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Triple Arthrodesis for Neglected Congenital Talipes Equinovarus: A Prospective Study of Functional Outcomes

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ABSTRACT

Background: Neglected congenital talipes equinovarus (CTEV) in adolescents and young adults is associated with rigid deformity, pain, gait abnormalities, difficulty with footwear, and significant functional impairment. Triple arthrodesis is a well-established salvage procedure aimed at achieving a stable, plantigrade, and painless foot. However, evidence regarding its functional and radiological outcomes in neglected CTEV remains limited, particularly in developing countries where delayed presentation is common.

Objective: To evaluate the functional and radiological outcomes of triple arthrodesis in patients with neglected congenital talipes equinovarus.

Methods: A prospective observational study was conducted in the Department of Orthopaedics of a tertiary care teaching hospital between April 2022 and October 2023. Sixteen patients with neglected or old CTEV underwent triple arthrodesis involving fusion of the talonavicular, subtalar, and calcaneocuboid joints. Clinical outcomes were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score and Visual Analog Scale (VAS) for pain. Radiological evaluation included measurement of the lateral calcaneal pitch angle (CPA), lateral talar–first metatarsal angle (T1stMTA), anteroposterior talar–first metatarsal angle, and talonavicular coverage angle (TNCA). Patients were followed for 5–6 months postoperatively.

Results: A total of 16 male patients with a mean age of 16.5 ± 1.71 years were included. The mean AOFAS hindfoot score improved significantly from 37.00 ± 4.32 preoperatively to 89.19 ± 2.17 at final follow-up ($p = 0.00001$). Mean VAS score decreased from 9.19 ± 0.65 to 0.50 ± 0.73 ($p = 0.00001$), indicating substantial pain relief. Radiological assessment demonstrated significant correction of deformity parameters. The mean calcaneal pitch angle improved from 8.00 ± 2.10° to 12.88 ± 1.86° ($p = 0.00001$), lateral talar–first metatarsal angle from 10.88 ± 3.50° to 4.06 ± 1.34° ($p = 0.00001$), anteroposterior talar–first metatarsal angle from 15.44 ± 4.18° to 2.88 ± 1.31° ($p = 0.00001$), and talonavicular coverage angle from 14.50 ± 7.28° to 1.19 ± 0.75° ($p = 0.00001$). At final follow-up, 81.2% of patients achieved excellent outcomes and 18.8% achieved good outcomes.

Conclusion: Triple arthrodesis is a reliable and effective salvage procedure for neglected congenital talipes equinovarus in adolescents and young adults. The procedure provides significant pain relief, substantial improvement in functional outcomes, and excellent radiological correction of deformity, resulting in a stable and plantigrade foot. Triple arthrodesis remains a valuable treatment option for rigid neglected clubfoot deformities.

Keywords*:* Triple arthrodesis; Congenital talipes equinovarus; Neglected clubfoot; AOFAS score; Visual Analog Scale; Hindfoot arthrodesis; Functional outcome; Radiological outcome.

INTRODUCTION

Triple arthrodesis is a versatile and well-established surgical procedure primarily utilized in the management of complex hindfoot pathologies and persistent gait disturbances. By definition, a "triple" arthrodesis involves the fusion of three distinct joints within the hindfoot: the subtalar joint, the talonavicular joint, and the calcaneocuboid joint. This procedure is frequently employed as a definitive surgical treatment for severe pedal deformities that have failed conservative management, aiming to provide patients with a stable, plantigrade, and pain-free foot during the propulsive phase of gait. Extensive literature supports the long-term efficacy of this procedure, with numerous studies reporting high patient satisfaction rates; one landmark study indicated that 95% of patients remained satisfied with the functional outcome even after a follow-up period of 44 years (1). Similarly, other longitudinal assessments have consistently demonstrated significant improvements in clinical and functional scores, such as those from the American Orthopaedic Foot and Ankle Society, following successful arthrodesis (2,3). Nevertheless, the procedure is not devoid of challenges, as the permanent loss of motion in the fused joints can potentially lead to increased stress on adjacent joints, sometimes making alternative, more conservative procedures a more prudent choice depending on the patient's specific presentation.

