

Research Article

Sinus Tarsi approach and percutaneous nailing of dislocated intraarticular calcaneus fractures. Results of retrospective two-center study

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Abstract...

Objective: Displaced Intraarticular Calcaneal Fractures (DIACFs) present a challenging treatment scenario, with outcomes heavily dependent on the surgical approach and fixation method. Minimally invasive techniques, such as the Sinus Tarsi Approach (STA) combined with C-nailing, have gained attention for potentially reducing complications compared to the Extended Lateral Approach (ELA) with plate fixation.

Methods: This retrospective, comparative study aims to compare (at Level of Evidence III) the outcomes of 308 DIACEF surgeries performed using STA combined with C-nailing at two independent trauma centres in the Czech Republic, EU, A-GROUP with results published in relevant literature on DIACEFs treated with ELA and plate osteosynthesis or other nailing systems. Literature with more than 100 cases published since year 2000 were used for comparison, B-GROUP.

Postoperative outcomes in A-group were assessed based on complications, restoration of Bohler's angle, and reconstruction of the posterior joint surface, using X-rays and CT scans at postoperative and 12-month follow-up. Functional outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Scale. The same parameters were found in studies of B-group for comparison.

Results: The results of our study A-group, compared with weighted average results of enlisted studies in B-group are as follows (A-group/B-group): AOFAS: 91.4 / 74.1, Infection superficial 1.4%/ 6.73%, Infection deep 0.3% / 5.21%, other complications requiring surgery 0.4% / 8.6%). Bohler's angle improved from an average of +8.1° preoperatively to +29.8° postoperatively in A-group.

Conclusion: Compared to ELA with plate fixation, the combination of C-nailing and STA significantly reduces the risk of soft tissue and bone-related complications. The high biomechanical stability provided by C-nailing, coupled with minimal soft tissue disruption, contributes to the low complication rates, even in cases involving open fractures, diabetes, or smoking history.

Keywords: Intraarticular calcaneal fracture; Sinus Tarsi approach; Locking calcaneal nail; C-nail.

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Introduction

In managing Displaced Intraarticular Calcaneal Fractures (DIACFs), Open Reduction and Internal Fixation (ORIF) has become the standard approach, with significant advantages over conservative treatment. This shift was supported by the pioneering work of Griffin et al. in 2014, who demonstrated superior outcomes with ORIF. However, many studies have shown that ORIF techniques, particularly those involving the Extended Lateral Approach (ELA) and locking plate fixation, became more widely accepted in the 1980s following the introduction of Computed Tomography (CT) for fracture assessment. CT scanning enabled a more detailed understanding of fracture pathology, ushering in a paradigm shift in DIACF management [1–14] (Figure 1a, 1b).

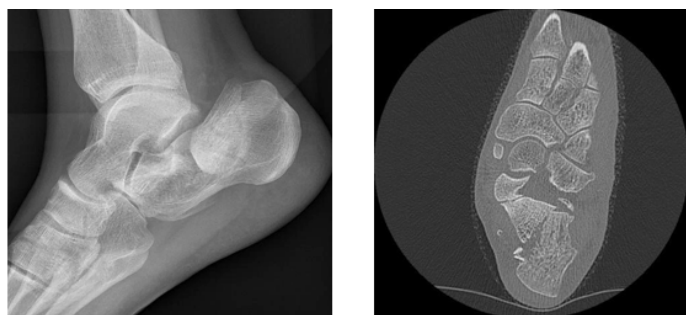


Figure 1: (A) Preoperative calcaneal fracture, tongue type, with a Böhler's angle of -10° ; (B) Preoperative CT scan of a Sanders Type IIIAC fracture.

Despite the widespread adoption of ELA for anatomic reduction, the international literature continues to debate the optimal approach for achieving good long-term outcomes while minimizing complications associated with ELA. Operative-related complications, such as wound healing issues, are prevalent with the use of ELA, prompting a re-examination of less invasive techniques [15–27]. One promising alternative is the small sinus Tarsi Approach (STA), which aims to reduce soft tissue complications while allowing for adequate anatomic reduction and stable osteosynthesis. This technique has gained attention for potentially lowering complication rates compared to ELA [19–27].

The development of minimally invasive procedures, including the STA combined with Closed Reduction and Internal Fixation (CRIF) principles and percutaneous screw insertion, offers a viable strategy to reduce soft tissue damage. In recent years, interlocking calcaneal nails (such as C-Nail®, Calca-Nail®, and Ni-Nail®), which have been in clinical practice since 2011, present another mini-invasive option for stabilizing DIACFs. These implants have demonstrated comparable or superior biomechanical stability to traditional locking plates in experimental studies on cadaveric models [28–45].

