues to exist across different clinical settings and levels of surgical experience. Moreover, published evidence evaluating the reliability of RUST in the Indian population remains limited.^{11,12}

Therefore, the present study was undertaken to evaluate the inter-observer reliability of the Radiographic Union Scale for Tibial fractures (RUST) in assessing fracture healing following intramedullary interlocking nailing.

Objective

To evaluate the inter-observer reliability of the Radiographic Union Scale for Tibial fractures (RUST) in assessing fracture healing after intramedullary interlocking nailing.

MATERIALS & METHODS

Study design and setting

This prospective observational study was conducted in the Department of Orthopaedics, Shri Ram Murti Smarak Institute of Medical Sciences (SRMS IMS), Bareilly, Uttar Pradesh, India, between April 2024 and September 2025. The study was approved by the Institutional Ethics Committee (Ref. No. SRMSIMS/ECC/2024/9), and written informed consent was obtained from all participants prior to enrolment.

Study participants

A total of 37 adult patients with tibial shaft fractures treated by intramedullary interlocking nailing were included using consecutive sampling. Hence no predetermination of sample size was done. Patients aged 18 years or older with acute tibial shaft fractures undergoing primary intramedullary fixation were eligible for inclusion. Patients aged less than 18 years, those managed by treatment modalities other than intramedullary nailing, pathological fractures, revision surgeries, and patients with chronic systemic diseases, peripheral neuropathy, vascular disease, or advanced arthritis were excluded from the study.

Radiographic assessment

Standardized anteroposterior and lateral radiographs of the operated tibia were obtained at 6, 12, and 24 weeks following surgery. Fracture healing was assessed using the Radiographic Union Scale for Tibial fractures (RUST). The RUST scoring system evaluates the medial, lateral, anterior, and posterior cortices, assigning each cortex a score from 1 to 3 based on callus formation and fracture-line visibility. The total RUST score ranges from 4 to 12, with higher scores indicating greater radiographic union. To ensure unbiased assessments, the examiners were blinded to patient history, age of the fracture, and all clinical information pertaining to the sets of radiographs.

Observer assessment

A group of seven reviewers, comprising 2 orthopedic senior residents, 4 orthopedic surgeons and 1 radiologist who were blinded to patient identity, clinical findings, and follow-up information. To assess inter-observer reliability, all observers independently scored the same radiographs at each follow-up interval. Observer agreement was evaluated using the initial assessment of the radiographs.

Statistical Analysis

Data were entered into Microsoft Excel 2019 and analyzed using IBM SPSS Statistics version 27.0. Continuous variables were summarized as mean $\pm$ standard deviation, whereas categorical variables were expressed as frequencies and percentages. Inter-observer reliability of the RUST score was assessed using the Intraclass Correlation Coefficient (ICC) with corresponding 95% confidence intervals (CI). ICC values were interpreted according to standard criteria as poor (<0.50), moderate ($0.50-0.74$), good ($0.75-0.89$), and excellent (≥ 0.90). Comparison of mean RUST scores across follow-up intervals was performed using repeated measures analysis of variance (ANOVA). A p-value <0.05 was considered statistically significant.

RESULT

A total of 37 patients with tibial shaft fractures treated with intramedullary interlocking nailing were included in the study. The mean age of the participants was 38.03 ± 15.01 years. Most patients were male (86.5%), while females accounted for 13.5% of the study population. Transverse fractures were the most common fracture pattern (37.8%), followed by oblique (27.0%) and spiral fractures (27.0%), whereas segmental fractures constituted 8.1% of cases. Regarding the mechanism of injury, road traffic accidents were the leading cause (40.5%), followed by trauma (37.8%), falls (16.2%), and other causes (5.4%) (Table 1).

