

Clinical, Functional, and Radiological Outcomes Following Tibiototalcalcaneal Fusion with a Retrograde Intramedullary Nail

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Abstract

Background: Tibiototalcalcaneal (TTC) arthrodesis is an established salvage procedure for patients with end-stage ankle and hindfoot arthritis. Retrograde intramedullary nailing provides stable fixation, promotes fusion, and facilitates early weight bearing.

Methods: This prospective study included 31 patients with end-stage ankle and hindfoot arthritis who underwent TTC arthrodesis using a retrograde intramedullary nail between 2020 and 2022. Patients were evaluated clinically and radiologically using serial ankle radiographs and the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score. Time to fusion, time to full weight bearing, functional outcome, and postoperative complications were assessed during a 12-month follow-up.

Results: The mean age of the study population was 38.58 ± 14.61 years, with males accounting for 80.6% of patients. The mean AOFAS score improved significantly from 24.87 ± 4.75 preoperatively to 79.00 ± 12.91 at 12 months ($p < 0.001$). The mean time to fusion was 14.48 ± 3.36 weeks, and 51.6% of patients achieved full weight bearing by 3 months. Good-to-excellent functional outcomes were observed in 71.0% of patients. Infection occurred in 9.7% of patients, while non-union was observed in 3.2%.

Conclusion: TTC arthrodesis using a retrograde intramedullary nail is a reliable and effective salvage procedure, providing satisfactory fusion, significant functional improvement, early restoration of weight bearing, and a low complication rate in patients with advanced ankle and hindfoot arthritis.

Keywords: Tibiototalcalcaneal Arthrodesis; Retrograde Intramedullary Nail; Ankle Arthrodesis; Hindfoot Fusion; AOFAS Score; End-Stage Ankle Arthritis; Functional Outcome.

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Introduction

Tibiototalcalcaneal (TTC) arthrodesis is a well-established salvage procedure for the treatment of complex ankle and hindfoot disorders in patients with end-stage disease who have failed conservative management or joint-preserving surgery [1]. The procedure fuses the tibiotalar and subtalar joints to create a painless, stable, and plantigrade foot, thereby correcting deformity, restoring alignment, and improving functional mobility. Common indications include post-traumatic arthritis, primary osteoarthritis, rheumatoid arthritis, Charcot neuroarthropathy, avascular necrosis of the talus, failed ankle arthroplasty or ankle fusion, severe hindfoot deformity, and complex fractures not suitable for reconstruction. Although ankle motion is sacrificed, successful fusion provides substantial

pain relief and restores independent ambulation and weight-bearing ability [2,3]. The ankle is a hinge-type synovial joint formed by the distal tibia, fibula, and talus. Its stability depends on the congruent articulation of the talus within the ankle mortise and the surrounding ligamentous structures. Fusion of the ankle in a neutral position produces minimal biomechanical compromise because compensatory motion occurs at adjacent joints, allowing preservation of overall gait mechanics. Furthermore, the extensive cancellous bone surfaces of the tibia and talus facilitate successful osseous union following arthrodesis [4–6]. Ankle arthrodesis remains the gold-standard surgical treatment for end-stage ankle arthritis. Several fixation techniques have been described, including crossed cancellous screws, plates, external fixation,

and intramedullary devices. Conventional fixation methods may be associated with prolonged immobilization, limited biomechanical stability, wound complications, hardware failure, and delayed or non-union, particularly in patients with poor bone quality or severe deformity. Retrograde intramedullary (IM) nailing has emerged as a preferred technique because it provides rigid internal fixation, superior axial compression, enhanced rotational stability, and load-sharing characteristics while minimizing soft-tissue disruption and allowing earlier weight-bearing [7–10]. The concept of TTC arthrodesis using an intramedullary device was first introduced by Lexer in 1906 using boiled cadaveric bone, and Adams later reported the first successful metallic intramedullary nail fixation in 1948 [11].