The standard, most commonly employed surgical approach to triple arthrodesis utilizes a dual-incision technique—typically one lateral and one medial incision—to provide optimal exposure of the three joints. During the lateral approach, the surgeon must carefully navigate various critical anatomical structures. The nerves frequently encountered include the sural nerve and the intermediate dorsal cutaneous nerve, which necessitate meticulous dissection to prevent iatrogenic injury. Vascular structures identified during the lateral dissection include the artery of the tarsal sinus and various venous connections supplying the extensor digitorum brevis. Furthermore, muscle and tendon structures such as the peroneal tendons, the extensor digitorum brevis muscle belly, and the peroneus tertius tendon must be retracted or managed to achieve adequate joint surface exposure (4,5). Conversely, the medial approach commonly involves the identification of the posterior tibial tendon near its distal insertion. Depending on the specific technique and exposure required, the surgeon may also encounter the deltoid artery, the artery of the tarsal canal, and the great saphenous vein along with its tributaries, requiring vigilant protection to minimize the risk of wound healing complications and neurovascular damage (4).

Given these anatomical considerations, there has been increasing interest and discussion regarding the use of a single medial incision approach for hindfoot arthrodesis, which sometimes includes the sparing of the calcaneocuboid joint (6,7). The primary advantages of this streamlined approach include the avoidance of lateral soft-tissue structures, a reduction in the risk of wound-related complications, decreased operative time, and overall reduced operating costs (7,8). However, this approach is not universally applicable and presents its own set of potential disadvantages, including increased dissection requirements that may inadvertently damage the vasculature supplying the talar body if not performed with precision (9). Consequently, the choice of surgical approach remains a critical decision that must be tailored to the patient’s underlying deformity, soft-tissue quality, and the surgeon’s experience (10).

Although triple arthrodesis is widely accepted as a reliable salvage procedure for rigid hindfoot deformities, literature regarding its effectiveness in neglected congenital talipes equinovarus remains somewhat limited, particularly in developing countries where delayed presentation is common (11). Neglected clubfoot frequently leads to severe, rigid deformity, chronic pain, significant gait abnormalities, difficulty with footwear, and progressive, debilitating degenerative changes in the hindfoot joints, all of which substantially diminish the patient's quality of life (12). In these challenging cases, triple arthrodesis has been strongly advocated as a salvage procedure capable of restoring a stable, plantigrade, and painless foot (11,12). Despite the potential for excellent functional restoration, surgeons must remain cognizant of, and actively manage, persistent concerns regarding postoperative complications, including non-union, residual deformity, persistent wound problems, and long-term adjacent joint degeneration (3,13). Given these considerations, rigorous clinical, functional, and radiological assessment remains essential to evaluate the true outcomes of triple arthrodesis in patients with neglected CTEV, to accurately assess the degree of deformity correction and pain relief achieved, and to comprehensively document the fusion rates and procedure-related complications throughout the postoperative follow-up period.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational analytical study was conducted in the Department of Orthopaedics at a tertiary care teaching hospital between April 2022 and October 2023. The study was designed to evaluate the functional and radiological outcomes of triple arthrodesis in patients with neglected or old congenital talipes equinovarus (CTEV).

Study Population and Sample Size

A consecutive non-probability sampling technique was employed. All eligible patients presenting during the study period and undergoing triple arthrodesis for neglected or old CTEV were included. A total of 16 patients were enrolled in the study. All participants were male, with eight right-sided and eight left-sided deformities.

Patients commonly presented with foot deformity, restricted ankle range of motion, and calf muscle weakness. One patient had an associated seizure disorder. The diagnosis of neglected or old CTEV was established based on clinical and radiological findings.

Inclusion Criteria
Patients diagnosed with neglected or old CTEV presenting with one or more of the following were included in the study:

- Persistent or residual clubfoot deformity causing pain and functional limitation.
- Progressive hindfoot deformity with adaptive changes in adjacent joints.
- Degenerative changes secondary to long-standing deformity.
- Gait abnormalities affecting daily activities.
- Patients deemed suitable candidates for triple arthrodesis.

Exclusion Criteria
Patients were excluded if they had:

- Active local or systemic infection.
- Acute Charcot arthropathy.
- Peripheral arterial insufficiency.
- Uncontrolled medical comorbidities.
- Significant ankle arthritis requiring additional surgical procedures.
- Inadequate trial of conservative management.
- Any condition precluding safe surgical intervention or follow-up.