Given these evolving techniques, the present study assesses whether a sinus tarsi approach with percutaneous nailing can minimize complications while maintaining the benefits of stable fixation and anatomic reconstruction. By conducting a two-center analysis, this research seeks to identify the ideal operative treatment strategy that optimizes clinical outcomes while reducing the risk of operative-related complications.

Materials and methods

Approach

The minimally invasive sinus tarsi approach was used for all patients. This involved making a straight incision, 3–5 cm in length, starting below the tip of the fibula and extending towards the base of the fourth metatarsal. This approach provided direct visualization of the subtalar joint, which, in rare cases, appeared to widen distally.

Reduction technique

The reduction of the posterior facet was initiated by applying a stainless-steel calcaneal distraction device laterally. One Schanz screw was placed into the tuber calcanei from the lateral aspect, and the other was positioned in the distal tibia. This setup facilitated the reduction and provided better visualization of the subtalar joint. The distraction device allowed correction of the calcaneal alignment, including the length, height, and width, while restoring the correct hindfoot angle, which was checked using fluoroscopic axial projection (Figure 2a–2c).

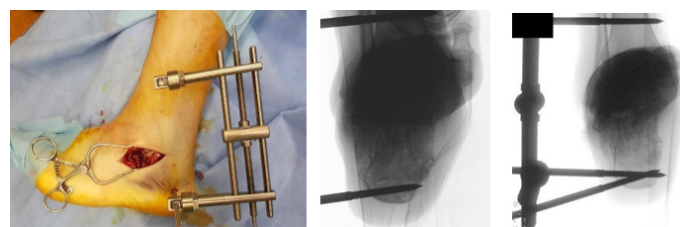


Figure 2: (A) Intraoperative view showing the sinus tarsi approach with the calcaneal distraction device in place; (B) Axial view before reduction, showing valgus malposition; (C) Axial view after distraction and reduction, with the corrected calcaneal axis.

The posterior facet was anatomically restored from the medial to lateral side. For cases involving Mult fragmented posterior facets, the K-wire “inside-out-inside” technique was employed to secure the fragments. Once the posterior facet and Böhler's angle were appropriately reduced, the fragments were temporarily fixed using two Kirschner wires from the tuber calcanei into the talus, one placed medially and the other laterally. The distraction device was then removed, and the Schanz screws were extracted, allowing the commencement of the C-nail procedure.

C-Nail insertion

A horizontal incision, approximately 10–15 mm in length, was made on the dorsal side of the calcaneus, just below the Achilles tendon insertion. The guidewire was introduced slightly laterally from the tuber's central axis, following the calcaneus's longitudinal axis, and aimed at the center of the Calcaneus-Cuboid (CC) joint. Under fluoroscopic C-arm guidance, both lateral and dorsoplantar views confirmed the optimal positioning of the guidewire. A cannulated drill was then used to create a pathway for the C-nail, stopping 5 mm before the CC joint (Figure 3).

The C-nail, attached to a three-armed aiming device, was inserted using slight rotational movements. Guide sleeves were fitted onto the targeting device, and the first guide wire was introduced through the “sustentacular arm” into the sustentaculum tali. Proper positioning was verified

fluoroscopically. A second guide wire was introduced once the first guide wire was correctly placed. If adjustments were needed, the nail was rotated slightly. The guide wires were then replaced by screws of appropriate length, securing the sustentaculum. The remaining screws were inserted through the “superior arm” and “lateral arm,” securing the implant in multiple planes. An end cap was applied flush with the bone, a suction drain was placed, and the incisions were closed. The procedure concluded with intraoperative X-ray confirmation in four planes. Postoperatively, an X-ray and a CT scan are performed (Figure 4).



Figure 3: C-Nail aiming device positioned during the procedure.

Postoperative care

Postoperatively, no cast was applied; an elastic bandage was used, and the lower leg was elevated. All patients were administered Low-Molecular-Weight Heparin (LMWH) prophylactic doses for one month. Active range of motion exercises began on the first postoperative day under physiotherapeutic guidance. The suction drain was removed on the second postoperative day. Before hospital discharge, a postoperative CT scan was performed for quality control. Partial weight bearing of approximately 20 kg on the operated limb was recommended for the first six weeks.

