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Ankle Fusion with Tibiotalocalcaneal Retrograde Nail for Fragility Ankle Fractures: Outcomes at a Major Trauma Centre
--Manuscript Draft--

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Abstract:	Purpose Fragility ankles fractures in the geriatric population are challenging to manage, due to fracture instability, soft tissue compromise, and patient co-morbidities. Traditional management options include open reduction internal fixation, or conservative treatment, both of which are fraught with high complication rates. We aimed to present functional outcomes of elderly patients with fragility ankle fractures treated with retrograde ankle fusion nails. Methods A retrospective observational study was performed on patients who underwent intramedullary nailing with a tibiotalocalcaneal nail. Twenty patients met the inclusion criteria of being over sixty and having multiple co-morbidities. Patient demographics, AO/OTA fracture classification, intra-operative and post-operative complications, time to mobilisation and union, AOFAS and Olerud-Molander scores, and patient mobility were recorded. Results There were 7 males and 13 females, with a mean age of 77.82 years old, five of whom are type 2 diabetics. Thirteen patients returned to their pre-operative mobility state, and the average Charlson Comorbidity Index (CCI) was 5.05. Patients with a low CCI are more likely to return to pre-operative mobility status (p=0.16;OR=4.00). All patients achieved radiographical union, taking on average between 92.5 days to 144.6 days. The mean post-operative AOFAS and Olerud-Molander scores were 53.0 and 50.9, respectively. There were four cases of superficial infection, four cases of broken or loose distal locking screws. There were no deep infections, periprosthetic fractures, nail breakages, or non-unions. Conclusion

	Tibiotalocalcaneal nailing is an effective and safe option for managing unstable ankle fractures in the elderly. This technique leads to lower complication rates and earlier mobilisation than traditional fixation methods.

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Professor Cyril Mauffrey
Editor-in-chief
European Journal of Orthopaedic Surgery & Traumatology

Dear Prof. Mauffrey,

Re: Ankle Fusion with Tibiotalocalcaneal Retrograde Nail for Fragility Ankle Fractures: Outcomes at a Major Trauma Centre

Thank you very much for reviewing our submission and providing us with the reviewers' comments. We have revised our manuscript taking into account the reviewers' comments and highlight the responses to the comments below.

Reviewer 1 Comments	Authors' Responses
Inclusion criteria need to be more strict and more defined. What was the criteria of fragility fractures , why the open fractures were included, why the pilot fractures were included?	We have clarified and made the inclusion criteria more well-defined. We have also included a definition of fragility fractures in the introduction section on page 2. Open fractures were included because all nine were caused by low-velocity trauma which is within the scope of our definition of a fragility fracture.
I could find at least 2 RCT comparing ORIF and TCC nailing in the fragility fractures: Tibiotalocalcaneal Intramedullary Nailing for Unstable Geriatric Ankle Fractures 2021 (Kulakli-Inceleme et al.) The role of intramedullary fixation in ankle fractures - A systematic review (Jordan et al.) Fragility fractures of the ankle in the elderly: Open reduction and internal fixation versus tibio-talo-calcaneal nailing: Short-term results of a prospective randomized-controlled study. (Georgiannos et al.)	Thank you very much for suggesting these three studies. The paper by Kulakli-Inceleme et al. is reference number 20 in the manuscript, and is located in three different sections. The paper by Jordan et al. is reference number 17 in the manuscript, and is located in three different sections. The paper by Georgiannos et al. is reference number 3 in the manuscript, and is located in three different sections.
1-The authors did not define what is a fragility ankle fracture	We have now defined a fragility ankle fracture in the introduction as one that occurs in patients