Table 1: Baseline Characteristics of Study Participants

Variable	n (%) / Mean $\pm$ SD
Age (years), Mean $\pm$ SD	38.03 $\pm$ 15.01
Gender	
Male	32 (86.5)
Female	5 (13.5)
Fracture Type	
Transverse	14 (37.8)
Oblique	10 (27.0)
Spiral	10 (27.0)
Segmental	3 (8.1)
Mechanism of Injury	
Road Traffic Accident	15 (40.5)
Trauma	14 (37.8)
Fall	6 (16.2)
Others	2 (5.4)

The mean RUST scores assigned by the seven reviewers increased progressively over the follow-up period, indicating radiographic progression of fracture healing. At 6 weeks, the mean RUST scores ranged from 5.27 ± 0.52 to 5.51 ± 0.52 , with a statistically significant difference among reviewers ($p = 0.024$). At 12 weeks, the mean scores increased to a range of $7.49 \pm$

1.08 to 8.35 ± 1.10 , and the difference among reviewers remained statistically significant ($p = 0.030$). By 24 weeks, the mean RUST scores had further increased, ranging from 11.08 ± 1.54 to 11.32 ± 1.62 , with no statistically significant difference among reviewers ($p = 0.137$), suggesting convergence in radiographic assessment as fracture healing progressed (Table 2).

Table 2: Mean RUST Scores Assigned by Reviewers during Follow-up

Reviewer	6 weeks	12 weeks	24 weeks
Clinician 1	5.30 ± 0.52	7.49 ± 1.08	11.14 ± 1.54
Clinician 2	5.27 ± 0.52	7.57 ± 1.09	11.08 ± 1.54
Clinician 3	5.43 ± 0.52	7.65 ± 1.08	11.16 ± 1.54
Clinician 4	5.51 ± 0.52	7.68 ± 1.08	11.14 ± 1.54
Clinician 5	5.43 ± 0.56	8.35 ± 1.10	11.32 ± 1.62
Senior Resident 1	5.40 ± 0.54	8.10 ± 1.05	11.22 ± 1.58
Senior Resident 2	5.39 ± 0.53	8.05 ± 1.03	11.18 ± 1.55
p-value	0.024	0.03	0.137

Note: Repeated measures ANOVA test used.

Inter-observer reliability of the RUST scoring system improved throughout the follow-up period. At 6 weeks, the intraclass correlation coefficient (ICC) was 0.800 (95% CI: 0.668–0.887), indicating good agreement among reviewers. Reliability increased to an excellent level at 12 weeks (ICC = 0.945; 95% CI: 0.910–0.969) and

further improved at 24 weeks (ICC = 0.977; 95% CI: 0.961–0.987). The overall inter-observer reliability across all follow-up intervals was excellent (ICC = 0.953; 95% CI: 0.928–0.973), demonstrating a high level of consistency in RUST scoring among different observers (Table 3).

Table 3: Inter-observer Reliability

Time Interval	ICC (95% CI)	Interpretation
6 weeks	0.800 (0.668–0.887)	Good
12 weeks	0.945 (0.910–0.969)	Excellent
24 weeks	0.977 (0.961–0.987)	Excellent
Overall	0.953 (0.928–0.973)	Excellent

DISCUSSION

The present prospective observational study evaluated the inter-observer reliability of the Radiographic Union Scale for Tibial fractures (RUST) in assessing fracture healing following intramedullary interlocking nailing. The principal finding of the study was that the RUST scoring system demonstrated excellent overall inter-observer reliability (ICC = 0.953), with agreement improving progressively from good reliability at 6 weeks (ICC = 0.800) to excellent reliability at both 12 weeks (ICC = 0.945) and 24 weeks (ICC = 0.977). These findings support the use of RUST as a reliable and reproducible method for radiographic assessment of tibial fracture healing.

The demographic profile of our study population was consistent with the epidemiology of tibial shaft fractures reported in previous studies. The mean age of the participants was 38.03 ± 15.01 years, and the majority was males (86.5%). This predominance of young adult males has been consistently reported in the literature and reflects the greater exposure of this population to high-energy trauma, particularly road traffic accidents.^{1,2} In the present study, road traffic accidents constituted the commonest mechanism of injury (40.5%), followed by trauma (37.8%), which is in agreement with previous epidemiological reports of tibial shaft fractures.^{2,4}

The mean RUST scores increased progressively during follow-up, from approximately 5.3 at 6 weeks to 11.2 at 24 weeks, indicating gradual radiographic progression of fracture healing after intramedullary nailing. Although statistically significant differences in mean RUST scores among reviewers were observed at 6 and 12 weeks, these differences disappeared by 24 weeks. This finding suggests that radiographic interpretation becomes more consistent as fracture union progresses and cortical bridging becomes more apparent. Similar observations have been reported by Leow et

al., who found improved agreement among observers during later stages of fracture healing when radiographic features were more clearly defined.¹²

The primary objective of this study was to determine the reliability of the RUST scoring system. Our overall inter-observer ICC of 0.953 indicates excellent agreement among observers and is comparable with previously published validation studies. Whelan et al., who originally developed the RUST scoring system, demonstrated that the scoring system substantially improved the consistency of radiographic assessment compared with conventional subjective evaluation.¹⁴ Similarly, Stephen et al. reported excellent inter-observer reliability with an ICC of 0.86 and intra-observer reliability of 0.88, confirming that RUST provides a standardized and reproducible assessment of fracture union.¹¹ The slightly higher ICC observed in the present study may be attributed to the use of standardized radiographic protocols, observer familiarity with the scoring criteria, and the inclusion of serial follow-up radiographs.