Preoperative Assessment
All patients underwent a detailed clinical and radiological evaluation. Demographic details, clinical presentation, side involved, duration of symptoms, gait abnormalities, ankle range of motion, and associated comorbidities were documented. Standard weight-bearing radiographs of the foot and ankle were obtained to assess deformity, joint involvement, and surgical planning.

Surgical Technique
All patients underwent triple arthrodesis involving fusion of the following joints:

1. Talonavicular joint
2. Subtalar joint
3. Calcaneocuboid joint

Under general anesthesia, patients were positioned supine with a thigh tourniquet applied. A standard lateral approach was used to expose the subtalar and calcaneocuboid joints. Care was taken to protect the sural nerve and surrounding neurovascular structures. Fibrofatty tissue within the sinus tarsi was excised, and adequate exposure of the subtalar joint was achieved.

A separate medial incision was made to expose the talonavicular joint while preserving the posterior tibial tendon. Articular cartilage from all three joints was removed using curettes, osteotomes, burrs, or sagittal saws until healthy subchondral bone was exposed. When required, wedge resections and deformity corrections were performed to achieve a plantigrade foot.

Temporary fixation was achieved using Kirschner wires or Steinmann pins. Definitive fixation was performed using appropriate internal fixation devices. Typically, 6.5-mm cannulated screws were used for subtalar fixation, while 4.5-mm screws, plates, or staples were utilized for fixation of the talonavicular and calcaneocuboid joints as required. Intraoperative fluoroscopy was used to confirm correction, alignment, and implant positioning.

The final position aimed for a plantigrade foot with the heel in neutral to slight valgus and satisfactory correction of hindfoot alignment.

Intraoperative Management
A thigh tourniquet was used to achieve hemostasis during the procedure. Intraoperative fluoroscopic imaging was routinely utilized to assess joint preparation, deformity correction, implant placement, and overall alignment. Additional distraction devices were employed when necessary to facilitate adequate joint exposure and preparation.

Postoperative Management
Following wound irrigation and layered closure, patients were immobilized in a below-knee splint or cast. All patients were maintained non-weight-bearing during the initial postoperative period. Postoperative care included wound monitoring, pain management, infection surveillance, and physiotherapy guidance.

Physical therapy and rehabilitation were initiated according to individual patient requirements to facilitate safe mobilization and functional recovery. Patients requiring additional support were referred for appropriate rehabilitation services.

Follow-up and Outcome Assessment
Patients were followed up at 6 weeks, 12 weeks, and 5–6 months postoperatively. Clinical assessment included evaluation of pain, functional improvement, gait pattern, correction of deformity, ankle range of motion, and postoperative complications. Radiographic assessment was performed during follow-up visits to evaluate maintenance of correction, progression of fusion, and implant status.

Statistical Analysis
All clinical and radiological data were prospectively recorded using a predesigned study proforma and entered into a computerized database for analysis. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA), while graphical representations were prepared using Microsoft Excel 2021.

Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. The normality of data distribution was assessed using the Kolmogorov–Smirnov test.

Comparisons between preoperative and postoperative outcome measures were performed using the paired Student's t-test for normally distributed data. For non-normally distributed variables, the Wilcoxon signed-rank test was used. Associations between categorical variables were analyzed using the Chi-square (χ^2) test, where appropriate.

A two-tailed p-value < 0.05 was considered statistically significant. Results were presented in both tabular and graphical formats where appropriate.

Ethical Considerations
The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment and surgical intervention. Patient confidentiality was maintained throughout the study period.

RESULTS
A total of 16 patients (16 feet) with neglected congenital talipes equinovarus (CTEV) underwent triple arthrodesis during the study period. All patients completed the scheduled follow-up and were available for both clinical and radiological evaluation.

Demographic Characteristics
The mean age of the study population was 16.5 ± 1.71 years (range, 14–19 years). All participants were male. Eight patients (50%) underwent surgery on the right foot and eight (50%) on the left foot. The demographic characteristics of the study cohort are summarized in Table 1.

Table 1. Demographic characteristics of the study population

Variable	Value
Age (years), mean ± SD (range)	16.5 ± 1.71 (14–19)
Sex, n (%)	16 (100%) Male
Side involved, n (%)	Right: 8 (50%)
	Left: 8 (50%)

Clinical Outcomes
The mean preoperative American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score was 37.0 ± 4.32, which improved significantly to 89.19 ± 2.17 at final follow-up ($p = 0.00001$). This represented a substantial improvement in functional outcome following triple arthrodesis.

