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Tibiotalocalcaneal nailing for osteoporotic ankle fractures in the frail patient: a narrative review with a clinical score proposal for the decision-making process

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- Osteoporotic ankle fractures result from mechanical forces that would not ordinarily result in fracture, known as 'low-energy' trauma, such as those equivalent to a fall from a standing height or less.
- Osteoporotic ankle fractures in frail patients are becoming more and more frequent in daily practice and represent a therapeutic challenge for orthopaedic surgeons.
- The main problems with frail patients are the poor condition of the soft tissues around the ankle, dependence for activities of daily living and high comorbidity.
- The decision to operate on these patients is complex because conservative treatment is poorly tolerated in unstable fractures and conventional open reduction and internal fixation is associated with a high rate of complications.
- The authors conducted a narrative review of the literature on primary tibiotalocalcaneal nailing of ankle fractures in frail patients and categorized the different factors to consider when treatment is indicated for this conditon. Difficulty of ambulation, age over 65 years old, deteriorated baseline state and instability of the fracture were the most frequently considered factors.
- Finally, the authors propose an easy and quick clinical scoring system to help in the decision-making process, although further comparative studies are required to explore its validity.

Keywords

- ankle fracture
- osteoporotic ankle fracture
- tibiotalocalcaneal nailing (TTC nailing)

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Introduction

Low-energy fractures result from mechanical forces that would not ordinarily result in fracture, also known as 'low-energy' trauma, such as those equivalent to a fall from a standing height or less. These are fractures strongly related to osteoporosis affecting mainly the hip, spine, and distal radius, but also the distal tibia and ankle (1, 2). The definition of a 'frail patient' goes beyond osteoporosis itself and it is defined as one with greater vulnerability associated with a degeneration related to aging that affects the psychological, physical and social sphere. Therefore, the concept of fragility fracture implies not only a deterioration of the bone structure (osteoporosis) and soft tissues but also the physical condition of the patient.

Frailty is accelerating with the aging of the population, affecting between 25 and 50% of adults aged 85 years (1, 2, 3, 4, 5), consequently, osteoporotic ankle fractures in frail patients are increasingly frequent in daily practice. The decision to operate on these patients is complex and must be assessed case by case, although the literature has highlighted two aspects: conservative treatment is poorly

tolerated in unstable fractures and conventional open reduction and internal fixation (ORIF) is associated with a high rate of complications (1, 2, 3, 4).

Acute tibiotalocalcaneal (TTC) nailing has been used to treat osteoporotic ankle fractures with good results since 2005 (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11), especially in frail patients, and, although several risk factors have been described in the literature as predictors of adverse effects after ankle ORIF (12), no specific inclusion criteria have been identified to opt for this surgical treatment.

This article provides an updated narrative review on this topic and proposes a clinical score system based on clinical factors to help orthopaedic surgeons in the decision-making process.

Methodology

First, a narrative review of the literature was conducted (Table 1) using a simple search strategy that included the following terms: nail and ankle fracture for the first search, and tibiotalocalcaneal nail and ankle fracture for the second search (Table 1) and was conducted independently by two authors. After applying the eligibility criteria, we finally identified and reviewed 11 articles (Tables 2 and 3): ten had an evidence level of IV and only one had a level of II (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11).

Secondly, the authors have attempted to design an easy and quick clinical scoring system to help in the decision-making process when dealing with osteoporotic ankle fractures in frail patients.

Narrative review results

Lemon *et al.* (7) published the first article using TTC nailing for osteoporotic ankle fractures in 2005 reporting good functional results and highlighting that all patients achieved early full weight-bearing. However, the only inclusion criteria that led to treating them with nailing was an unstable fracture pattern (supramalleolar or trimalleolar fracture).

In 2008, Amirfeyz *et al.* (2) published a retrospective study of 13 patients with an average age of 79 years and a follow-up period of 11 months showing functional results similar to the pre-fracture status. This study clearly defined specific inclusion criteria: age of over 60 and frail physical state, poor bone stock, poor soft tissue around the ankle and an unstable fracture pattern.

In 2010, O'Daly *et al.* (8) published a series of nine cases of fragility-related ankle fractures treated with TTC nailing after the failure of conservative treatment with closed manipulation. These authors found fracture healing in 89% of cases. The previous functional level was restored in 70% of patients.