	over 60, as a result of minimal trauma, and in patients with osteoporotic bone.
2-Almost 50% of the patients had open ankle fractures (was it low energy , what was the mechanism of injury in the open fracture patient, did that affect the outcome?)	All nine open fracture patients in our cohort acquired low-velocity trauma, with six suffering a fall from standing height, and three tripping over on stairs; these injury mechanisms were the same as those that caused the eleven closed fractures in our cohort.
3- Almost 40% of the cohort were non primary cases (failed conservative , failed ORIF and failed TCC)	Tibiotalocalcaneal nailing was used as a salvage procedure for patients who couldn't be adequately manged by conventional methods. Our aim was to present clinical and functional outcomes of elderly patients with fragility ankle fractures treated with retrograde TTC nails, and hence included patients who received TTC nailing as a primary treatment, as well as patients who received TTC nailing as a 'salvage procedure'
4- In 3 cases no joint preparation was done compared to the other 18. why was the decision not to prepare the joints in these cases ?	The surgeons who elected to not prepare the joints felt that doing so would devascularise the talar fragments excessively, increase surgical insult and create an unnecessarily invasive procedure that would introduce wound healing issues, in return for arthrodesis union which is hard to achieve in a host with multiple co-morbidities.

Reviewer 3 Comments	Authors' Responses
Comment 1: In the abstract: it would be appropriate to refer to the characteristics of the study.	We have included the statement in the abstract that this a retrospective observational study.
Comment 2: In the introduction: Some information about etiology, diagnosis and treatment of Fragility ankle fractures should be deepened please adding appropriate bibliographical references. (Roux S, et al (2018) "Risk of Subsequent Fragility Fractures Observed After Low-Trauma Ankle Fractures").	Thank you very much for the suggesting this study. The paper by Roux et al. is reference number 13 in the manuscript. We have added a paragraph to the introduction using the study by Roux et al. as a guide, whilst also including other relevant literature to address the aetiology, diagnosis, and treatment of fragility ankle fractures adequately and succinctly.
Comment 3: In the introduction: "These fractures are difficult to manage not least because of osteoporosis, whose incidence is also on the rise due to increasing life expectancy, together with other systemic disorders such as diabetes." Please adding appropriate bibliographical references.	Appropriate references have been added, as well as some relevant literature discussing the relationship between fragility fractures and osteoporosis.
Comment 4: In the materials and method: please clearly indicate the exclusion criteria in this study.	We have clarified and made the exclusion criteria more well-defined.
Comment 5: In the materials and method: Were all surgical procedures performed by the same orthopedic surgeon?	Yes, all ankle fusion procedures were performed by one surgeon M.K.
Comment 6: In the materials and method: "All patients had multiple co-morbidities, which was quantified using the Charlson co-morbidity index (CCI); average score was 5.05." Please adding appropriate bibliographical references about Charlson co-morbidity index.	The appropriate reference have been added, which is Charlson's original paper on CCI.
Comment 7: In the Results: How long did it take to re-evaluate the patients clinically and radiographically?	We apologise for not understanding the question, but here is how we interpreted it: Patients were re-evaluated clinically and radiography on average 30 days after discharge, followed by clinics at 4 week intervals.
Comment 8: In the Results: Were the hospitalization times the same in all patients?	Hospitalisation times were different for patients, but the average length of hospital stay was 10.8 days (range 2-31).

Comment 9: In the discussion: It would be appropriate to refer to previous studies carried out on the same topic, for example: (Testa G, et al (2019) "Negative prognostic factors in surgical treatment for trimalleolar fractures").	Thank you very much for the suggesting this study. The paper by Testa et al. is reference number 31 in the manuscript, and is located in two different sections.

We are grateful to the reviewers for their comments. We believe that the comments have helped improve the manuscript considerably, and we are very grateful for their input.

Yours Sincerely,

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Ankle Fusion with Tibiotalocalcaneal Retrograde Nail for Fragility Ankle Fractures: Outcomes at a Major Trauma Centre

Abstract

Purpose

Fragility ankles fractures in the geriatric population are challenging to manage, due to fracture instability, soft tissue compromise, and patient co-morbidities. Traditional management options include open reduction internal fixation, or conservative treatment, both of which are fraught with high complication rates. We aimed to present functional outcomes of elderly patients with fragility ankle fractures treated with retrograde ankle fusion nails.

Methods

A retrospective observational study was performed on patients who underwent intramedullary nailing with a tibiotalocalcaneal nail. Twenty patients met the inclusion criteria of being over sixty and having multiple co-morbidities. Patient demographics, AO/OTA fracture classification, intra-operative and post-operative complications, time to mobilisation and union, AOFAS and Olerud-Molander scores, and patient mobility were recorded.