Our findings are also consistent with those of Leow et al., who independently validated the RUST scoring system and demonstrated high reproducibility across different observers, supporting its applicability in routine clinical practice.¹² Likewise, Cekiç et al. reported a strong correlation between RUST scores and clinical progression following intramedullary nailing, suggesting that increasing RUST scores accurately reflect advancing fracture healing.¹³ Collectively, these studies and the present findings reinforce the reliability and clinical utility of the RUST scoring system.

An important observation in the present study was the progressive improvement in inter-observer agreement with increasing follow-up duration. At six weeks, fracture healing is generally characterized by early callus formation, making interpretation relatively subjective and resulting in lower agreement among observers. As healing advances, bridging callus becomes more evident and fracture lines become

progressively indistinct, thereby reducing subjective variation and improving agreement. Similar temporal improvements in observer reliability have been described in previous validation studies of the RUST score.^{11,12}

The excellent reliability observed in the present study has important clinical implications. Reliable radiographic assessment facilitates objective monitoring of fracture healing, assists clinicians in determining the timing of weight-bearing progression, and helps identify delayed union or non-union at an early stage. Furthermore, because RUST provides a standardized numerical score, it enables meaningful comparison of outcomes across institutions and enhances the methodological quality of clinical trials evaluating fracture management strategies.¹⁰⁻¹²

The strengths of the present study include its prospective design, standardized radiographic follow-up, blinded assessment by multiple independent observers, and inclusion of both experienced orthopedic clinicians and senior residents, thereby reflecting routine clinical practice. The use of the Intraclass Correlation Coefficient with 95% confidence intervals provided a robust statistical evaluation of observer agreement.

However, several limitations should be acknowledged. The study was conducted at a single tertiary care center with a relatively small sample size, which may limit the generalizability of the findings. Only patients treated with intramedullary interlocking nailing were included; therefore, the results may not be directly applicable to other methods of fracture fixation. Furthermore, only inter-observer reliability was evaluated in the present analysis, whereas correlation with functional outcomes or advanced imaging modalities such as computed tomography was beyond the scope of this study. Future multicenter studies involving larger patient populations and different treatment modalities are warranted to further validate

the applicability of the RUST scoring system.

CONCLUSION

The present study demonstrated that the Radiographic Union Scale for Tibial fractures (RUST) is a highly reliable and reproducible tool for assessing radiographic fracture healing following intramedullary interlocking nailing. The RUST score showed excellent overall inter-observer reliability (ICC = 0.953), with observer agreement improving progressively from good at 6 weeks to excellent at 12 and 24 weeks. This progressive increase in reliability reflects the greater radiographic clarity of fracture healing over time. The findings support the use of RUST as a simple, objective, and standardized scoring system that minimizes subjectivity in the evaluation of fracture union. Incorporation of RUST into routine orthopedic practice and clinical research may facilitate consistent monitoring of fracture healing, improve communication among clinicians, and assist in evidence-based decision-making regarding rehabilitation and the need for further intervention.

Declaration by Authors

Ethical Approval: Approved

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Puccetti VLYA, de Miranda FL, de Figueiredo CCN, Medeiros KAA, Leonhardt MC, Silva JDS, Kojima KE. Risk factors for non-union of tibial fracture treated with intramedullary nail. *Acta Ortop Bras.* 2024 Jun;32(2): e278581. doi: 10.1590/1413-785220243202e278581.
2. Chaudhry YP, Gutierrez-Naranjo JM, Raad M, Ghanem D, Salazar LM, Goodrum JT, Luksameearunothai K, Zelle BA, Hasenboehler EA. Risk factors for malalignment after intramedullary nail treatment of distal tibia fractures with associated fibula fractures. *Eur J Orthop*