Results

Patient demographics and clinical characteristics

A total of 290 patients, accounting for 308 Displaced Intraarticular Calcaneal Fractures (DIACFs), underwent surgical treatment using the Sinus Tarsi Approach (STA) with C-nail between 2011 and 2021. The age of patients ranged from 17 to 87 years, with a mean of 47.4 years (SD±13.3). The cohort consisted predominantly of male patients (89.7%, n=260), while females comprised 10.3% (n=30). Nearly half of the patients (49.0%) were cigarette smokers, and 8.6% (n=25) had type I or II diabetes mellitus. The average time from admission to surgery was 5 days, from 0 to 23 days. The mean duration of hospital stay was 7.8 days (range: 3-63 days). Detailed demographic and clinical characteristics are summarized in Table 1.

Table 1: Patient demographics and clinical characteristics.

The main characteristics of 290 patients with 308 intraarticular calcaneal fractures were treated with the sinus tarsi approach and C-nail.

Variable	Value
Age (years)	17–87, Mean: 47.4, SD±13.3
Sex	
Male	260 (89.7%)
Female	30 (10.3%)
Cigarette Smoker	
Yes	142 (49.0%)
No	148 (51.0%)
Diabetes Mellitus	
Yes	25 (8.6%)
No	265 (91.4%)
Bilateral Calcaneal Fractures	
Yes	18 (6.2%)
No	272 (93.8%)
Admission to surgery (days)	0–23, Mean: 5
Hospital Stay (days)	3–63, Mean: 7.8

Radiological and CT data preoperative and postoperative

Fractures were classified preoperatively using the Sanders classification system, with most cases falling under Type IIA (33.1%, n=102). The distribution of fracture classifications is presented in Table 2. Additionally, six cases (1.6%) of open fractures were classified according to the Gustilo-Anderson system, while the soft tissue status was assessed using the Tscherne-Oestern classification.

Radiological assessments significantly improved Böhler's angle and articular step-off after surgery. The average reoperative Bohler's angle was 8.1° (SD±13.2), which increased to 29.8° (SD±9.1) postoperatively. At the 1-year follow-up, the mean Bohler's angle decreased slightly to 27.5° (SD±10.0). The average articular step-off before surgery was 5.9 mm (SD±4.8), reduced to 0.9 mm (SD±1.4) postoperatively. The detailed measurements are provided in Table 3.

Table 2: Sanders classification and soft tissue damage.

Classification of 308 calcaneal fractures based on Sanders, Gustilo-Anderson, and Tscherne-Oestern systems.

Classification	n	Percentage (%)
Sanders Classification		
Type I	19	6.2
Type IIA	102	33.1
Type IIB	72	23.4
Type IIC	16	5.2
Type IIIAB	41	13.3
Type IIIAC	18	5.9
Type IIIBC	16	5.2
Type IV	24	7.8
Gustilo-Anderson Classification		
Type I	1	0.3
Type II	3	1.0
Type IIIa	1	0.3
Type IIIb	1	0.3
Tscherne-Oestern Classification		
Grade 0	35	11.4
Grade I	156	50.6
Grade II	110	35.7
Grade III	1	0.3

Table 3: Radiological measurements of calcaneal fractures. Radiological parameters were measured preoperatively, postoperatively, and at the 1-year follow-up.

Parameter	Average	SD	Min	Max
Bohler's Angle				
Preoperative	8.1°	± 13.2	-60°	40°
Postoperative	29.8°	± 9.1	15°	40°
12 Months Follow-up	27.5°	± 10.0	15°	40°
Articular Step-Off				
Preoperative	5.9 mm	± 4.8	0 mm	30 mm
Postoperative	0.9 mm	± 1.4	0 mm	10 mm

Early postoperative outcomes

Early postoperative complications were relatively low. There were no cases of sural nerve injury. Marginal necrosis of the incision occurred in 1.4% (n=4), and superficial infections were also noted in 1.4% (n=4) of the cases. One patient (0.3%) experienced a deep infection with *Staphylococcus aureus*, which required C-nail removal, debridement, and antibiotic therapy. Twelve patients (3.9%) elected to have the C-nail removed, while hardware removal was indicated in five cases (1.6%) due to pain or potential allergic reactions.

Results at 1-year follow-up

At the 1-year follow-up, 210 patients (72.4%) with 228 nails were assessed, as 80 patients (27.6%) were lost to follow-up. The average AOFAS score at 12 months was 91.4 points (SD±9.1). A significant correlation between fracture severity (according to Sander's classification) and functional outcomes was observed. Patients with Sanders Type I fractures achieved the highest average AOFAS score (94.5), while those with Type IV fractures had lower scores (86.8). Detailed results are shown in Table 4.