Results

There were seven males and thirteen females, with a mean age of 77.82 years old, five of whom are type 2 diabetics. Thirteen patients returned to their pre-operative mobility state, and the average Charlson Comorbidity Index (CCI) was 5.05. Patients with a low CCI are more likely to return to pre-operative mobility status ($p=0.16$;OR=4.00). All patients achieved radiographical union, taking on average between 92.5 days to 144.6 days. The mean post-operative AOFAS and Olerud-Molander scores were 53.0 and 50.9, respectively. There were four cases of superficial infection, four cases of broken or loose distal locking screws. There were no deep infections, periprosthetic fractures, nail breakages, or non-unions.

Conclusion

Tibiotalocalcaneal nailing is an effective and safe option for managing unstable ankle fractures in the elderly. This technique leads to lower complication rates and earlier mobilisation than traditional fixation methods.

Keywords: Ankle fusion, Tibiotalocalcaneal nailing, Ankle fractures, Mobility, Co-morbidity

Introduction

Fragility ankle fractures are increasing in incidence, and is now the third most common type of fracture in the elderly, after hip and distal radius fractures, with 184 cases per 100,000 people per year [1]. The rising life expectancy contributes to the growing number of cases, which has been projected to increase 25% by 2050 [1,2]. Ankle fractures show a bimodal age distribution, with the majority in men seen between the ages of 15 and 24, whilst the highest incidence in females is between 75 and 84 years old [2]. These fractures are difficult to manage not least because of osteoporosis, whose incidence is also on the rise due to increasing life expectancy, as well as other co-morbidities such as diabetes [3,4]. Osteoporosis is responsible for over 9 million fractures a year, and creates fractures patterns that are more complex and unstable [5]. Despite a Korean study suggesting that body mass index (BMI) rather than bone mineral density (BMD) is a risk factor for ankle fracture, which could be due to the small sample size and retrospective nature of the study [6], a meta-analysis of over 25000 patients demonstrated a significant association between fragility ankle fractures in the elderly population and reduction in BMD [7].

A fragility ankle fracture was defined as one that occurs in patients over 60, as a result of minimal trauma, and in patients with osteoporotic bone [8,9]. A meta-analysis with over 60000 patients concluded that a previous fragility fracture (FF) located anywhere increases the risk of acquiring a subsequent fragility fracture (RR=1.86; 95% CI=1.75–1.98) which is largely independent of BMD [10]. Nevertheless, some studies suggest that ankle FFs have a lower predictive value for subsequent FFs than FFs occurring at more typical osteoporotic locations such as the hip and vertebrae [11]. This could be because ankle fractures have a weaker dependence on age and bone mass [12], are more driven by mechanical factors such as twisting or distortion rather than osteoporosis [13], and have a stronger relationship with lifestyle factors [14]. Risk factors also differ from FFs at other sites, for example menopause was strongly and linearly related to wrist fractures but not to ankle fractures [15]. Multivariate analyses of a cohort of patients aged ≥50 concluded that those with ankle FFs who are still physically active or at low/moderate risk according to the WHO's fracture risk assessment tool (FRAX) may not need subsequent investigation or treatment [13].

The goal for ankle fracture primary management includes anatomical restoration of the tibiotalar mortise, a stable and pain-free ankle, and a rapid return to baseline mobility. Particularly in the elderly, important considerations are early mobilisation and weight bearing, the benefits of which have been shown in a study investigating mortality and immobility in hip fracture patients [16]. Prolonged periods of non-weight bearing is difficult for the elderly, may lead to complications such as pressure ulcers and deep vein thrombosis, and often leads to a lengthy stay at a nursing home. Management of fragility ankle fractures in the elderly is difficult, because of poor bone quality, healing ability, soft tissue condition, suboptimal skin quality, and lack of patient compliance. Intramedullary nails are beneficial since they allow early weight bearing, require only a small incision, and minimises soft tissue trauma [17]. Since 2005, the literature contains optimistic reports of using tibiotalocalcaneal (TTC) nails for treatment, with no non-union [18] and immediate weight-bearing post-operatively [19]. However, few studies assessed functional outcomes with adequate follow-up times [18-22].

2

76 This paper presents a cohort of fragility ankle fractures in the elderly, treated with retrograde
77 ankle fusion nails. The primary objective was to assess whether the number of co-morbidities is
78 associated with a return to pre-operative mobility status and post-operative complications. The
79 secondary objective was to assess the time to radiographical union and patient reported outcome
80 measures (PROMs).