Advances in implant design and surgical techniques have since established retrograde IM nailing as a reliable method for TTC fusion. Contemporary studies have reported union rates exceeding 80–90%, along with significant improvements in pain relief, functional outcomes, and patient satisfaction. However, complications such as delayed union, non-union, infection, implant failure, malalignment, and revision surgery continue to occur, particularly in patients with diabetes, peripheral neuropathy, smoking history, obesity, or poor bone quality [12–15]. Outcome assessment following TTC arthrodesis requires evaluation of clinical, functional, and radiological parameters. Functional recovery is commonly measured using the American Orthopaedic Foot and Ankle Society (AOFAS) score and the Visual Analogue Scale (VAS), whereas radiological assessment confirms fusion, maintenance of alignment, implant integrity, and complications such as non-union or hardware failure [1,12–14]. Despite favourable outcomes reported internationally, variability persists regarding fusion rates, rehabilitation protocols, complications, and long-term functional outcomes following TTC arthrodesis using retrograde IM nails [8,12–15]. Moreover, prospective evidence from the Indian population remains limited. Therefore, the present study was undertaken to evaluate the functional and radiological outcomes of TTC arthrodesis using a retrograde intramedullary nail, with emphasis on pain relief, functional recovery, and radiological union, time to weight-bearing, and procedure-related complications.

Materials and Methods

The present prospective observational study was conducted in the Department of Orthopaedics and Traumatology, at tertiary care centre. A total of 31 patients presenting with arthritic changes of the ankle joint were enrolled prospectively.

All patients who fulfilled the predefined inclusion and exclusion criteria were screened and included after providing written informed consent for participation and willingness to undergo the required investigations and surgical management.

Preoperative Evaluation: A standardized preoperative assessment was performed for all patients. This included detailed history taking, comprehensive clinical examination, and routine laboratory investigations. Radiological evaluation consisted of standard weight-bearing anteroposterior (AP) and lateral radiographs of the affected ankle to assess the severity of arthritic changes, deformity, and joint involvement. Baseline demographic and clinical characteristics were recorded for all participants.

Surgical Procedure: All patients underwent tibiototalcanal arthrodesis through a posterolateral approach. Joint surfaces were adequately prepared to achieve fusion, and fixation was performed using a retrograde intramedullary nail. The operative technique was standardized as far as possible for all patients.

Postoperative Assessment and Follow-up: Postoperative evaluation included clinical examination and radiographic assessment using anteroposterior and lateral radiographs of the ankle to assess implant position, alignment, and progression of fusion. Functional outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score during follow-up. Radiological union, complications, and functional recovery were documented throughout the study period.

Inclusion Criteria

The study included patients with any of the following conditions:

- Post-traumatic ankle arthritis.
- Avascular necrosis (AVN) of the talus.
- Post-infective sequelae involving the ankle joint.
- Rheumatoid arthritis affecting the ankle.
- Charcot arthropathy.

Exclusion Criteria

Patients were excluded if they had:

- Peripheral vascular disease.
- Uncontrolled diabetes mellitus.
- Skeletally immature patients (children).

Outcome Measures: The primary outcome measure was functional outcome as assessed by the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score. Secondary outcome measures included radiological evidence of fusion, time to union, postoperative

complications, and restoration of weight-bearing ability.

Results

A total of 31 patients with end-stage ankle and hindfoot arthritis underwent tibiototalcalcaneal arthrodesis using a retrograde intramedullary nail and were included in the final analysis. The mean age of the study participants was 38.58 ± 14.61 years. The majority of patients (45.2%) belonged to the 31–45 years age group. Males constituted 80.6% ($n = 25$) of the study population, while females accounted for 19.4% ($n = 6$). The left side was involved slightly more frequently (54.8%) than the right side (45.2%) (Table 1). The most common diagnosis was tibiotalar arthritis of the right ankle (25.8%), followed by tibiotalar arthritis of the left ankle (19.4%) and chronic left ankle arthritis (19.4%). Other diagnoses included chronic right ankle arthritis, left ankle arthritis, right ankle arthritis, and left Charcot ankle (Table 2, Figure 1). Functional outcome improved progressively during follow-up. The mean AOFAS score increased significantly from 24.87 ± 4.75 preoperatively to 49.03 ± 7.49 at 3 months, 63.13 ± 11.06 at 6 months, and 79.00 ± 12.91 at 12 months.

Improvement was statistically significant at each follow-up interval (Table 3, Figure 2). Radiological fusion was achieved in the majority of patients by 12–16 weeks, with a mean fusion time of 14.48 ± 3.36 weeks. More than half of the patients (51.6%) achieved full weight bearing by 3 months. At final follow-up, 45.2% of patients had a good outcome and 25.8% had an excellent outcome, resulting in 71.0% achieving a good-to-excellent functional result (Table 4). Postoperative complications were uncommon. Infection occurred in 3 patients (9.7%), while 1 patient (3.2%) developed non-union. No complications were observed in 87.1% of patients. There was no statistically significant association between gender and postoperative complications ($p = 0.731$) (Table 5, Figure 3). Gender-wise comparison of functional outcomes showed similar improvement in both groups. The mean preoperative AOFAS score was 22.67 ± 3.44 in females and 25.40 ± 4.92 in males. At 3 months, the corresponding scores improved to 49.17 ± 8.64 and 49.00 ± 7.77 , respectively. Good-to-excellent outcomes were achieved in 66.7% of females and 72.0% of males, with no statistically significant difference in overall functional outcome between genders ($p = 0.742$) (Table 6).

