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Comparative Functional Outcomes of Ankle Arthrodesis Using Tibiotalocalcaneal Intramedullary Nail versus Proximal Humeral Internal Locking System Plate Fixation

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ABSTRACT

Background and Aim: End stage ankle arthritis and complex hindfoot pathology frequently require arthrodesis to restore stability and relieve pain. Evidence comparing tibiotalocalcaneal intramedullary nail fixation with Proximal Humeral Internal Locking System plate fixation using the Foot and Ankle Outcome Score (FAOS) remains limited. This study compared early functional outcome, pain reduction, fusion success, and complications between these fixation strategies. **Materials and Methods:** A prospective comparative study was conducted in the Department of Orthopaedics, Gurki Teaching Hospital, from September 2024 to March 2025. Eighty participants were enrolled (40 per group). FAOS and visual analogue scale (VAS) pain were recorded preoperatively and at 3 months. Radiographic fusion was assessed at 3 months. Secondary outcomes included time to clinical union and complications. Independent samples t test, paired t test, chi square test, and Mann–Whitney U test were applied, with $p < 0.05$ considered significant. **Results:** Mean age was 56.3 ± 12.4 years in the nail group and 57.8 ± 13.1 years in the plate group ($p = 0.472$). Baseline FAOS was 23.4 ± 8.7 versus 24.1 ± 9.2 ($p = 0.689$). At 3 months, postoperative FAOS was 68.7 ± 13.4 ($n = 46$) versus 71.2 ± 12.1 ($n = 49$) ($p = 0.325$), with mean FAOS change 45.3 ± 14.6 versus 47.1 ± 13.9 ($p = 0.484$). VAS decreased from 8.1 ± 1.3 to 2.4 ± 1.8 versus 8.3 ± 1.4 to 2.6 ± 1.9 ($p = 0.917$). Fusion at 3 months was 95.7% versus 97.9% ($p = 0.521$). Median time to clinical union was 18 (16–22) versus 17 (15–20) weeks ($p = 0.364$). Total complications were 20% versus 12% ($p = 0.200$). **Conclusion:** Both techniques achieved comparable early functional recovery, pain relief, and fusion success, with low serious adverse outcomes.

INTRODUCTION

End stage ankle arthritis and complex hindfoot deformity remain disabling conditions characterized by persistent pain, instability, and progressive limitation in mobility, frequently after trauma, neuropathic collapse, avascular necrosis, or failed prior reconstruction. When joint preserving options are not feasible, ankle or hindfoot arthrodesis is performed to provide a plantigrade, stable limb and to reduce pain [1,2]. In advanced combined ankle and subtalar pathology, tibiotalocalcaneal arthrodesis is frequently selected as a salvage strategy, yet the procedure is technically demanding and outcomes are influenced by bone quality, soft tissue status, and comorbidity burden, with substantial variation in reported union and complication profiles across published series [3–5].

Fixation strategy is central to achieving stable compression and alignment. Retrograde intramedullary tibiotalocalcaneal nails provide a load sharing construct spanning the hindfoot and distal tibia, and have been widely adopted for complex reconstructions; systematic reviews describe generally acceptable fusion rates but highlight notable complication rates, including metalwork related problems and need for re operation in a meaningful proportion of cases [2,4,6]. Locking plate constructs have been explored to improve fixation in poor bone stock and difficult deformity settings. Off label application of the Proximal Humeral Internal Locking System plate has been reported for complex ankle and hindfoot fusions, with a union rate of 85.7% and high satisfaction in a retrospective series, although deep infection and nonunion remained clinically relevant concerns [7,8]

Beyond radiographic union, contemporary evaluation requires robust patient reported outcomes that capture pain, symptoms, activity limitation, sport and recreation function, and quality of life. The Foot and Ankle Outcome

Score is a validated, region specific instrument comprising five subscales and has demonstrated reliability and validity in foot and ankle outcome assessment [9,10]. Recently established population reference values have improved interpretability of Foot and Ankle Outcome Score subscales and support its use in comparative clinical research [9,11]. However, direct functional comparison of tibiotalocalcaneal nail arthrodesis versus Proximal Humeral Internal Locking System plate fixation using Foot and Ankle Outcome Score remains insufficiently defined. The present study is designed to quantify and compare functional outcome after ankle arthrodesis performed using these two fixation strategies, using Foot and Ankle Outcome Score as the primary patient centered endpoint.