Table 1 Search keywords of Medline-Pubmed.

Search number	Keywords	Number of articles
Search 1	Nail and ankle fracture	668
Search 2	Tibiotalocalcaneal nail and ankle fracture	89
Combined Search		84

In 2013, Jonas *et al.* (6) published a series of 31 patients who underwent this method after presenting with unstable ankle fractures. Although the inclusion criteria were not well defined, they were the first authors to assess previous mobility, the pre-existing morbidity, the state of the soft tissue, and the degree of patient compliance. Despite showing good functional results, they found a high percentage of complications (38.7%) linked to three peri-implant fractures and two nail failures, thus highlighting the fact that the more active the patient is, the higher the rate of failure when treated with this method.

In 2014, Al-Nammari *et al.* (1) published a retrospective study of 48 frail patients, with an average age of 82 years, treated with long retrograde femoral nailing. The inclusion criteria were an American Society of Anesthesiologists (ASA) (Table 4) classification greater than 3, severe comorbidity and the inability to walk independently for more than 200 m, poor bone stock and patients physically and/or mentally too frail to manage restricted weight-bearing postoperatively. In their series, these authors recommended the use of long nails which pass through the isthmus of the tibia to avoid peri-implant fractures. Their results showed that 90% of cases had returned to their previous functional level. However, a high percentage of complications were recorded: deep infection (2%), valgus malunion (4%), and other medical complications (29%). Additionally, one patient had to undergo a below-knee amputation.

In 2016, Taylor *et al.* (10) published a retrospective study of 31 patients with a mean age of 63 years and a follow-up period of 13.6 months. Although these authors did not clearly define the inclusion criteria, they did highlight obesity and diabetes as risk factors. In 90.3% of cases, fractures healed and the functional results were also very satisfactory.

Georgiannos *et al.* (5) published the only prospective and randomized comparative study between ORIF and TTC nailing. In this article, the inclusion criteria for both treatments were patients over 70 years of age presenting

Table 2 Eligibility criteria.

Inclusion criteria	Exclusion criteria
Patients over 65 years	Case reports
Use of a tibiotalocalcaneal nail	Cadaver studies
6 months of minimum follow-up	Biomechanical studies
Reporting of clinical outcomes	
English, German or Spanish language	

Table 3 Summary of selected articles highlighting TTC nailing for fragility ankle fractures.

Reference	Type	LOE	Sample	Age	Inclusion criteria	Nail	Postop WB	FU (months)	Complications
Lemon *et al.* (7)	RT	IV	12	84	Unstable fracture pattern	Long expandable humeral nail	Full	16	8.3%: three DVT
Amirfeyz *et al.* (2)	RT	IV	13	78.9	Age >60; frail physical state; poor bone stock; poor ankle soft tissues; Unstable fracture pattern; failed primary ORIF.	Humeral nail and TTC nail	Partial	11	7.7%: one minor wound breakdown one delayed union
O´Daly *et al.* (8)	RT	IV	9	81	Ankle fragility fractures; failed conservative treatment	Long humeral nail	Full	34	No
Jonas 2013 (12)	RT	IV	31	77	Fragility ankle or distal tibia fracture; patient´s mobility; patient´s morbidity; patient´s compliance with NWB; unstable fracture pattern.	TTC nail	Full	18	38.7%: two periimplant fractures; two broken nails
Al-Nammari *et al.* (1)	RT	IV	48	82	Physically and/or mentally frail; restricted mobility; poor bone stock; ASA score > 3	Long femoral nail	Full	6	47%: two superficial infections, one deep infection, three broken distal screw, two valgus malunion, one BKA
Taylor *et al.* (10)	RT	IV	31	63	Ankle or pilon low-energy fractures.	TTC nail	*Full/Partial	13.6	29.1%: three Implant failures, two superficial infections, three deep infections, one BKA
Georgiannos *et al.* (5)	PT	II	37	78	Over 70 years of age; unstable fracture pattern.	TTC nail	Full	12	8.1%: one superficial infection, one DVT, one Protrusion of the nail
Persigant *et al.* (9)	RT	IV	14	79.6	Over 65 years of age; Restricted mobility (walking distance < 500 meters); ASA score ≥ 2.	Long femoral nail	Full	12	20%: one deep infection, one distal screw loosening
Baker *et al.* (3)	RT	IV	16	73	Poor baseline mobility; unstable fracture pattern; unsuitable for standard ORIF or external fixation	Long femoral nail	Non WB 10—10days10 days (then full WB)	21	Nr
Ebaugh *et al.* (4)	RT	IV	27	66	Ankle fracture; Complicated diabetes	TTC nail	Non WB until healing of plantar wound (then full WB)	29.6	18.5%: one superficial infection, three deep infections, one nail failure, one AKA
Herrera-Perez *et al.* (11)	RT	IV	17	81.5	Over 65 years of age. Periarticular fragility ankle fracture.	TTC nail	Full	20.9	23,5%: one distal screw loosening, one painful subtalar nonunion, one superficial infection