- Surg Traumatol. 2024 Aug;34(6):3265–3273. doi: 10.1007/s00590-024-04062-x.
3. Leow JM, Clement ND, Simpson AHRW. Application of the Radiographic Union Scale for Tibial fractures (RUST): assessment of healing rate and time of tibial fractures managed with intramedullary nailing. *OrthopTraumatol Surg Res.* 2020 Feb;106(1):89–93. doi: 10.1016/j.otsr.2019.10.010.
 4. Aishwarya A, Yadkikar SV, Goyal D, Saumy S. Outcomes of intramedullary nailing in tibial shaft fractures: experience from a low-resource, economically constrained setting. *J Contemp Clin Pract.* 2025 Jun;11(6):733–42. DOI: 10.61336/jccp/25-06-106
 5. Mane SS, Yamajala S, Vinjamuri MLNS, Mitnala SRP. Evaluating reliability of the RUST score in diaphyseal tibia fractures: a collaborative assessment by orthopaedic surgeons and radiologists. *J Orthop Rep.* 2024; 3:100325. DOI: 10.1016/j.jorep.2024.100325
 6. Azevedo Filho, F. A., Cotias, R. B., Azi, M. L., & Teixeira, A. A. Reliability of the radiographic union scale in tibial fractures (RUST). *Revista brasileira de ortopedia.* 2016;52(1), 35–39. doi: 10.1016/j.rboe.2016.05.006
 7. Kooistra BW, Dijkman BG, Busse JW, Sprague S, Schemitsch EH, Bhandari M. The Radiographic Union Scale in Tibial fractures: reliability and validity. *J Orthop Trauma.* 2010 Mar;24 Suppl 1: S81–6. doi: 10.1097/BOT.0b013e3181ca3fd1.
 8. Atwan Y, Schemitsch EH. Radiographic evaluations: which are most effective to follow fracture healing? *Injury.* 2020;51 Suppl 2: S18–22. doi: 10.1016/j.injury.2019.12.028.
 9. Bizzoca D, Vicenti G, Caiaffa V, Abate A, De Carolis O, Carrozzo M, Solarino G, Moretti B. Assessment of fracture healing in orthopaedic trauma. *Injury.* 2023;54 Suppl 1: S46–52. <https://doi.org/10.1016/j.injury.2020.11.014>
 10. Kizkapan TB, Misir A, Oguzkaya S, Ozcamdalli M, Uzun E, Sayer G. Reliability of radiographic union scale in tibial fractures and modified radiographic union scale in tibial fractures scores in the evaluation of pediatric forearm fracture union. *Jt Dis Relat Surg.* 2021;32(1):185–191. doi: 10.5606/ehc.2021.78465.
 11. Whelan DB, Bhandari M, Stephen D, Kreder H, McKee MD, Zdero R, Schemitsch EH. Development of the radiographic union score for tibial fractures for the assessment of tibial fracture healing after intramedullary fixation. *J Trauma.* 2010 Mar;68(3):629–32. doi: 10.1097/TA.0b013e3181a7c16d.
 12. Leow JM, Clement ND, Tawonsawatruk T, Simpson CJ, Simpson AHRW. The Radiographic Union Scale in Tibial (RUST) fractures. *Bone Joint Res.* 2016 Aug 17;5(4):116–121. doi: 10.1302/2046-3758.54.2000628
 13. Erman Cekic, Emin Alici, Murat Yesil. Reliability of the Radiographic Union Score for Tibial Fractures. *Acta Orthopaedica et Traumatologica Turcica.* 2014 Nov. 1;48(5):533–40. doi:10.3944/AOTT.2014.14.0026
 14. Whelan DB, Bhandari M, Stephen D, Kreder H, McKee MD, Zdero R, Schemitsch EH. Development of the Radiographic Union Score for Tibial fractures for the assessment of tibial fracture healing after intramedullary fixation. *J Trauma.* 2010 Mar;68(3):629–32. doi: 10.1097/TA.0b013e3181a7c16d.

How to cite this article: Sharma A., Khan A., Gupta S., Agarwal D., Buddhist H. Reliability of the radiographic union scale for tibial fractures (RUST) in assessing fracture healing following intramedullary interlocking nailing: a prospective observational study. *Int J Health Sci Res.* 2026; 16(7):252–258. DOI: <https://doi.org/10.52403/ijhsr.20260726>