81

Methodology

83 The patient record database was retrospectively reviewed for patients who received a retrograde
84 ankle fusion nail. Our inclusion criteria were:

85 - Age over 60.
86 - Patients who are able to give informed consent.
87 - Patients with two or more co-morbidities.
88 - Patients who are unable to comply with post-operative non-weight bearing instructions
89   due to mental or physical reasons.
90 - Patients with poor bone stock, verified by radiological evidence of osteopenia or a history
91   of fragility fractures.
92 - Unstable fracture pattern necessitating operative management, as determined by a medial
93   clear space ≥5mm on anteroposterior radiographs taken in dorsiflexion.
94 - Poor soft tissue condition around the ankle upon physical examination

95 In addition to excluding patients who didn't meet the aforementioned criteria, the following
96 patients were also excluded:

97 - Patients who were not fit for anaesthesia
98 - Patients with high energy mechanism of injury
99 - Patients with peripheral vascular disease
100 - Patients with previous fracture of the affected limb
101 - Pathological fractures

102 Out of 171 patients who received a hindfoot nail, twenty patients met the inclusion criteria.
103 Thirteen were female and seven were male. The mean age was 77.8 years old (range 61 to 95).
104 Injury was low energy in all patients, including the nine patients who had open fractures, two of
105 whom had Gustilo-Anderson type 3a fractures and one with Gustilo-Anderson type 3b fracture,
106 all of whom required soft tissue coverage. Fractures were classified using the
107 Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA)
108 classification. There were 7 trimalleolar fractures (three AO/OTA 44C1, three 44B2, one 44B1),
109 12 bimalleolar fractures (six AO/OTA 44C1, four 44A2, two 44B2), and one pilon fracture
110 (AO/OTA 43C1). Twelve operations were performed as primary fracture management, four for
111 failed conservative treatment, three for failed open reduction internal fixation (ORIF), and one
112 for failed TTC nailing at a different hospital. All ankle fusion procedures were performed by one
113 consultant orthopaedic surgeon (MK). The average follow-up time was 499.3 days.

114 All patients had multiple co-morbidities, which was quantified using the Charlson co-morbidity
115 index (CCI) [23]; average score was 5.05. CCI produces a comorbidity-age combined risk score,
116 and can be converted using a formula to give a predicted 10-year survival percentage, based on
117 the 10-year survival from a theoretical low-risk population (98.3%).

118 $$\text{Predicted 10-year survival} = 0.983\textasciicircum(e^{0.9 \times CCI})$$

119 As CCI increases from 0 to 6, predicted 10-year survival percentage drops as follows:
120 99,96,90,77,53,21. We defined a high CCI as a value that has a corresponding 10-year survival
121 of less than 50%, i.e. CCI≥5; the remainder (CCI<5) is defined as low CCI.

122 The decision to proceed with TTC nailing was made by the consultant, following assessment of
123 patient's preoperative mobility, co-morbidities, bone quality, fracture pattern/stability, and
124 ability to comply with non-weight bearing status. On admission, patients were managed with our
125 standard trauma protocol. All open fracture patients received prophylactic antibiotics, as per
126 BOAST guidelines for open fracture management [24]. A standard ankle fusion procedure was
127 followed. Three operations were performed by senior fellows, the rest (85%) were consultant-
128 led. Patients on average spent 10.8 days in hospital. One patient spent 31 days due to a heel ulcer
129 which got infected, leading to osteomyelitis of the calcaneum. This was successfully treated with
130 teicoplanin and ciprofloxacin. PROMs were collected twelve months after surgery, namely
131 AOFAS ankle-hindfoot score and Olerud and Molander (O&M) score. PROMs were unable to
132 be collected in three patients who passed away within one month of surgery.

133 Statistical analysis was performed using IBM SPSS Statistics version 27. Categorical binary data
134 was analysed with Pearson's Chi-squared test. A significance value of p≤0.05 was used.