Similarly, pain assessment using the Visual Analog Scale (VAS) demonstrated a marked reduction in pain severity. The mean VAS score decreased from 9.19 ± 0.65 preoperatively to 0.50 ± 0.73 postoperatively ($p = 0.00001$), indicating significant pain relief after surgery.

Regarding patient satisfaction, 13 patients (81.2%) achieved excellent outcomes, while 3 patients (18.8%) achieved good outcomes at the final follow-up.

Radiological Outcomes
Radiographic evaluation revealed significant correction of all measured parameters following surgery (Table 2).
The mean lateral calcaneal pitch angle (CPA) increased from 8.0 ± 2.1° preoperatively to 12.88 ± 1.86° postoperatively, corresponding to a mean correction of 4.88° ($p = 0.00001$).

The mean lateral talar–first metatarsal angle (T1stMTA) improved from 10.88 ± 3.50° preoperatively to 4.06 ± 1.34° postoperatively, with a mean correction of 6.82° (p = 0.00001).

On the anteroposterior radiograph, the mean talar–first metatarsal angle improved from 15.44 ± 4.18° to 2.88 ± 1.31°, resulting in a mean correction of 12.56° (p = 0.00001).

Likewise, the talonavicular coverage angle (TNCA) improved significantly from 14.50 ± 7.28° preoperatively to 1.19 ± 0.75° postoperatively, corresponding to a mean correction of 13.31° (p = 0.00001).

Overall, triple arthrodesis resulted in significant improvements in both clinical and radiological parameters, demonstrating effective deformity correction, pain relief, and restoration of foot function.

Table 2. Comparison of preoperative and postoperative clinical and radiological outcomes

Variable	Preoperative (Mean ± SD)	Postoperative (Mean ± SD)	p-value
Clinical Outcomes			
American Orthopaedic Foot and Ankle Society (AOFAS) Score	37.00 ± 4.32	89.19 ± 2.17	0.00001
Visual Analog Scale (VAS) Score	9.19 ± 0.65	0.50 ± 0.73	0.00001
Radiological Outcomes			
Lateral Calcaneal Pitch Angle (CPA)	8.00 ± 2.10	12.88 ± 1.86	0.00001
Lateral Talar–First Metatarsal Angle (T1stMTA)	10.88 ± 3.50	4.06 ± 1.34	0.00001
AP Talar–First Metatarsal Angle (T1stMTA)	15.44 ± 4.18	2.88 ± 1.31	0.00001
AP Talonavicular Coverage Angle (TNCA)	14.50 ± 7.28	1.19 ± 0.75	0.00001

DISCUSSION

The management of neglected or old congenital talipes equinovarus in adolescents and young adults presents a formidable challenge due to the rigidity of the deformity and the presence of adaptive bony changes (11). Our study demonstrates that triple arthrodesis remains a highly effective salvage procedure for achieving a stable, plantigrade, and pain-free foot in this demographic. By fusing the subtalar, talonavicular, and calcaneocuboid joints, we achieved significant improvements across all clinical and radiological parameters evaluated.

Clinical Outcomes

The primary objective of surgical intervention in neglected CTEV is functional restoration and pain alleviation. In our cohort of 16 male patients (mean age 16.5 years), the mean American Orthopaedic Foot and Ankle Society hindfoot score improved dramatically from a preoperative 37.0 ± 4.32 to 89.19 ± 2.17 at the final follow-up (p = 0.00001). This finding is consistent with the results reported by Shivanna, where AOFAS scores in a similar neglected clubfoot cohort rose from 36 to 90 (12). Furthermore, Nogdallah et al. highlighted that while adults with CTEV are less flexible than children, extensive repair through triple arthrodesis can yield excellent functional outcomes, mirroring the 81.2% "excellent" satisfaction rate observed in our study (11).

The marked reduction in pain severity is perhaps the most significant benefit for the patient. The mean Visual Analog Scale score in our study decreased from 9.19 ± 0.65 preoperatively to 0.50 ± 0.73 postoperatively (p = 0.00001). This profound reduction in pain, combined with the stabilization of the hindfoot, allows for improved gait patterns and easier shoe wear, which are critical quality-of-life factors in low-resource settings where early intervention is often unavailable (10).