*According to surgeon preference.
AKA, above-knee amputation; ASA, Functional score from the American Society of Anaesthesiology; BKA, below-knee amputation; DVT, deep vein thrombosis; FU, follow-up; LOE, level of evidence; Nr, non reported; NWB, Non-weight-bearing; ORIF, open reduction and internal fixation; PT, prospective; RT, retrospective; TTC, tibiotalocalcaneal; WB; weight-bearing.

Table 4 **American Society of Anaesthesiologists Physical Status Classification** (ASA Classification).

ASA 1	Healthy patient without organic, biochemical or psychiatric disease.
ASA 2	A patient with mild systemic disease. No significant impact on daily activity. Unlikely impact on anaesthesia and surgery.
ASA 3	Significant or severe systemic disease that limits normal activity. Significant impact on daily activity. Likely impact on anaesthesia and surgery.
ASA 4	Severe disease that is a constant threat to life or requires intensive therapy. Serious limitation of daily activity. Major impact on anaesthesia and surgery.
ASA 5	Moribund patient that is likely to die in the next 24 h with or without surgery.
ASA 6	Brain-dead organ donor.

with closed bimalleolar or trimalleolar fractures and ankle fracture dislocation. They studied 37 patients with an average age of 78 years. The functional results were similar in both groups (TTC nailing vs ORIF), although the time spent in hospital, the complication rate, and the mortality rate were lower in the nailing group.

Baker *et al.* (3) published their results from a series of patients with three or more comorbidities, all of them with unstable ankle fractures. Other inclusion criteria were poor baseline mobility and patients considered unsuitable for standard ORIF or external fixation. The good results reported were notable.

Persigant *et al.* (9) published their results from a series of 14 patients treated with retrograde femoral nailing and immediate weight-bearing with an average follow-up of 12 months. These authors found satisfactory functional results as well as healing of the fractures and only one major complication (deep infection that required removal of the nail).

In 2019, Ebaugh *et al.* (4) published their series of 27 patients with complicated diabetes treated with this method. These authors reported good functional results, with restoration of the same level of autonomy that patients used to have, limb salvage, as well as few complications.

In 2020, Herrera-Pérez *et al.* published the results of a series of 17 patients treated with primary TTC nailing (11). The inclusion criteria were age >65 years, periarticular fragility-related fracture of the ankle and surgical treatment with TTC nailing at the surgeon's discretion, with a follow-up of at least six months. Despite the high prevalence of diabetes (11 of 17 patients), there was only one superficial infection and no deep infection with very good functional results.

Surgical technique description

All the authors used solid nails except Lemon (7), who used an expandable nail. The nail was inserted without preparing the joint surfaces (subtalar and tibiotalar), so, no cartilage removal or joint surface refreshment was done in any case (Fig. 1).

Discussion

The most important findings of the present review are, first, that TTC nailing seems to be a valid surgical technique in unstable periarticular osteoporotic ankle fractures in selected frail patients (2, 6, 7, 8); secondly, that the decision to perform a TTC nailing is often arbitrary, the scientific evidence is weak and there are no clear indications that would incline the treating doctor towards an ORIF or a TTC nailing, bearing in mind that conservative treatment is usually poorly tolerated, especially in unstable fractures. In view of the increasing need for decision-making algorithms or clinical scores in clinical practice, we have analysed separately each risk factor evaluated in the 11 articles considered herein.

Figure 1
Final result after TTC nailing without addressing the joint surfaces (look at the entry point in the sole of the foot).