135 This study was registered with the clinical research department on May 25th 2021; registration
136 number PRN9832.

137
138

139 **<u>Results</u>**

140 Demographical information is provided in table 1 and clinical outcomes in table 2. Thirteen
141 patients (65%) returned to their pre-operative mobility state and seven patients had inferior post-
142 operative mobility compared to pre-operative mobility. Five patients who could previously walk
143 independently subsequently required a crutch at all times. Two patients who previously used a
144 walking frame subsequently required a wheelchair. Compared to those with a high CCI score
145 (CCI≥5), patients with a low CCI score (CCI<5) were more likely to return to their pre-operative
146 mobility status (p=0.16; OR=4.00).

147 After 24 hours of strict elevation of the affected limb, all patients were allowed to fully mobilise,
148 as far as pain could be tolerated. The average time to mobilisation was 7.63 days. Those who
149 could not mobilise after day 4 all suffered from complications. One patient who could only
150 mobilise after 24 days had a hindfoot ulcer, grade 3 pressure ulcers, and severe back pain due to
151 non-union of a previous public rami fracture.

152 The average length of hospital stay was 10.8 days (range 2-31). Patients were re-evaluated
153 clinically and radiography on average 30 days after discharge, followed by clinics at 4 week
154 intervals. All patients eventually achieved radiographic union, defined as the presence of bony
155 bridging on antero-posterior and lateral X-ray views, together with painless full weight bearing.
156 Bone union took on average between 92.5 days and 144.6 days to occur. Average AOFAS score
157 6 months post-injury was 53.0 (17-88). The O&M score was not calculated pre-injury, but the
158 average value 6 months post-injury was 50.9 (range 20-85).

159 The six-month mortality rate was 15% (3/20). One patient passed away eleven days after
160 surgery, due to post-operative ileus, causing vomiting and aspiration pneumonia, eventually
161 leading to respiratory failure. Surgical complications included four superficial infections (20%),
162 treated with topical antibiotics. Patients with a high CCI were more likely to acquire superficial
163 infections (p=0.264, OR=3.857). Four patients experienced pain due to broken or loose distal
164 locking screws, which were subsequently removed. Otherwise, metalwork removal was not
165 performed. One patient experienced paraesthesia in the distribution of superficial peroneal nerve
166 and sural nerve, probably damaged iatrogenically, or due to scarring of soft tissue. There were no
167 deep infections, periprosthetic fractures, nail breakages, or non-unions. However, one patient had
168 delayed union (279 days to union), which eventually united after regular observation, and
169 lymphoedema causing an equinus deformity, leading to a low AOFAS score of seventeen.

170

Discussion

Patient Demographics and Surgical Management

173 Surgical management of fragility fractures in the elderly is challenging, with traditional
174 management yielding poor results [25]. Conservative management using fracture manipulation
175 or plaster mobilisation produced a non-union rate of 73% [26], with 79% experiencing chronic
176 pain [27]. ORIF produces poor outcomes in the elderly due to patient-specific conditions such as
177 poor condition of the skin and soft tissue, which is exacerbated by the fracture, poor bone
178 quality, limited pre-injury mobility, advanced age, complex and unstable fracture patterns [28].
179 Surgical wound complications are a concern, as well as an increased risk of deep infection and
180 delayed wound healing due to conditions such as diabetes and peripheral vascular disease, and
181 potential use of corticosteroids [29]. Studies that performed ORIF reported a 19% non-union rate
182 and 43% (37/86) patient dissatisfaction rate [25]. Beauchamp et al. reported a 23% wound
183 complication incidence, and anatomical fixation was achieved in only 54% (38/71); this was
184 significantly more biased towards men (17/22 in men versus 21/49 in women), perhaps due to an
185 increased proportion of osteoporotic bone in women during surgery, increasing the morbidity
186 associated with ORIF [4]. Georgiannos et al. performed a randomised control study between
187 patients treated with TTC nailing and ORIF; the former cohort had a reoperation rate of 2.7%,
188 whilst the latter was 13.8% [3]. Ali et al. reported optimistic results using ORIF, with 8.7%
189 (10/115) malunion rate and only 1 patient with non-union [30]. However, it is a biased study
190 since they excluded those with severe mobility problems, who are most likely to fall and injure
191 themselves, and likely to have osteoporotic bones. Litchfield et al. suggested that inactivity

192 mitigates against ORIF success, and those who were active on their feet pre-injury had the best
193 results [25]. However, the majority of our cohort were dependent on a crutch or frame pre-injury,
194 and all had some degree of impaired mobility.

