

Tibiototalcaneal Intramedullary Nailing for Unstable Geriatric Ankle Fractures

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Abstract

Background: Tibiototalcaneal (TTC) intramedullary nailing has been suggested as an alternative to open reduction and internal fixation (ORIF) for the primary treatment of unstable fragility ankle fractures with a poor soft tissue envelope. This study aims to investigate the clinical efficacy of TTC intramedullary nail fixation for the primary treatment of unstable ankle fractures in frail elderly patients with poor soft tissue condition, by assessing the number of postoperative complications and the patient-reported functional outcomes. **Methods:** A retrospective cohort study was performed including patients with an unstable ankle fracture treated between 2015 and 2019 with TTC stabilization using a retrograde intramedullary hindfoot nail that was inserted without joint preparation and allowing immediate weight-bearing postoperatively. The primary outcome was the total number of postoperative complications. **Results:** A total of 10 patients were included out of 365 operatively treated ankle fractures. The mean age was 85.2 years (range 66-92) with a mean follow-up of 11.2 months (range 6-16). Fracture types included AO/OTA 44-B2 (n = 1), 44-B3 (n = 6), 44-C1 (n = 2) and 44-C3 (n = 1). Postoperative complications were observed in 4 patients (40%), including 3 nonunions, 2 implant related complications and 1 wound infection. No wound healing disorder or below-the-knee amputation was observed. Four patients (40%) deceased between post-operative 6 to 16 months due to medical conditions unrelated to surgery. The mean Foot and Ankle Outcome Score was 52.6 (range 44.2-73.8). **Conclusion:** Hindfoot nailing is a viable treatment option in selected high-risk patients with an advanced age, unstable ankle fractures with significant bone loss, poor soft tissue condition and/or severely impaired pre-injury mobility. In a frail geriatric population, hindfoot nailing may be a safe alternative fixation method with a low risk of wound complication or major amputation. However, unprepared joint may lead to symptomatic nonunion after TTC intramedullary nailing.

Keywords

unstable ankle, fracture, tibiototalcaneal, hindfoot nailing, intramedullary nail, retrospective cohort

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Background

The annual incidence of ankle fractures ranges between 122 and 184 fractures per 100,000 people.^{1,2} This incidence is currently increasing in the elderly population, with most ankle fractures occurring in female patients aged between 75 and 84 years.³

Operative treatment is preferred for unstable fractures in elderly patients as non-operative treatment is associated with increased mortality and decreased functional outcome.^{4,5} Open reduction and internal fixation (ORIF) is the most common method of operative treatment.⁶ However, ORIF is challenging in elderly patients with osteoporotic bone and compromised

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soft tissue conditions. As a result, complication rates range between 21.5% and 50.7% with typical issues being a high risk of wound-related complications, failed fixation and posttraumatic arthrosis.^{7,8} Also, postoperative restriction to non-weight-bearing may decrease the functional outcome in the elderly population with a higher risk of other complications caused by a prolonged bedrest.^{9,10}

Tibiototalocalcaneal (TTC) stabilization using a retrograde intramedullary nail has been described as a primary treatment option for frail patients who are contra-indicated for ORIF due to severe bone loss or poor soft tissue quality.^{11,12} In contrast to ORIF, TTC intramedullary nailing uses a less invasive technique avoiding extensive soft tissue dissection in the malleolar region, especially with omission of ankle joint preparation for fusion. In addition, the locking TTC nailing construct provides rigid internal fixation by compression of both tibiotalar and subtalar joints, allowing immediate weight-bearing. Ultimately, these advantages of TTC nailing may lead to fewer postoperative complications while improving functional outcomes compared to conventional ORIF. Therefore, hindfoot nailing should be considered in selected elderly patients who may be relatively contra-indicated to undertake open surgical treatment due to advanced age, significant medical comorbidity, osteoporosis or compromised soft tissue condition.¹²

The aim of this retrospective cohort study was to investigate the clinical efficacy of TTC intramedullary nail fixation for the primary treatment of unstable ankle fractures in frail elderly patients with poor soft tissue condition. This was assessed by analyzing the number of postoperative complications and the patient-reported functional outcomes after surgery.

Methods

This study was performed according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.¹³

Study Design

A retrospective cohort study was conducted using data from a level 1 trauma center in Switzerland. All patients with an operatively treated ankle fracture between January 1st 2015 and January 1st 2019 were identified using the electronic hospital surgical registration database. The inclusion criteria were 1) patients with an unstable ankle fracture (AO/OTA 44 type A2-3, B2-3, C1-3), 2) treated with primary TTC stabilization using a retrograde intramedullary hindfoot nail, and 3) a minimum clinical and radiographic follow-up of 6 months. The exclusion criteria were the presence of an additional ipsilateral fracture or unwillingness to participate in the study.