Ambulation capacity

This factor was highlighted by 9 of the 11 articles reviewed (Table 3). Retrograde nail will impede mobility in the ankle and in the subtalar joint, thus meaning that this treatment is not indicated for patients who ambulated either independently or with minor walking aid prior to the fracture, and for whom the objective should be to restore this level of mobility.

Age

This factor was highlighted by 6 of the 11 articles reviewed (Table 3). Age is an important factor to consider when making a radical decision about the future of the ankle joint, the cut-off being at 65 years. On the other hand, it is also important to highlight that biological age itself is an independent risk factor that has been well defined in terms of the occurrence of complications. Belmont *et al.* (12) reported that, in hospitalized patients over 70 years of age, there is an increase in both the percentage of complications and the average hospital stay after being treated for ankle fractures. Similarly, Dodd *et al.* reported that being over 65 years of age already increases the risk of complications significantly, particularly when associated with a deterioration of the mental state (13).

Comorbidity – risks of anaesthesia

Seven of the 11 articles mention the baseline of the patients as an important inclusion criterion for the TTC nailing. The presence of associated comorbidity significantly increases perioperative complications, as described by multiple authors (7, 14), with an emphasis on patients who live in nursing homes. Thus, Schray *et al.* (14) reported that orthogeriatric patients must receive special care due to the high rate of complications. With regards to the presence of comorbidity, Charlson's comorbidity index (15), which is accepted internationally, is a system for assessing life expectancy for the following 10 years depending on the age at which the assessment is carried out and the individual's comorbidity. In addition to age, it includes 19 other factors which, if present, have been proven to specifically impact an individual's life expectancy. Although we recognise the validity of this index and its universal acceptance, we did not find it practical enough for quick decision-making given that many of these patients must receive urgent treatment. Thus, we opted for the ASA classification for anaesthetic risk, devised by the ASA (Table 4) (16), which is a widely used system for categorising the preoperative status of patients and is a good independent predictor of perioperative morbidity and mortality. Further, authors such as Belmont *et al.* (12), Dodd *et al.* (13), and Basques *et al.* (17) have reported that an ASA score >3 is linked to higher morbidity and mortality, whereas other authors such as Varenne *et al.* (18) consider an ASA score >2 to already be an important risk factor for complications after surgery for an ankle fracture. Finally, in the meta-analysis conducted by Shao *et al.* in 2018, an ASA score >3 was also considered to be a bad prognosis risk factor (19).

Diabetes – obesity

Diabetes and obesity, which often go hand in hand, are highlighted in many publications as important risk factors for complications. Basques *et al.* identified insulin-dependent diabetes mellitus and a high ASA score as independent risk factors which increase morbidity and readmission rates of patients after conventional osteosynthesis of ankle fractures (17). Diabetes is especially dangerous in the case of poor glycaemic control (defined as HbA1c >7.5) or diabetes with complications (diabetic nephropathy, retinopathy and/or diabetic vasculopathy) (17). Subsequently, Dodd *et al.* published an interesting article in 2016 analysing 6800 patients treated for ankle fractures and defined the following risk factors for complications 30 days after surgery: ASA score >2, BMI >30, dependent performance status, diabetes and type of surgery (13). Lanzetti *et al.* reported a longer delay in wound healing and an increase in complications in young diabetic patients with a BMI >30 treated for bimalleolar fracture (20). Similarly, Haddix *et al.* (21) and Stavem *et al.* (22) showed that a significant increase in complications is found among insulin-dependent diabetics. In summary, poorly controlled diabetes, and morbid obesity (BMI> 30) are independent risk factors for a poor outcome with conventional osteosynthesis. On the other hand, both factors are usually associated with the same patient and further deteriorate the prognosis.

Dementia – non-compliance with treatment orders

Deterioration of the mental state is more prevalent in elderly patients and directly linked to the ability to follow postoperative orders. In this regard, Fong *et al.* published an interesting study in more than 2000 patients over 80 years of age in which they assessed how patients who did not follow orders due to some type of mental deterioration showed more complications (23).