195 The average age of our cohort at time of injury was 77.8, which is similar to other cohorts
196 [18,21]. According to our definition for a fragility fracture, only those over 60 years old were
197 included; this itself was suggested to be a negative prognostic factor for surgical treatment of
198 trimalleolar ankle fractures according to O&M score (p = 0.000002) and VAS score (p=0.048)
199 [31]. The average age of women and men in our cohort were 82.8 and 70.7, respectively; this
200 was surprising given that women over 50 have a four-fold higher rate of osteoporosis than men
201 [32]. The average hospital stay of 10.8 days was shorter than cohorts treated conservatively or by
202 ORIF [27,28].

203 The proportion of open fractures in our cohort (45%) is higher than those in the literature [8,22],
204 whilst some cohorts had no patients with open fractures [18,19]. This could be due to our clinic
205 being located in a major trauma centre. Although commonly associated with high-energy
206 injuries, all nine open fracture patients in our cohort acquired low-velocity trauma, with six
207 suffering a fall from standing height, and three tripping over on stairs. The open fracture was
208 likely caused by sharp fracture fragments piercing through the soft tissue and skin in patients
209 with poor soft tissue condition. A large proportion of our cohort (40%) received TTC nailing as a
210 'salvage procedure' after unsuccessful prior management. Despite being higher than other
211 cohorts [21], a fair comparison may not be possible, due to the lack of definitive guidelines for
212 when TTC nailing should be used first-line, with surgeons themselves deciding if patients fit the
213 criteria to receive TTC nailing. Nevertheless, this salvage technique has shown promising results
214 in previous reports, with radiological union occurring three months following surgery [33].

215 Ankle and subtalar joints were prepared prior to nail insertion, meaning that they were denuded
216 of cartilage down to subchondral bone (figure 1, figure 2). Surgeons in three operations elected
217 to not prepare the joints (figure 3, figure 4). Studies mention that preparing the subtalar joint
218 reduces non-union rate [20,34]; nevertheless, whether or not subtalar joint needs open
219 debridement remains a contentious point. The surgeons who elected to not prepare the joints felt
220 that doing so would devascularise the talar fragments excessively, increase surgical insult and
221 create an unnecessarily invasive procedure that would introduce wound healing issues, in return
222 for arthrodesis union which is hard to achieve in a host with multiple co-morbidities. Preparing
223 the joint is not a common routine in the literature, and all three patients managed without joint
224 preparation achieved radiographical union. Perhaps joint preparation is more important for
225 young, active patients, whereby hardware failure is more likely due to cyclic loading on the
226 metalwork.

227

Mobility

229 Ankle fusion is not necessarily a life changing procedure. Georgiannos et al. reported that 81.8%
230 of patients treated with a hindfoot nail returned to their pre-operative mobility status [3]. The
231 figure was 65% in our cohort. We found that having a low number of co-morbidities (low CCI

232 score) is positively correlated with regaining one's pre-operative mobility (p=0.160; OR=4.00).
233 However, the association was not statistically significant, probably because our sample size was
234 too small to be adequately powered. Additionally, we noticed that those who took longer than 4
235 days post-surgery to mobilise all suffered some form of post-operative complication. This is
236 similar to Lemon et al. who found that all who failed to mobilise within 72 hours of surgery
237 suffered a post-operative medical complication [19]. Furthermore, we found that patients with a
238 high CCI score are likely to get superficial infections (p=0.264; OR=3.857). All this suggests
239 that patients who have more co-morbidities (higher CCI score), who are less likely to return to
240 pre-operative mobility status, are also expected to suffer from post-operative complications,
241 likely superficial infections.