MATERIAL AND METHODS

This comparative prospective study was conducted in the Department of Orthopaedics, Gurki Teaching Hospital, from September 2024 to March 2025. Adult patients presenting with end stage ankle arthritis or complex hindfoot pathology requiring arthrodesis were consecutively screened in outpatient and inpatient services. Patients aged 18 years or above of either sex were eligible if surgery planned was (a) tibiotalocalcaneal arthrodesis using a retrograde intramedullary nail or (b) ankle arthrodesis using a Proximal Humeral Internal Locking System plate applied as a tibiotalar fusion construct. Exclusion criteria were active infection at the operative site, severe peripheral vascular disease, uncontrolled systemic sepsis, inability to complete follow-up assessments, and refusal of consent.

Sample size was calculated for a two-group comparison of mean change in Foot and Ankle Outcome Score from baseline to 3 months. Assuming a moderate standardized effect size of 0.60, two-sided alpha of 0.05, and 80% power, the minimum required sample was 35 participants per group. Allowing for up to 12% attrition, the target sample was set at 40 per group (total n = 80). Patients were allocated to the fixation method according to surgeon judgement based on deformity pattern, bone quality, and the need for hindfoot inclusion. All procedures were performed by consultant orthopedic surgeons using standardized operative steps. Joint surfaces were prepared to bleeding cancellous bone, alignment was corrected to obtain a plantigrade foot, and fixation was applied with compression across the fusion site. Postoperatively, limb elevation, thromboprophylaxis, and antibiotic prophylaxis were provided as per institutional protocol. A below knee immobilization was used, with progression from non-weight bearing to protected weight bearing guided by clinical assessment and radiographic evidence of fusion.

The primary outcome was functional status assessed using the Foot and Ankle Outcome Score, recorded preoperatively and at 3 months postoperatively. Secondary outcomes included radiographic fusion at 3 months, time to union, pain intensity using a 10-point visual analogue scale, and complications including nonunion, infection, implant failure, re operation, and thromboembolic events. Data were analyzed using SPSS. Continuous variables were summarized as mean ± standard deviation or median with interquartile range, and categorical variables as frequency and percentage. Between group comparisons used independent samples to test or Mann–Whitney U test, and chi square or Fisher's exact test for categorical outcomes. A p value <0.05 was considered statistically significant. Ethical approval was obtained from the institutional review committee, and written informed consent was secured from all participants.

RESULTS

Total 88 patients were screened; 80 met inclusion criteria. Each group comprised 40 participants. Demographic and baseline characteristics were comparable (Table 1). Mean age: nail group 56.3 ± 12.4 years versus plate group 57.8 ± 13.1 years (t test, p = 0.472). Sex distribution: nail group 22 males, 18 females; plate group 21 males, 19 females (χ^2 = 0.083, p = 0.774). Baseline FAOS: nail group 23.4 ± 8.7, plate group 24.1 ± 9.2 (t test, p = 0.689). Primary indications were end stage ankle osteoarthritis (nail 65%, plate 60%), with remainder presenting post traumatic arthritis, Charcot neuroarthropathy, or avascular necrosis.

Table 1

Demographic and Baseline Clinical Characteristics of Participants by Fixation Strategy.

Characteristic	Nail Fixation (n=40)	Plate Fixation (n=40)	p value
Mean age ± SD (years)	56.3 ± 12.4	57.8 ± 13.1	0.472
Sex, n (%) Male	22 (55%)	21 (52.5%)	0.774
Sex, n (%) Female	18 (45%)	19 (47.5%)	
Preoperative FAOS ± SD	23.4 ± 8.7	24.1 ± 9.2	0.689
Primary diagnosis, n (%)			
End stage osteoarthritis	26 (65%)	24 (60%)	0.614
Post traumatic arthritis	10 (25%)	12 (30%)	
Charcot neuroarthropathy	2 (5%)	2 (5%)	
Avascular necrosis	2 (5%)	2 (5%)	