Open fractures

Although it has been considered by only 3 of the 11 articles studies, open ankle fractures result in an increased percentage of surgical site infections and must be considered a relevant risk factor for a bad result. The meta-analysis carried out by Shao *et al.*, published in 2018, which included over 80 000 patients, shows that the rate of infection is higher in patients with open and unstable fractures (19). The infection percentage is also higher in open fractures above grade I in Gustilo and Anderson's classification (24), as described by Belmont *et al.* (12) In their analysis of over 57 000 patients treated with ankle

ORIF, SooHoo *et al.* also identified open fracture as an independent risk factor linked to a bad prognosis (25).

Fracture stability

The instability of the fracture has been considered an inclusion criterion in 6 of the 11 articles studied. Unstable ankle fractures are those which cannot be properly controlled using closed reduction and cast immobilization, thus meaning that they are more likely to develop local complications (ulceration, loss of reduction, etc.). Therefore, in frail patients with risk of complications for whom orthopaedic treatment has been attempted after fracture manipulation, this treatment is more likely to fail if the fracture is unstable (Figs 2 and 3). These fractures include any fracture with failed conservative treatment, ankle fracture dislocation, bi- or trimalleolar fracture, and comminuted fracture of the tibial pylon or distal tibia. Many authors consider this pattern of instability to be a criterion against conservative treatment (2, 3, 20, 25).

Soft tissue

The state of the soft tissue is mentioned in 4 of the 11 articles reviewed. As outlined in the original publication by Tscherne & Oestern (26), the severity of the resulting soft tissue damage increases in higher-energy fracture patterns from values of C0–C3 (Figs 4 and 5).

The following risk factors have not been mentioned in all the articles reviewed, but we consider that they are also relevant when making decisions, because they all have been reported as predictors of bad functional outcomes when considering ORIF (13, 14).

Previous degenerative arthropathy of the ankle

Although the prevalence of this disease is unknown in frail elderly patients (27), when present and symptomatic, it

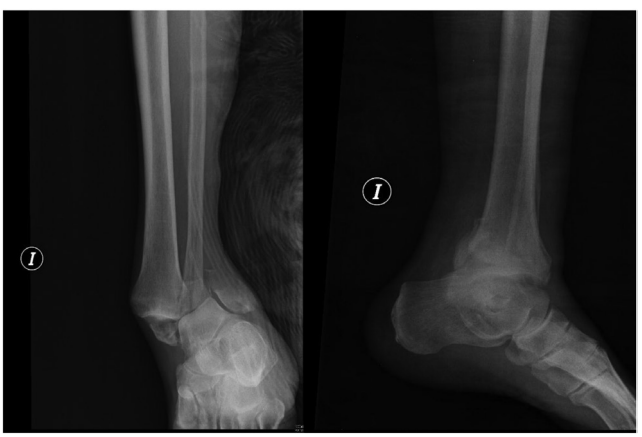

Figure 2
An 86-year-old woman sustained an unstable ankle fracture (ankle fracture dislocation).

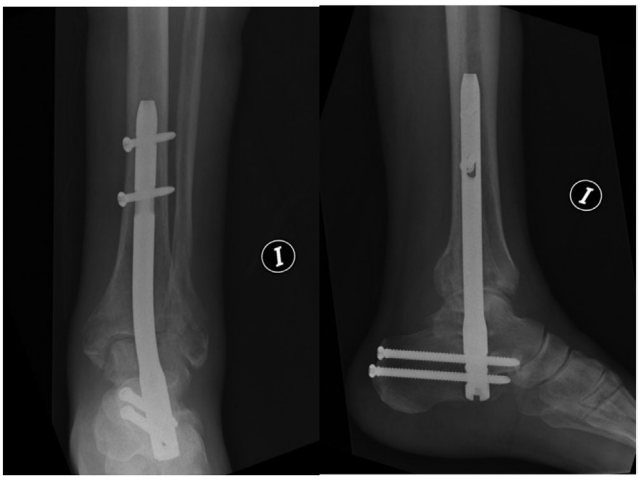

Figure 3
Same case as Fig. 2: satisfactory X-ray control at 3 months follow-up after acute TTC nailing.

Figure 4
Lateral aspect of the distal foot and ankle showing the bad condition of the soft tissues in a 83-years-old diabetic woman.

Figure 5
Same case as Fig. 4: medial aspect of the foot and ankle.

presents with painful limitation of mobility in the ankle. As such, pre-existing ankle osteoarthritis is a clinical factor in favour of TTC nailing.