Data were collected from the patient's electronic medical records. All fractures were classified according to the AO/OTA classification by 2 investigators (EK and FB) using both mortise and lateral view radiographs and preoperative computer tomography.¹⁴ Classification disagreement was resolved by discussion with a third investigator (RB).

Study Variables

Definitions of all study variables are described in Online Resource 1. The medical condition of the included patients was assessed by the American Association of Anesthesiologists (ASA) classification system.¹⁵ Ankle joint luxation included anterior, posterior, medial, lateral or multi-directional tibiotalar dislocation. Open fractures were subdivided according to the Gustilo classification.¹⁶ Postoperative mobility and care setting were assessed 6 months after surgery.

Surgical Technique and Postoperative Treatment

In this trauma center, TTC nailing was exclusively performed as a last resort in case of severe fragility ankle fractures in patients with poor medical condition and/or impaired pre-injury mobility. All patients received prophylactic antibiotics and were placed in supine position. Tibiototalocalcaneal nailing was performed by either the T2 Ankle Arthrodesis Nail (Stryker, Mahwah, New Jersey) or the Expert Hindfoot Arthrodesis Nail (DePuy Synthes, Oberdorf, Switzerland) based on the surgeon's preference. All procedures were performed under fluoroscopic guidance. Closed reduction and temporary fixation was achieved using Kirschner wires. A longitudinal incision of 2 to 4 cm was made to gain access through the plantar surface of the calcaneus. A guidewire was introduced and advanced to the center of the superior surface of the talus, after which the tibial canal was opened by a reamer. After graduated reaming, the TTC retrograde nail was inserted over the guidewire. No cartilaginous debridement was performed in order to minimize soft tissue injury. Nevertheless, joint compression was performed in order to contain and optimize alignment of the ankle joint. Fracture reposition as well as correct nail and ankle positioning were verified by fluoroscopy with the optimal ankle position being neutral dorsal-plantar flexion, 5 to 10 degrees external rotation and 0 to 5 degrees hindfoot valgus. The nail was locked after clinical and radiographic control of axis and rotation. The T2 Ankle Arthrodesis Nail used 2 tibial screws, a single talar screw and 2 calcaneal screws, while joint apposition was established using an internal compression screw (Figure 1). In contrast, the Expert Hindfoot Arthrodesis Nail used 2 tibial screws, a single talar screw and 1 or 2 calcaneal screws, while external compression was provided by hammer blows on the distal end of the nail (Figure 2).

The postoperative treatment consisted of 6 weeks immobilization by either a cast or removable walker depending on the soft tissue condition. All patients were allowed immediate weight-bearing as tolerated. Routine clinical and radiographic follow-up was performed 6 weeks, 3 months, 6 months and 12 months postoperatively.

Outcome Measures

All outcome measures and definitions used in this study are provided in Online Resource 2.



Figure 1. A) Preoperative radiographs of a trimalleolar ankle fracture and B) postoperative radiographs after TTC nailing using the T2 Ankle Arthrodesis Nail (Stryker, Mahwah, New Jersey).

The primary outcome measure was the total number of postoperative complications, including 1) nonunion, 2) implant related complications, 3) wound infection, 4) wound healing disorders, and 5) below-the-knee amputation. Fracture nonunion was defined as symptoms of nonunion in combination with radiological absence of bridging callus over more 2 or more cortices on radiographs taken in 2 perpendicular planes and persisting fracture lines 6 months postoperatively.¹⁷ Radiographic assessment of fracture union was performed by 2 investigators (EK and FB). Wound healing disorder was defined as any deviation in the postoperative course excluding wound infection, without the necessity of pharmacological or surgical intervention.

The secondary outcome measures were 1) mortality, 2) patient-reported functional outcome using the Foot and Ankle Outcome Score (FAOS), 3) return to pre-injury mobility, 4) return to pre-injury care setting, and 5) duration of hospital



Figure 2. A) Preoperative radiographs of a subluxation trimalleolar ankle fracture and B) postoperative radiographs after TTC nailing using the Expert Hindfoot Arthrodesis Nail (DePuy Synthes, Zuchwil, Switzerland).

stay. Mortality was defined as loss of life during follow-up for any reason without a demonstrable relation to the operative treatment. The FAOS is a validated patient-reported outcome measure for functional ankle outcome based on 5 categories (pain, symptoms, activities of daily living, sport and quality of life), that is presented as a score ranging from 0 to 100 with a higher score representing superior functional outcome.¹⁸ In addition, the patient's need for walking aids (including walking stick, walker, wheelchair) and care setting (including home, nursery facility, rehabilitation unit) were evaluated pre- and postoperatively.