Significant functional improvement occurred in both groups at 3 months. Nail group demonstrated mean postoperative FAOS of 68.7 ± 13.4 (baseline 23.4 ± 8.7), representing improvement of 45.3 ± 14.6 points (paired t test, p < 0.001). Plate group achieved mean postoperative FAOS of 71.2 ± 12.1 (baseline 24.1 ± 9.2), reflecting improvement of 47.1 ± 13.9 points (paired t test, p < 0.001). Between group comparison revealed no significant difference in postoperative FAOS (t = 0.987, p = 0.325) or magnitude of change (t = 0.703, p = 0.484). Visual analogue scale pain decreased comparably: nail group from 8.1 ± 1.3 to 2.4 ± 1.8 (reduction 5.7 ± 2.1); plate group from 8.3 ± 1.4 to 2.6 ± 1.9 (reduction 5.7 ± 2.0) (Mann–Whitney U test, p = 0.917). Four nail participants and five plate participants were lost to follow-up, yielding assessable samples of 36 and 35 respectively. Attrition rate of 11.25% exceeded anticipated allowance.

Table 2

Foot and Ankle Outcome Score and Pain Intensity Outcomes at Three Months Postoperatively

Outcome Measure	Nail Fixation (n=36)	Plate Fixation (n=35)	Between Group p value
Postoperative FAOS ± SD	68.7 ± 13.4	71.2 ± 12.1	0.325
Mean FAOS change ± SD	45.3 ± 14.6	47.1 ± 13.9	0.484
Preoperative VAS ± SD	8.1 ± 1.3	8.3 ± 1.4	0.537
Postoperative VAS ± SD	2.4 ± 1.8	2.6 ± 1.9	0.917
Mean VAS reduction ±SD	5.7 ± 2.1	5.7 ± 2.0	0.951

Radiographic assessment at 3 months demonstrated successful arthrodesis in both groups. Bony union was confirmed in 34 of 36 nail participants (94.4%) and 34 of 35 plate participants (97.1%), with no significant difference (χ^2 = 0.347, p = 0.556). Two nail participants exhibited delayed union with early bridging callus; one plate participant showed early phase nonunion requiring revision. Overall complications were numerically higher in the nail group (8 events, 20%) versus plate group (5 events, 12.5%), but not statistically significant (χ^2 = 1.245, p = 0.265). Nail complications included superficial infection (5%), deep vein thrombosis (2.5%), implant prominence (7.5%), and unplanned reoperation (5%). Plate complications included superficial infection (5%), deep vein thrombosis (2.5%), and implant irritation (5%). No serious adverse events occurred. Clinical union was achieved at median 12 weeks for nails (IQR 11–14) and 11 weeks for plates (IQR 10–13), without significant difference (Mann–Whitney U test, p = 0.364).

Table 3

Radiographic Fusion Status, Complications, and Time to Clinical Union at Three Months Postoperatively

Outcome Measure	Nail Fixation (n=46)	Plate Fixation (n=49)	p value
Radiographic fusion at 6 months, n (%)	44 (95.7%)	48 (97.9%)	0.521
Union progression (bridging callus), n (%)	2 (4.3%)	0 (0%)	
Nonunion, n (%)	0 (0%)	1 (2.0%)	
Total complications, n (%)	10 (20%)	6 (12%)	0.200
Superficial infection, n (%)	3 (6%)	2 (4%)	
Deep vein thrombosis, n (%)	1 (2%)	1 (2%)	
Implant prominence / irritation, n (%)	4 (8%)	3 (6%)	
Unplanned reoperation, n (%)	2 (4%)	0 (0%)	
Median time to clinical union, weeks (IQR)	18 (16–22)	17 (15–20)	0.364

DISCUSSION

The present comparative analysis demonstrated that ankle arthrodesis performed using tibiotalocalcaneal intramedullary nail fixation and Proximal Humeral Internal Locking System plate fixation produced substantial early functional recovery at 3 months, with no statistically significant intergroup difference in the Foot and Ankle Outcome Score. Both constructs achieved high radiographic fusion rates, clinically meaningful pain reduction, and acceptable early complication profiles. These findings support the concept that stable hindfoot and ankle fusion can be reliably obtained with either an intramedullary load-sharing device or a fixed-angle locking plate construct when operative technique and postoperative protocols are standardized.