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population (n = 31)

Variable	n (%) / Mean $\pm$ SD
Age group (years)	
15–30	10 (32.3)
31–45	14 (45.2)
46–60	4 (12.9)
>60	3 (9.7)
Mean age (years)	38.58 $\pm$ 14.61
Sex	
Male	25 (80.6)
Female	6 (19.4)
Side involved	
Left	17 (54.8)
Right	14 (45.2)

Table 2: Clinical Diagnosis and Operative Characteristics (n = 31)

Variable	n (%) / Mean $\pm$ SD
Diagnosis	
Tibiotalar arthritis (right ankle)	8 (25.8)
Tibiotalar arthritis (left ankle)	6 (19.4)
Chronic left ankle arthritis	6 (19.4)
Chronic right ankle arthritis	4 (12.9)
Left ankle arthritis	4 (12.9)
Right ankle arthritis	2 (6.5)
Left Charcot ankle	1 (3.2)

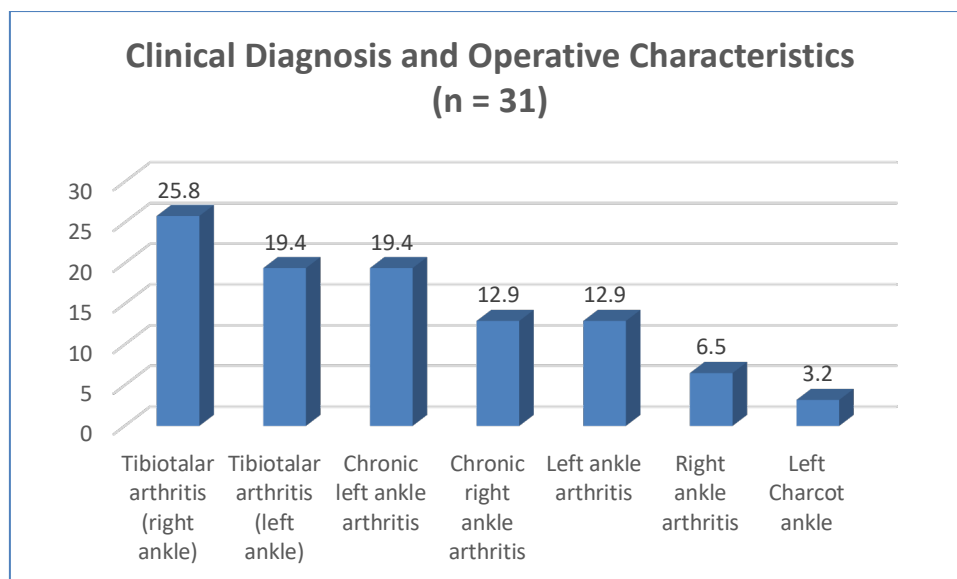


Figure 1: Clinical Diagnosis and Operative Characteristics (n = 31)

Table 3: Functional Outcome (AOFAS Score) During Follow-up

Follow-up	Mean $\pm$ SD	P value*
Preoperative	24.87 $\pm$ 4.75	—
3 months	49.03 $\pm$ 7.49	0.004
6 months	63.13 $\pm$ 11.06	<0.001
12 months	79.00 $\pm$ 12.91	<0.001

*Compared with the previous follow-up using paired t-test.