Descriptive results were presented as frequencies with percentages for dichotomous outcomes and as mean values with

Table 1. Study Variables of All Included Patients With an Ankle Fracture (n = 10).

Characteristics		Patients (total n = 10)	
Patient demographics	Sex	Male Female	1 (10%) 9 (20%)
	Age (years, mean \pm SD, range)		85.2 \pm 8.2 range 66-92
	ASA classification	I	1 (10%)
		II	2 (20%)
		III	6 (60%)
		IV	1 (10%)
	Smoking		3 (30%)
	Anti-coagulant medication		7 (70%)
	Osteoporosis		10 (100%)
	Diabetes		1 (10%)
Peripheral arterial disease		3 (30%)	
Pre-injury immobility		0	
Fracture variables	Side of injury	Left	4 (40%)
		Right	6 (60%)
	Malleolar involvement	Unimalleolar	0
		Bimalleolar	2 (20%)
		Trimalleolar	8 (80%)
	AO/OTA classification	44-B2	1 (10%)
		44-B3	6 (60%)
		44-C1	2 (20%)
		44-C3	1 (10%)
	Luxation fracture		2 (20%)
Open fracture	Gustilo type I	0	
	Gustilo type II	1 (10%)	
	Gustilo type III	0	
Surgical variables	Type of implant	T2 Arthrodesis Nail	7 (70%)
		Expert Hindfoot Arthrodesis Nail	3 (30%)
	Temporary external fixation		8 (80%)
	Time between trauma and external fixation	<24 hours	2 (25%)
		\geq 24 hours	6 (75%)
Time between trauma and definitive surgery (days, mean \pm SD, range)		7.9 \pm 3.6 range 5-16	
Postop variables	Operative time (minutes, mean \pm SD, range)		104.6 \pm 21.2 range 71-136
	Postoperative immobilization	Cast	9 (90%)
		Removable walker	1 (10%)
	Postoperative weight-bearing		6 (60%)
Follow-up (months, mean \pm SD, range)		11.2 \pm 3.9 range 6-16	

ASA = American Association of Anesthesiologists

Postop = Postoperative

SD = Standard Deviation

standard deviations (SD) and range for continuous outcomes. Missing data were excluded from results. Calculation of percentages and SD's was performed using the SPSS software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp).

Results

Patient Demographics

A total of 365 patients with an unstable ankle fracture were surgically treated between January 1st 2015 and January 1st 2019, including 88 patients who were 70 years-old or older. Of these 365 patients, 10 patients who were treated with primary TTC intramedullary nailing were included in this study. The demographic data is presented in Table 1. There were 1 male

and 9 female patients with a mean age of 85.2 years (range 66-92). The ankle fractures were classified as AO/OTA 44-B2 (n = 1), 44-B3 (n = 6), 44-C1 (n = 2), and 44-C3 (n = 1). All fractures occurred in osteoporotic bone. Two fractures (20%) were associated with ankle joint subluxation. One patient (10%) had an open fracture that was classified as Gustilo type II. The T2 Ankle Arthrodesis Nail was used in 7 patients (70%) with an implant length of 200 mm and a diameter of 10 mm (n = 3), 11 mm (n = 3) or 12 mm (n = 1). The Expert Hindfoot Arthrodesis Nail was used in 3 patients (30%) with an implant length of 240 mm and a diameter of either 10 mm (n = 1) or 12 mm (n = 2). Six out of 10 patients were able to fully weight-bear immediately, while 4 patients were limited to supervised wheelchair transfer as the risk of falling whilst mobilizing in a plaster was judged as being too high. The mean duration of

Table 2. Results of Intramedullary TTC Nailing of Ankle Fractures in Frail Elderly Patients (n = 10).