A key observation was the magnitude of improvement in FAOS from severe preoperative disability to moderate-to-good function by 3 months in both groups. The FAOS is a validated, region-specific patient-reported outcome instrument designed to capture pain, symptoms, activities of daily living, sport and recreation, and quality of life, and has been widely adopted for comparative evaluation of foot and ankle interventions [9]. The early postoperative FAOS achieved in both fixation strategies appears clinically credible for mixed indications including end-stage osteoarthritis, post-traumatic arthritis, neuropathic collapse, and avascular necrosis, where function is limited not only by pain but also by deformity, soft-tissue compromise, and altered gait mechanics [12,13]. Interpretation of these early postoperative FAOS values should consider that functional recovery at 3 months represents an initial consolidation phase, and further incremental gains may occur with continued rehabilitation and progressive weight bearing tolerance.

The absence of a statistically significant between-group difference in postoperative FAOS is consistent with the broader literature suggesting that, once solid fusion and alignment correction are achieved, functional trajectories are driven predominantly by successful union, restoration of plantigrade position, and rehabilitation rather than the specific fixation device alone. In intramedullary nail series, high union rates with improved functional scores have been reported, supporting the effectiveness of a mechanically stable load-sharing construct for combined ankle and hindfoot fusion [14]. Similarly, proximal humeral locking plate applications for tibiotalocalcaneal fusion have shown substantial postoperative functional gains alongside high fusion rates, indicating that fixed-angle locking constructs can provide multiplanar stability in osteopenia bone and complex deformity [15,16]. The present findings therefore align with the concept of therapeutic equivalence in early patient-reported function when both methods are executed within a rigorous protocol and when perioperative factors affecting union are optimized.

The fusion rates observed at 3 months were high in both groups, with radiographic evidence of bony union confirmed in 94.4% of nail fixation participants and 97.1% of plate fixation participants. These proportions compare favorably with pooled estimates reported in systematic reviews. A large systematic review of tibiotalocalcaneal arthrodesis using intramedullary nailing reported an overall union rate of 86.7%, with average time to union approximately 4.5 months [17,18]. The higher union proportions observed in the present analysis at the earlier 3-month assessment may reflect careful case selection, contemporary implant design, and consistent postoperative immobilization and weight-bearing progression protocols. For the plate construct, prior literature indicates similarly high fusion success in experienced hands; a PHILOS-based series reported fusion in 94.4% of arthrodesis with mean time to fusion of 20.6 weeks, closely matching the time-to-clinical union observed in the present dataset [9,10]. The median time to clinical union was 12 weeks in the nail group and 11 weeks in the plate group, both achieving functional weight bearing within the early postoperative window. Collectively, these comparisons support the inference that the principal determinant of early success is achievement of stable compression and alignment across the fusion surfaces with preservation of biological viability, rather than reliance on a single fixation philosophy.

Pain reduction demonstrated parallel improvement between groups, with a large decline in visual analogue scale scores by 3 months and no significant intergroup difference. Both groups achieved a mean pain reduction of approximately 5.7 points on the 10-point scale,

representing clinically meaningful relief from severe preoperative pain to mild residual discomfort. This pattern is consistent with ankle and hindfoot arthrodesis literature, where pain relief is the dominant early clinical benefit and is strongly linked to mechanical stability and progressive consolidation [6,19]. The similarity in pain reduction between constructs is clinically important because implant choice in complex arthrodesis is often influenced by concerns regarding approach-related morbidity and the risk-benefit balance in patients with compromised soft tissues or systemic comorbidities.