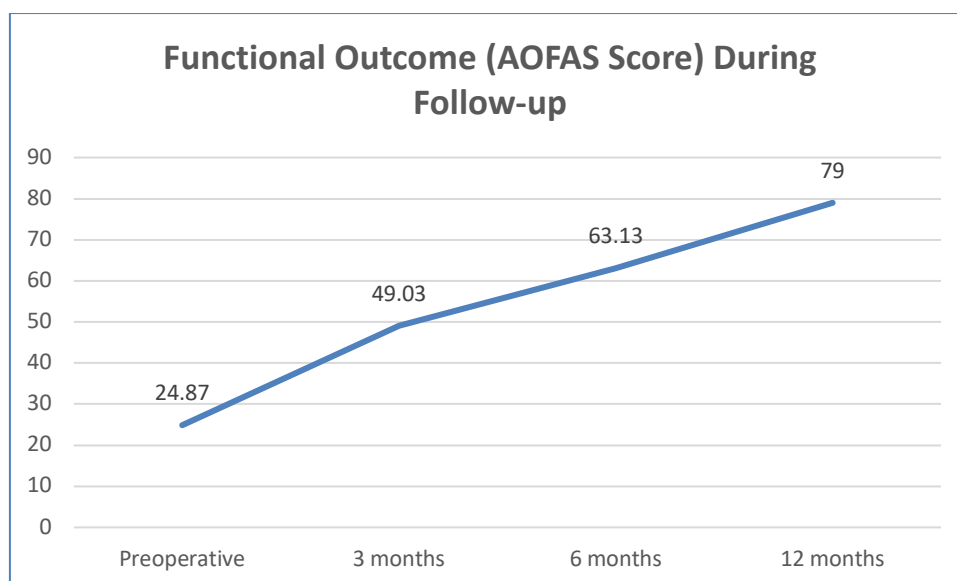


Figure 2: Functional Outcome (AOFAS Score) During Follow-up

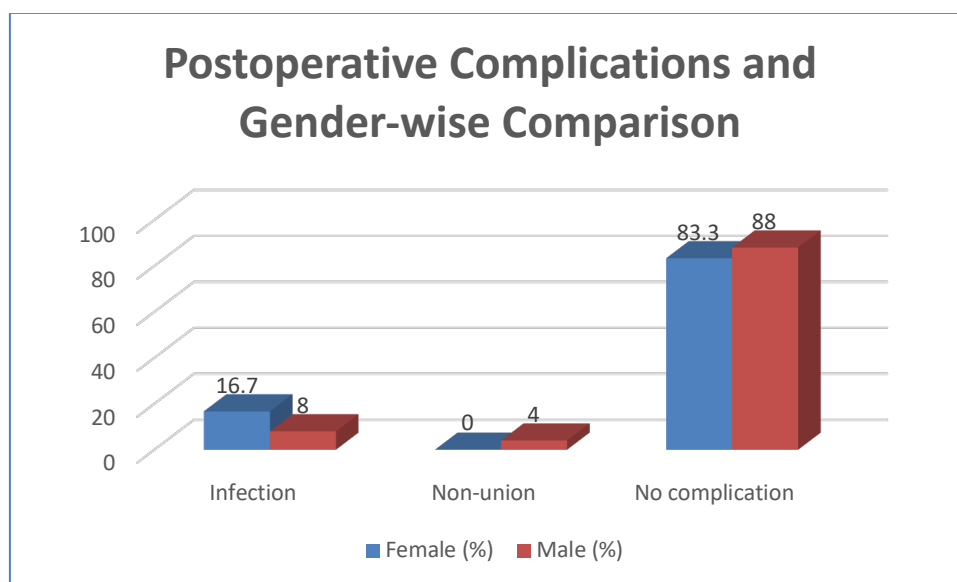
Table 4: Fusion, Weight-bearing and Functional Outcome (n = 31)

Variable	n (%) / Mean $\pm$ SD
Time to fusion	
12 weeks	12 (38.7)
14 weeks	7 (22.6)
16 weeks	8 (25.8)
24 weeks	1 (3.2)
26 weeks	1 (3.2)
Non-union	2 (6.5)
Mean fusion time (weeks)	14.48 $\pm$ 3.36

Time to full weight bearing	
2.5 months	8 (25.8)
3 months	16 (51.6)
4 months	4 (12.9)
5 months	3 (9.7)
Final functional outcome	
Excellent	8 (25.8)
Good	14 (45.2)
Fair	5 (16.1)
Poor	2 (6.5)
Failed	2 (6.5)

Table 5: Postoperative Complications and Gender-wise Comparison

Variable	Female (n = 6)	Male (n = 25)	P value
Infection	1 (16.7)	2 (8.0)	
Non-union	0 (0.0)	1 (4.0)	
No complication	5 (83.3)	22 (88.0)	0.731

**Figure 3: Postoperative Complications and Gender-wise Comparison****Table 6: Gender-wise Functional Outcomes**

Variable	Female (n = 6)	Male (n = 25)	P value
Preoperative AOFAS score	22.67 ± 3.44	25.40 ± 4.92	
3-month AOFAS score	49.17 ± 8.64	49.00 ± 7.77	<0.001*
Excellent/Good outcome	4 (66.7)	18 (72.0)	
Fair/Poor/Failed outcome	2 (33.3)	7 (28.0)	0.742

Discussion

The present prospective study evaluated the functional and radiological outcomes of tibiotalocalcaneal (TTC) arthrodesis using a retrograde intramedullary nail in 31 patients with end-stage ankle and hindfoot arthritis. The findings demonstrated significant functional improvement, a high fusion rate, early restoration of weight bearing, and a low complication rate, consistent with previous reports.