Postoperative outcomes	Patients (total n = 10)	Percentages
Total number of postoperative complications	4	40%
Nonunion	3	30%
Implant related complications	2	20%
Wound infection	1	10%
Wound healing disorders	0	0%
Below-the-knee amputation	0	0%
Mortality	4	40%
Foot and Ankle Outcome Score (mean ±SD, range)*	52.6 ± 14.2 range 44.2-73.8	NA
Pain (mean ±SD)	56.3 ± 22.9	NA
Symptoms (mean ±SD)	66.0 ± 25.3	NA
ADL (mean ±SD)	52.0 ± 10.3	NA
Sport (mean ±SD)	45.0 ± 38.1	NA
Quality of life (mean ±SD)	43.8 ± 30.6	NA
Return to pre-injury mobility	5	50%
Return to pre-injury care setting	6	60%
Duration of hospital stay (days, mean ±SD, range)	15.4 ± 3.9 range 9-22	NA

ADL = Activities of Daily Living

NA = Not Applicable

SD = Standard Deviation

*Results are based on 4 patients available for assessment of patient-reported functional outcome

follow-up was 11.2 months (range 6-16). Six patients (60%) were not available for assessment of functional outcome due to mortality (n = 4) and loss to follow-up (n = 2).

Postoperative Complications and Mortality

Four patients (40%) developed one or more postoperative complications, with a total number of 6 complications observed in this study (Table 2). Symptomatic nonunion occurred in 3 patients (30%). Implant related complications were observed in 2 patients (20%), consisting of re-operation for symptomatic loosening of the end cap (n = 1) and a loose locking screw (n = 1). One patient (10%) developed a wound infection 3 weeks postoperatively, requiring wound debridement and removal of the locking blade, after which further healing was uneventful. No wound healing disorder or below-the-knee amputation was observed in this study.

Four patients (40%) deceased due to medical conditions unrelated to the operative treatment between 6 and 16 months postoperatively.

Functional Outcomes

Foot and Ankle Outcome Scores were available for 4 patients (40%) with a mean total score of 52.6 (range 44.2-73.8) (Table 2). The FAOS subscale scores are plotted in Figure 3, showing the most favorable scores for pain and other symptoms such as ankle stiffness and swelling.

Five patients (50%) returned to their pre-injury level of physical function using the same assistive device, while the remaining 5 patients (50%) showed reduced mobility with a

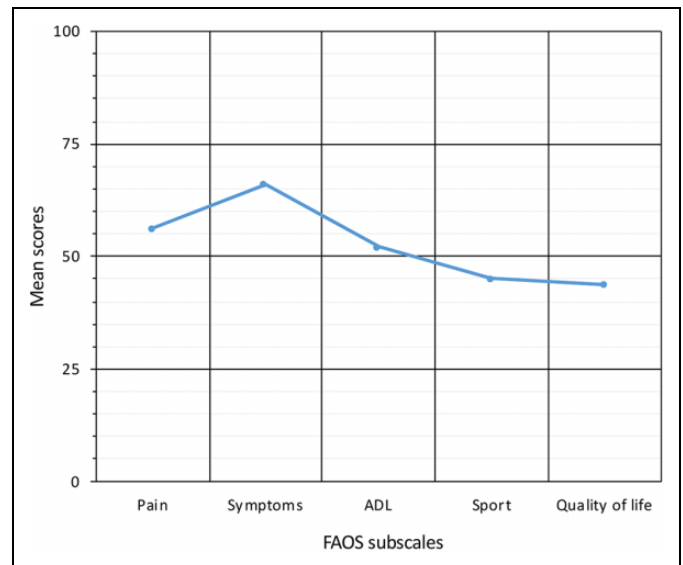


Figure 3. Plot demonstrating mean subscales of the Foot and Ankle Outcome Scores of 4 patients who underwent TTC intramedullary nailing.

Table 3. Patient Walking Aids Necessary for Mobilization and Care Settings before and after TTC Intramedullary Nailing (n = 10).

Patients	Walking aids		Care setting	
	Preoperative	Postoperative	Preoperative	Postoperative
1	Walker	Walker	Nursery facility	Nursery facility
2	Walker	Walker	Home	Nursery facility
3	Walker	Wheelchair	Home	Rehabilitation unit
4	Walker	Walker	Nursery facility	Nursery facility
5	None	Walker	Home	Nursery facility
6	Walker	Wheelchair	Nursery facility	Nursery facility
7	Walker	Wheelchair	Home	Home
8	None	Walking stick	Home	Home
9	Walking stick	Walking stick	Home	Home
10	None	None	Home	Nursery facility

changed need for walking aids (walking stick (n = 1), walker (n = 1) or wheelchair (n = 3)) (Table 3). Six patients (60%) returned to their pre-injury care setting after surgery (home (n = 3), nursery facility (n = 3)), while 4 patients required a change in care setting to either a rehabilitation unit (n = 1) or nursery facility (n = 3) (Table 3). The mean duration of hospital stay was 15.4 days (range 9-22).