242

Diabetes Mellitus

244 Five patients (25%) in our cohort were type 2 diabetics, two of whom had superficial wound
245 infection (40%). Management of patients with diabetes adds another layer of complexity, given
246 the high infection rates and wound healing problems that are known to be associated [35]. In
247 their cohort of 93 patients treated with ORIF, Low and Tan [36] reported five patients with
248 wound infections, all of whom were type 2 diabetics. With a 50% infection rate in their diabetic
249 cohort, this illustrates that infection is a serious problem in surgically treated diabetics with ankle
250 fractures. Diabetics are also at increased risk of other complications such as non-union and post-
251 traumatic arthritis; Blotter et al. suggested a 2.76-fold higher relative risk for postoperative
252 complications in patients with diabetes mellitus compared to control group [37]. This could be
253 due to diabetic neuropathy, leading to unprotected weightbearing on the senseless foot.
254 Furthermore, diabetes and obesity are closely interlinked, with four out of five diabetics (80%) in
255 our cohort being obese (BMI≥30). This could be due to biochemical relationships between
256 insulin signalling and adipose tissue, including inhibition of intracellular lipase and increased
257 triacylglycerol synthesis in liver [38]. Not only is average BMI in ankle fracture patients higher
258 than age-matched controls [6], but a retrospective study of 48 patients suggested that morbidly
259 obese patients (BMI≥40) is a negative prognostic factor for ankle fracture management [31].

260

Complications

262 Our overall complication rate was 20% (4/20). This falls within the range of 18 to 22.6% for
263 TTC nailing as quoted in a recent systematic review [17], which also reported that fibula nails
264 have a lower complication rate of 0 to 22%. Nevertheless, our complication rate was lower than
265 patient cohorts treated with ORIF [3,4]. Perhaps due to our high percentage of open fractures,
266 superficial infection rate was higher than the range of 0-6.5% quoted in the literature [8,22]. We
267 report no cases of deep infection or non-unions, which is very favourable compared to other
268 management options such as ORIF [4,27], as well as other studies utilising TTC nailing
269 [8,20,22], with non-union rates of 30% being reported [20]. We also report no periprosthetic
270 fractures, even though a long nail was not used, which was suggested to prevent periprosthetic
271 fractures [22]. Perhaps this was due to low functional demands in our cohort. Four patients

272 required removal of a broken or loose locking screw; one used a crutch whilst three did not need
273 a walking aid. These patients may have been too 'active' to receive TTC nailing, however they
274 were selected due to their poor skin and soft tissue conditions, and perceived lack of ability to
275 comply with non-weight bearing instructions.

276

277 PROMs and Bone union

278 AOFAS scores was reported in only one other study [39]. Our average value of 53.0 is lower
279 than their value of 85.4. Reason could be two-fold. We reported AOFAS scores at 6 months
280 post-injury, but Al-Ashhab et al. reported it at final follow-up [39]. Also, 45% of our patients had
281 open fractures, whereas their cohort had no open fractures [39]. Our average O&M score 6
282 months post-injury of 50.9 concurs with a recent systematic review on intramedullary nailing in
283 ankle fractures, which suggested that the mean O&M score for patient cohorts treated with TTC
284 nailing in the literature was 50-62 [17]. Nevertheless, the limitations of the systematic review,
285 namely the differences in patients included, varying definitions of outcome scores, and the low
286 quality of included studies precluded the ability to draw definitive conclusions [17].

287 Few studies report time to union. Bone union took on average 92.5 days to 144.6 days to occur,
288 which was longer than the average time to union of 63 days reported by Jonas et al. [18].
289 However, this may not be a fair comparison since in retrospective studies, finding when exactly
290 union occurred is difficult. Patients do not have frequent, evenly-spaced radiological follow-ups.
291 Furthermore, COVID-19 has exacerbated this issue, with virtual follow-ups prolonging the gap
292 between radiological checks. This is the reason we preferred to give a time interval within which
293 bone union occurs, rather than a definitive number.

294

295 Limitations

296 Our study has a few limitations, not least being the retrospective study design. There was no
297 control group to compare with other management options such as ORIF or conservative
298 treatment. Our population size is relative small and heterogenous, with patients having various
299 fracture patterns and classifications. Also, we could not obtain pre-operative O&M scores, which
300 would have been useful to compare with post-operative scores. Our cohort included patients who
301 received TTC nailing as a primary treatment, as well as patients who received TTC nailing as a
302 'salvage procedure' after failed treatment using more conventional methods. Our population size
303 was not large enough to provide a comparison between these two groups. Furthermore, there is a
304 lack of definitive guidelines for when TTC nailing should utilised as primary management for
305 ankle fractures.