The mean age of patients was 38.58 ± 14.61 years, and 80.6% were males. The relatively younger age

of our cohort compared with Western studies may reflect the higher prevalence of post-traumatic ankle arthritis in the Indian population. Jehan et al.[8] reported a mean age of 51.3 years in patients undergoing TTC arthrodesis with retrograde intramedullary nails, with post-traumatic arthritis being the most common indication. In our study, tibiotalar arthritis of the right ankle (25.8%) was the most frequent diagnosis, followed by tibiotalar arthritis of the left ankle (19.4%) and chronic left ankle arthritis (19.4%). Similarly, Franceschi et al.[15] identified post-traumatic arthritis, Charcot neuroarthropathy, rheumatoid arthritis, avascular

necrosis of the talus, and failed ankle arthrodesis as the principal indications for TTC arthrodesis using retrograde intramedullary nails. A major finding was the marked improvement in functional outcome. The mean AOFAS score improved from 24.87 ± 4.75 preoperatively to 49.03 ± 7.49 at 3 months, 63.13 ± 11.06 at 6 months, and 79.00 ± 12.91 at 12 months ($p < 0.001$). Comparable improvements have been reported in the literature. Hegeman et al.[16], in a systematic review of 356 patients, demonstrated improvement in the mean AOFAS score from 34.3 ± 7.9 to 72.4 ± 9.0 after intramedullary nail fixation. Jehan et al.[8] also reported sustained functional improvement and an 85.2% patient satisfaction rate after long-term follow-up.

Radiological union was achieved in most patients, with a mean fusion time of 14.48 ± 3.36 weeks and a non-union rate of only 6.5%. Similar findings have been reported by other authors. A Brazilian series reported an 82% union rate with a mean fusion time of 16 weeks, while Hegeman et al.[16] found pooled tibiotalar and subtalar union rates of 84% and 90%, respectively. Franceschi et al.[15] further concluded that union rates exceeded 80% in most published studies, supporting the reliability of retrograde intramedullary nailing. Early weight bearing is a major advantage of intramedullary fixation. In the present study, 25.8% of patients achieved full weight bearing by 2.5 months and 51.6% by 3 months. Jehan et al.[8] similarly reported restoration of ambulatory ability in most patients following TTC arthrodesis.

Overall, 71.0% of patients achieved good-to-excellent functional outcomes, whereas only 12.9% had poor or failed results. Postoperative complications were infrequent, with infection occurring in 9.7% and non-union in 3.2%, while 87.1% had no complications. No significant association was observed between gender and complications ($p = 0.731$) or functional outcome ($p = 0.742$). Hegeman et al.[16] reported lower complication rates with intramedullary nails compared with plate fixation, whereas the Brazilian study reported higher rates of infection and pseudoarthrosis. The comparatively lower complication rate in our study may reflect careful patient selection, standardized surgical technique, and meticulous postoperative care.

Conclusion

Tibiototalcaneal arthrodesis using a retrograde intramedullary nail was an effective salvage procedure for patients with end-stage ankle and hindfoot arthritis. The procedure achieved satisfactory fusion rates, significant improvement in AOFAS functional scores, and enabled the majority of patients to attain full weight bearing within three months. Good-to-excellent functional

outcomes were observed in most patients, with a low incidence of complications. Overall, retrograde intramedullary nailing proved to be a reliable and effective technique for restoring a stable, painless, and plantigrade foot while improving functional mobility and quality of life.

Limitations

The present study had several limitations. It was conducted at a single center with a relatively small sample size, which may limit the generalizability of the findings. The follow-up period of 12 months was relatively short to assess long-term implant survival, adjacent joint degeneration, and functional outcomes. Additionally, the absence of a comparison group using alternative fixation techniques precluded direct evaluation of the superiority of retrograde intramedullary nailing.

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