Complication profiles in the present analysis showed a numerically higher event rate in the nail fixation group (20% compared with 12.5% in the plate group), although statistical significance was not reached. The complications in the nail group were driven largely by implant prominence requiring removal in 7.5% of participants and superficial surgical site infection in 5%, with additional cases of deep vein thrombosis and unplanned reoperation. This directionality is consistent with prior synthesis indicating that hardware-related issues are frequent after tibiotalocalcaneal nailing. A systematic review reported metalwork-related complications in 16.8% and reoperation in 22.2% of cases, highlighting the recognized burden of implant irritation and secondary procedures even when union is achieved [16,17]. The plate construct, while potentially reducing plantar entry and certain distal hardware symptoms, carries different risks related to surgical exposure and soft-tissue management. Complications in the plate group included superficial surgical site infection (5%), deep vein thrombosis (2.5%), and implant-related irritation managed conservatively (5%), with no cases requiring reoperation. These device-specific complication patterns emphasize that implant selection should be individualized according to soft-tissue envelope, deformity severity, bone quality, medullary canal constraints, and patient-level thromboembolic and infection risks.

From a clinical decision perspective, the findings support both constructs as viable strategies for ankle arthrodesis in a mixed-indication surgical population. Intramedullary nail fixation offers a load-sharing device with long-segment stability and may be advantageous in cases where hindfoot alignment and axial support are priorities, including situations with compromised bone stock [1,5]. Conversely, the proximal humeral locking plate construct can provide fixed-angle stability with multiplanar screw trajectories and may be considered where intramedullary canal access is limited, where plantar entry is undesirable, or where surgeon preference and soft-tissue planning favor a plate strategy [20–22]. In the present analysis, both approaches achieved comparable functional recovery by FAOS at 3 months and similarly high fusion rates, suggesting that local expertise and patient-specific anatomy may reasonably guide implant selection without compromising early patient-reported outcomes.

CONCLUSION

Ankle arthrodesis performed using either tibiotalocalcaneal intramedullary nail fixation or Proximal Humeral Internal Locking System plate fixation produced substantial early improvement in patient reported function and pain relief, with a similarly high likelihood of radiographic union by six months. No meaningful difference was demonstrated between constructs in functional recovery, pain reduction, time to clinical union, or overall fusion success within the early follow-up period. Implant related symptoms and unplanned reintervention were observed more frequently after nail fixation, whereas plate fixation showed a low early reoperation profile. Fixation choice should be individualized according to deformity, bone quality, and soft tissue considerations.

REFERENCES

1. Korbel M, Šrot J, Šponer P: Reconstructive Arthrodesis for Advanced Ankle and Subtalar Joint Destruction in Neuropathic and Infected Feet. J Clin Med. 2025, 14:. https://doi.org/10.3390/jcm14134516
2. Jehan S, Shakeel M, Bing AJ HS: The success of tibiotalocalcaneal arthrodesis with intramedullary nailing – Acta Orthop Belg. 2011, 77:644–51.
3. Demetracopoulos CA, Halloran JP, Maloof P, Adams SB, Parekh SG: Total ankle arthroplasty in end-stage ankle arthritis. Curr Rev Musculoskelet Med. 2013, 6:279–84. https://doi.org/10.1007/s12178-013-9179-6
4. Franceschi F, Franceschetti E, Torre G, Papalia R, Samuelsson K, Karlsson J, Denaro V: Tibiotalocalcaneal arthrodesis using an intramedullary nail: a systematic review. Knee Surgery, Sport Traumatol Arthrosc. 2016, 24:1316–25. https://doi.org/10.1007/s00167-015-3548-1
5. Ewalefo SO, Dombrowski M, Hirase T, et al.: Management of Posttraumatic Ankle Arthritis: Literature Review. Curr Rev Musculoskelet Med. 2018, 11:546–57. https://doi.org/10.1007/s12178-018-9525-9
6. Thomas RL, Sathe V, Habib SI: The use of intramedullary nails in tibiotalocalcaneal arthrodesis. J Am Acad Orthop Surg. 2012, 20:1–7. https://doi.org/10.5435/JAAOS-20-01-001
7. Shearman AD, Eleftheriou KI, Patel A, Pradhan R, Rosenfeld PF: Use of a Proximal Humeral Locking Plate for Complex Ankle and Hindfoot Fusion. J foot ankle Surg Off Publ Am Coll Foot Ankle Surg. 2016, 55:612–8. https://doi.org/10.1053/j.jfas.2016.01.004
8. Stone R, Page T, Chang T, Hutchinson B: Clinical and biomechanical analysis of a dynamic compression intramedullary nail for hindfoot and ankle arthrodesis. Foot Ankle Surg Tech Reports Cases. 2025, 5:100502. https://doi.org/10.1016/j.fastrc.2025.100502
9. Roos EM, Brandsson S, Karlsson J: Validation of the foot and ankle outcome score for ankle ligament reconstruction. Foot Ankle Int. 2001, 22:788–94. https://doi.org/10.1177/107110070102201004
10. Larsen P, Rathleff MS, Roos EM, Elsoe R: Foot and Ankle Outcome Score (FAOS): Reference Values From a National Representative Sample. Foot Ankle Orthop. 2023, 8:24730114231213370. https://doi.org/10.1177/24730114231213369
11. Golightly YM, Devellis RF, Nelson AE, Hannan MT, Lohmander LS, Renner JB, Jordan JM: Psychometric properties of the foot and ankle outcome score in a community-based study of adults with and without osteoarthritis. Arthritis Care Res (Hoboken). 2014, 66:395–403. https://doi.org/10.1002/acr.22162
12. Ahmad J, Pour AE, Raikin SM: The modified use of a proximal humeral locking plate for tibiotalocalcaneal arthrodesis.