Discussion

This study shows that TTC intramedullary nailing can be used as a salvage procedure for frail geriatric patients with an

unstable fragility ankle fracture. Postoperative complications were observed in 40% of the patients treated with a retrograde hindfoot nail, with symptomatic nonunion (30%) occurring most frequently. However, a low number of wound-related complications (10%) and no below-the-knee amputations were observed after TTC nailing.

Previous studies have also assessed the postoperative complications of TTC intramedullary nailing using a retrograde hindfoot nail for primary treatment of elderly ankle fractures.¹⁹⁻²³ The postoperative complication rates reported in these studies ranged from 0% to 22.9%, which is considerably lower than in this study. This discrepancy is most likely explained by the different patient population in this study. Compared to the previous studies, our cohort showed a more advanced age (mean 82.4 years) and worse medical condition reflected by 73% of the patients being classified as ASA class III or IV. In addition, 80% had trimalleolar ankle fractures with all fractures occurring in osteoporotic bone. The fact that only 10 out of the total of 365 patients with ankle fractures were treated with TTC nailing demonstrates that in the trauma center this study was conducted in, this treatment is reserved as a last resort for patients with severe fragility ankle fractures, poor medical condition and/or impaired pre-injury mobility.

Of the complications associated with TTC nailing in this frail population, symptomatic nonunion was observed most frequently (30%). This considerable rate of nonunion may be explained by the conscious decision against routine cartilaginous debridement to avoid further soft tissue injury. Alternatively, frail ankle fractures can be treated with less invasive intramedullary fixation using either a fibular nail or screw which requires no formal arthrodesis and therefore reduces the risk of fracture nonunion.^{24,25} However, 80% of the included patients had a trimalleolar ankle fracture which would have also required fixation of the medial malleolus, therefore increasing the risk of wound-related problems. These risks may not outweigh the risk of fracture nonunion after TTC nailing.

Tibiototalocalcaneal intramedullary nailing offers multiple advantages over ORIF for primary treatment of ankle fractures in elderly patients. First, TTC nailing can be performed using a less invasive technique that avoids extensive soft tissue dissection.^{19,21,23} As a result, the risk of wound-related complications after TTC nailing is decreased compared to ORIF.²³ Furthermore, TTC nailing is less dependent on pristine soft tissue conditions due to its minimal invasive technique and can therefore be performed before swelling fully subsides, allowing earlier-stage surgery with significant shorter duration of hospital stay compared to ORIF.²³ Another advantage of TTC inline stabilization using a locked intramedullary nailing construct is that it permits immediate full weight-bearing. This may improve functional outcome and also allows immediate mobilization in a geriatric population that usually cannot limit weight-bearing, therefore reducing the risk of bed rest-related complications compared to ORIF.^{9,10}

On the other hand, disadvantages of TTC nailing include long-term complications such as tibiotalar and subtalar osteoarthritis, implant failure and periprosthetic fracture at the tip of the

nail.²³ Another disadvantage of hindfoot nailing are the high implant costs, with the price of a second-generation TTC nail described to be \$2700.²⁶

Several limitations of this study should be mentioned. First, the sample size was small due to the stringent indication for primary TTC nailing in this trauma center. In addition, a longer duration of follow-up is required for assessment of long-term complications and functional outcomes. Although the specific criteria for hindfoot nailing could not be predefined due to the retrospective design of this study, the patients included in this study reflect the relevant clinical considerations for primary treatment by TTC nailing.

Conclusion

Tibiototalocalcaneal intramedullary nailing should be considered as an alternative to ORIF in patients with an advanced age, unstable fragility ankle fracture, poor soft tissue condition and/or impaired pre-injury mobility. In these selected patients, the advantages of minimal soft tissue injury and immediate postoperative mobilization with permissive weight-bearing may outweigh the risk of long-term complications and high implant costs.

Authors' Note

This study was conducted according to the ethical principles of the Declaration of Helsinki, constituted by the World Medical Association (latest version October 2013, Fortaleza). Ethical approval was granted by the internal review board of the involved hospital (Ethikkommission Nordwest- und Zentralschweiz, Basel, Switzerland) with reference number EKNZ-2019-01098. Informed consent was obtained from all included patients that responded to the questionnaire for functional outcome during follow-up of this study. The authors confirm that the data supporting the findings of this study are available within the article and/or its supplementary material.

Author Contributions

All authors contributed to the study conception and design. Material preparation and data collection were performed by Elif Kulakli-Inceleme. The first draft of the manuscript was written by David B. Tas. Editing of previous versions of the manuscript was performed by David B. Tas. All authors reviewed and approved the final manuscript.


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Supplemental Material

Supplemental material for this article is available online.

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