Alcohol abuse and/or smoking

Alcohol and tobacco abuse have been widely studied as independent risk factors in the development of complications after ankle ORIF (28, 29, 30, 31).

Peripheral vascular insufficiency

The existing link between the delay in wound healing and superficial and/or deep infection after ankle ORIF in patients with peripheral vascular disease has been well documented (12, 23, 32, 33).

Indications for TTC nailing for fragility-related ankle fractures in frail patients

With the current available evidence, it is not possible to make a closed algorithm, nor is it possible to weigh all the factors to be considered. However, to assist the orthopaedic surgeon in the decision-making process, we have subdivided it into three groups, depending on how many times the criterion has been mentioned in the articles reviewed. They are divided into essential criteria (cited in the majority of the articles included in the revision), major criteria (cited in >50% of the articles) and minor criteria (cited in <50%).

Essential criterion Non-ambulatory patient or with assisted ambulation (crutches, walking stick or walker) for less than 200 m.

Major criteria

1. Age >65 years or <65 diagnosed with severe osteoporosis (associated with chronic kidney insufficiency, hyperparathyroidism, etc.), fracture dislocation or comminuted fracture due to the low-energy mechanism.
2. ASA classification >3.
3. Poorly controlled diabetes (defined as HbA1c >7.5) or diabetes with complications (defined as diabetic nephropathy, retinopathy and/or diabetic vasculopathy) and/or morbid obesity (BMI >30).
4. Unstable fracture pattern: any fracture with failed conservative treatment, ankle fracture dislocation, bi- or trimalleolar fracture, comminuted fracture of tibial pylon or distal tibia.

Minor criteria

1. Well-controlled diabetes or diabetes without complications and/or BMI 25–30.
2. Mentally or physically challenged patient.
3. Open fracture above Gustilo's grade I.
4. Soft tissue damage (Tscherne score ≥2).
5. Previous degenerative arthropathy of the ankle.
6. Alcohol abuse and/or smoking.
7. Peripheral vascular insufficiency.

Last but not the least from a practical point of view, although it is not the main objective of this review, the authors have designed the so-called RETRO SCORE as a clinical score that aims to be useful in decision-making in these especially complex cases. For this purpose and based on the specific weight of the relative frequency of each risk factor published in the reviewed articles and taking into account the literature on the complications of conventional osteosynthesis in especially fragile patients, we consider TTC nailing to be performed if:

- The essential criterion of limited mobility is present, as well as
- Three major criteria or
- Two major criteria and four minor criteria.

If the essential criterion of limited mobility is present, but the other two points are not met, the indication of TTC nailing must be assessed in each patient individually.

This study has several strengths and weaknesses that should be highlighted. Perhaps the main limitation of the present study is the lack of a comparative study between ORIF and TTC nailing before adopting the score proposed, although is the intention of the authors to begin a randomized comparative study based on this methodology. Another important limitation of the present work is the low level of evidence of the studies included in the narrative review (10 of 11 are level IV), therefore, the conclusions derived from this work should be interpreted with caution. Furthermore, the proposed scoring system has not been validated yet, although it has been used in three different centres so far (11).

On the other hand, the main strength of this work is that it addresses a difficult scenario and tries to help the orthopedic surgeon to make a decision on the definitive management in the acute setting. Although the proposed clinical score does not claim to be dogmatic, it does seek to identify the main risk factors to take into account when considering the final solution for this frail population, always bearing in mind that the final decision must be individualized for each case and that TTC nailing should still be considered as a salvage procedure in cases where all other surgical options would be of high risk and have been discarded.

Conclusions

Acute TTC nailing for treating frailty-related ankle fractures is a valid surgical treatment in selected cases. Although scientific evidence is weak and there are no clear indications to opt for this treatment over ORIF or conservative treatment, we have identified that the difficulty with ambulation, age over 65 years old, the deteriorated baseline state and the instability of the fracture, are the most frequent risk factors considered at the time of choosing the TTC nailing. The authors have attempted to define an easy and quick clinical scoring system to help in the decision-making process, although TTC should be still considered a salvage procedure in cases where all the other surgical options would be of high risk. Finally, further comparative studies between ORIF and TTC nailing are desirable to explore its validity.

ICMJE Conflict of Interest Statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the work reported.

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