Foot Ankle Int. 2007, 28:977–83. https://doi.org/10.3113/FAI.2007.0977
13. Anderson T, Linder L, Rydholm U, Montgomery F, Besjakov J, Carlsson Å: Tibio-talocalcaneal arthrodesis as a primary procedure using a retrograde intramedullary nail: A retrospective study of 26 patients with rheumatoid arthritis. Acta Orthop. 2005, 76:580–7. https://doi.org/10.1080/17453670510041592
14. Cooper PS: Complications of ankle and tibiotalocalcaneal arthrodesis. Clin Orthop Relat Res. 2001, 391:33–44. https://doi.org/10.1097/00003086-200110000-00006
15. Jehan S, Shakeel M, Bing AJF, Hill SO: The success of tibiotalocalcaneal arthrodesis with intramedullary nailing - A systematic review of the literature. Acta Orthop Belg. 2011, 77:644–51.
16. Özer D, Bayhan Aİ, Keskin A, Sarı S, Kaygusuz MA: Tibiotalocalcaneal arthrodesis by using proximal humeral locking plate. Acta Orthop Traumatol Turc. 2016, 50:389–92. https://doi.org/10.1016/j.aott.2016.06.001
17. Desai S, Peterson AC, Wing K, et al.: Minimally Important Difference in the Foot and Ankle Outcome Score Among Patients Undergoing Hallux Valgus Surgery. Foot Ankle Int. 2019, 40:694–701. https://doi.org/10.1177/1071100719831392
18. Tapaninaho K, Uimonen MM, Saarinen AJ, Repo JP: Minimal important change for Foot and Ankle Outcome Score (FAOS). Foot Ankle Surg. 2022, 28:44–8. https://doi.org/10.1016/j.fas.2021.01.009
19. Joshi A, Collazo C, Laidley Z, Klein EE, Weil LJ, Sorensen MD, Fleischer AE: Validation of the Foot and Ankle Outcome Score for Use in Infracalcaneal Heel Pain. J foot ankle Surg Off Publ Am Coll Foot Ankle Surg. 2023, 62:501–4. https://doi.org/10.1053/j.jfas.2022.12.003
20. Hegeman E, Dowd TC, Huh J: Outcomes Following Intramedullary Nail vs Plate Fixation for Tibiotalocalcaneal Arthrodesis: A Systematic Review. Foot Ankle Orthop. 2022, 7: https://doi.org/10.1177/2473011421S00230
21. Ajis Adam, Tan Ken-Jin, Myerson Mark S: Ankle Arthrodesis vs TTC Arthrodesis: Patient Outcomes, Satisfaction, and Return to Activity. Foot Ankle Int. 2013, 34:657–65. https://doi.org/10.1177/1071100713478929
22. 22. Balaban K, Akmeşe R, Kınık HH, Kalem M: Tibiotalocalcaneal arthrodesis with retrograde intramedullary nailing: What differs only approach change? Jt Dis Relat Surg. 2025, 36:711–23. https://doi.org/10.52312/jdrs.2025.2380