306

307 **Conclusion**

308 TTC nailing is an effective treatment methodology for the low-demand geriatric patient with
309 unstable fragility ankle fractures, and should be added to the armamentarium of management

8

310 options for fragility ankle fractures in the elderly. It effectively stabilises the hindfoot and
311 encourages early weight-bearing, maintaining mobility, which is important for preventing the
312 loss of socioeconomic independence. TTC nailing limits soft tissue injury and has few
313 complications, compared to other treatment options such as ORIF or conservative management.
314 It is not a life-changing procedure, with many being able to return to their pre-operative mobility
315 status, however, the number of co-morbidities is a negative predictive factor for returning to pre-
316 operative mobility status, and a positive predictive factor for the development of post-operative
317 complications.

318

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Figure 1: *Left* - AP view before nail insertion in a patient whose joint was prepared; *Right* - Lateral view before nail insertion in a patient whose joint was prepared.

Figure 2: *Left* - AP view after nail insertion with joint preparation; *Right* - Lateral view after nail insertion with joint preparation.

Figure 3: *Left* - AP view before nail insertion in a patient whose joint was not prepared; *Right* - Lateral view before nail insertion in a patient whose joint was not prepared.

Figure 4: *Left* - AP view after nail insertion with joint not prepared; *Right* - Lateral view after nail insertion with joint not prepared.

Table 1: Patient Demographics

Total Population	20
Male	7 (35%)
Female	13 (65%)
Age (years)	77.82 (61-95)
Male	70.71 (61-95)
Female	82.8 (66-89)
BMI	30.1 (16.65-49.54)
Smoking status	
Ex-smoker	10 (50%)
Non-smoker	8 (40%)
Current smoker	2 (10%)
Diabetes Mellitus	
Yes	5 (25%)
No	15 (75%)
Charlson Comorbidity Index	5.05 (3-9)
ASA Grade	2.44 (2-4)
Fracture Pattern	
Bimalleolar	12 (60%)
Trimalleolar	7 (35%)
Pilon	1 (5%)
Fracture Type	
Closed	11 (55%)
Open Gustilo-Anderson 2	6 (30%)
Open Gustilo-Anderson 3a	2 (10%)
Open Gustilo-Anderson 3b	1 (5%)
Fracture Classification	
AO/OTA 43C1	1 (5%)
AO/OTA 44A2	4 (20%)
AO/OTA 44B1	1 (5%)
AO/OTA 44B2	5 (25%)
AO/OTA 44C1	9 (45%)
Pre-Injury mobility	
Walk independently	5 (25%)
Crutches	7 (35%)
Frame	8 (40%)

Table 2: Clinical Outcomes

Time to Mobilisation (days)	7.6 (2-24)
Bone Union Time Interval (days)	92.5 to 144.6
Hospital length of stay (days)	10.8 (2-31)
Average operative time (min)	131.2 (68-227)
Average follow-up time (days)	499.3 (51-1360)
Post-operative complications	8 (40%)
Deaths within 6 months	3 (15%)
AOFAS score 6 months after operation	53.0 (17-88)
Olerud-Molander score 6 months after operation	50.9 (20-85)
Mobility 12 months after operation	
Walk independently	0
Crutches	6 (30%)
Frame	12 (60%)
Wheelchair	2 (10%)
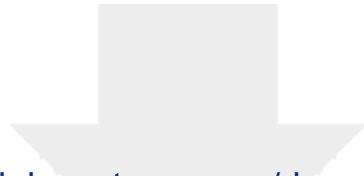
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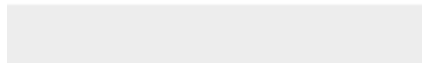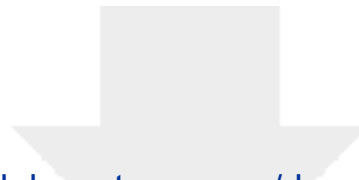
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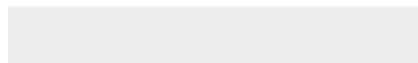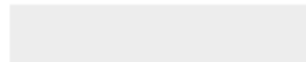
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Ankle Fusion with Tibiotalocalcaneal Retrograde Nail for Fragility Ankle Fractures: Outcomes at a Major Trauma Centre

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