Radiological Correction and Alignment

Radiological parameters provide an objective measure of the structural realignment achieved through joint resection and fixation. Our results showed significant improvements in the lateral Calcaneal Pitch Angle, which increased from 8.0 ± 2.1° to 12.88 ± 1.86° (p = 0.00001), indicating an effective restoration of the longitudinal arch. These findings align with Maier et al., who established that triple arthrodesis leads to favorable radiological outcomes in stabilizing unstable hindfoot deformities (2).

The correction of the Talar–First Metatarsal Angle (T1stMTA) in both lateral (from 10.88° to 4.06°) and anteroposterior (from 15.44° to 2.88°) views reflects the successful reduction of midfoot and forefoot adduction. Sangeorzan et al. reported average improvements of 17° in the lateral T1stMTA and 18° in the AP T1stMTA when using rigid internal fixation (14). Our mean correction of 6.82° (lateral) and 12.56°, though smaller in magnitude, was sufficient to bring the values within normal physiological ranges. Similarly, the AP Talonavicular Coverage Angle improved significantly from 14.50° to 1.19° (p = 0.00001), indicating excellent restoration of the talonavicular relationship, a critical component in correcting the supination and adduction components of the CTEV deformity.

Surgical Technique and Clinical Implications
The dual-incision approach employed in this study—utilizing a lateral incision for the subtalar and calcaneocuboid joints and a separate medial incision for the talonavicular joint—remains the gold standard for optimal joint exposure (4,5). Although some literature suggests a single medial approach to reduce wound complications and operative time (6,7), the complexity of neglected CTEV often necessitates the superior visualization and wedge resection capabilities provided by the dual-incision technique to ensure a plantigrade result.

Triple arthrodesis serves as a definitive "salvage" procedure (11). As noted by Bednarz et al., using rigid internal fixation in adults yields significant functional improvements (3). Our use of 6.5-mm cannulated screws for the subtalar joint and various fixation devices for the other joints facilitated stable fusion and early mobilization. Achieving an ideal plantigrade position is vital; Southwell and Sherman cautioned that inadequate surgical correction of varus deformity is a primary cause of failure, leading to symptomatic force concentrations in the midfoot and hindfoot (15).

Complications
Complications following triple arthrodesis are multifactorial. Wound dehiscence, potentially secondary to aggressive soft tissue handling or arterial compromise, is manageable through diligent post-operative wound care. Pseudoarthrosis or non-union, particularly at the talonavicular joint, may arise from inadequate joint resection or insufficient rigid internal fixation, necessitating interventions such as extended immobilization, bone stimulation, or surgical revision. Hardware failure, often linked to non-union or inadequate post-operative immobilization, may require surgical correction if symptomatic. Infections are typically addressed with antimicrobial therapy. Rare but significant vascular injury during dissection can lead to talar osteonecrosis, potentially requiring subsequent ankle fusion, talectomy, or bone grafting. Furthermore, improper final alignment of the arthrodesis sites may precipitate early ankle osteoarthritis, which, if symptomatic and progressive, may necessitate secondary ankle fusion.

Long-term Considerations and Limitations
While our short-term results are promising, it is essential to contextualize them within the long-term literature. Bennett et al. reported that 95% of patients remained satisfied with the functional outcome even after 44 years post-triple arthrodesis (1). However, long-term studies also warn of progressive degenerative changes in adjacent joints, such as the ankle and midtarsal joints, due to the loss of motion in the fused segments (16). Haritidis et al. found degenerative changes in 12 ankles and 9 feet in a 25-year follow-up study (16).

This study has several limitations that must be acknowledged. First, the sample size is relatively small (n=16), which may limit the generalizability of the findings. Second, the cohort consisted entirely of male patients, precluding an analysis of potential gender-based differences in outcomes. Finally, the follow-up period of 5–6 months is sufficient for assessing initial fusion and immediate functional gains, but it is inadequate for evaluating long-term complications such as adjacent joint arthritis or late recurrence of deformity.

CONCLUSION
Triple arthrodesis using a dual-incision approach and rigid internal fixation is a reliable and effective treatment for neglected or old CTEV in adolescents and young adults. It provides significant pain relief, restores foot alignment to near-normal physiological limits, and substantially improves functional capacity. Despite the inherent loss of hindfoot motion, the achievement of a stable, plantigrade foot offers a life-changing improvement for patients suffering from these debilitating deformities. Long-term longitudinal studies remain necessary to monitor the progression of adjacent joint degeneration in this specific patient population.

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