Posttraumatic arthrosis the subtalar of joint was diagnosed in six cases (2.9%), and one patient (0.4%) required secondary subtalar arthrodesis due to severe pain.

There are no data available for step-off at 1 year follow up.

Table 4: Functional results based on AOFAS scores at 1-year follow-up. Outcomes according to the Sanders classification of calcaneal fractures after 12 months.

Sanders Type	n (12 months)	AOFAS Score (Mean)
I	12	94.5
II (A, B, C)	142	92.5
III (AB, AC, BC)	57	89.4
IV	17	86.8

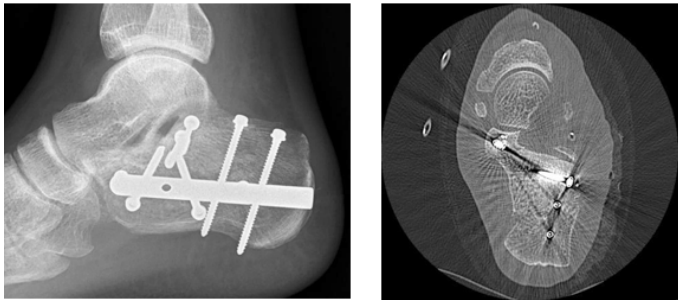


Figure 4: (A) Postoperative X-ray demonstrating the inserted C-Nail, with a corrected Böhler's angle of +35°; (B) Postoperative CT scan demonstrating successful reduction and fixation.

Discussion

Comparative analysis of postoperative complications and functional outcomes

A comparative analysis of postoperative complications and functional scores between STA with C-nail and the Extended Lateral Approach (ELA) with plate fixation revealed lower rates of superficial and deep infections in patients treated with STA and C-nail. The AOFAS scores were also higher in studies using STA and C-nail compared to ELA and plate fixation. Table 5 provides a detailed comparison of outcomes across different studies.

Table 5: Comparison of postoperative wound complications and functional outcomes. Comparing results of studies using the Extended Lateral Approach (ELA) and plate fixation versus the Sinus Tarsi Approach (STA) and C-nail.

Author (Year)	n	Superficial Infections (%)	Deep Infections (%)	Other Complications Requiring Surgery (%)	AOFAS Score
ELA + Plate Fixation					
Gaskill et al. (2010) [12]	158	2.5	5.7	10.8	75.0
Bergin et al. (2012) [13]	102	8.8	6.9	3.9	NA
Wu et al. (2012) [22]	170	7.1	1.2	2.4	NA
Ding et al. (2013) [10]	490	5.1	2.2	12.0	NA
Rammelt et al. (2013) [14]	149	NA	5.4	5.4	72.6
Backes et al. (2014) [8]	279	11.0	13.6	NA	NA
Sanders et al. (2014) [5]	108	NA	0.9	NA	75
STA + C-Nail					
Herlyn et al. (2019) [33]	20	5.0	-	-	70.3
Fourgeaux et al. (2019) [34]	26	0	3.8	11.5	79.0
Zwipp et al. (2016) [29]	106	1.9	0.9	0	92.6
Veliceasa et al. (2020) [36]	75	1.3	0	0	90.2
Pompach et al. (2021) [35]	265	0.8	0.4	0	90.5

The treatment of Displaced Intraarticular Calcaneal Fractures (DIACFs) is associated with various complications, often influenced by the choice of surgical approach and the stability of the fixation method. This section discusses how complications differ between the Extended Lateral Approach (ELA) and Sinus Tarsi Approach (STA), the stability of locking plates versus locking nails, and the impact of surgical techniques on long-term outcomes. The discussion also includes findings from biomechanical studies and recent literature comparing different fixation methods.

Extended lateral approach versus sinus tarsi approach (ELA vs. STA)

Meta-analyses comparing ELA and STA [46,47] have demonstrated that STA is associated with significantly fewer complications. Mehta et al. [46] reported a significant reduction in complications with STA ($p=0.0005$), including shorter operative times ($p=0.004$). The rates of wound necrosis (11.11% for ELA vs. 2.09% for STA), infections (6.56% for ELA vs. 0.8% for STA), and nerve injuries (2.69% for ELA vs. 0.96% for STA) were all lower with STA. Peng et al. [47] also highlighted the superiority of STA, citing fewer complications, better anatomical reduction, shorter surgical duration, and reduced hospital stay. The incidence of wound infections (9.21% for ELA vs. 2.63% for STA), flap necrosis (8.78% for ELA vs. 1.26% for STA), and nerve injuries (6.25% for ELA vs. 1.48% for STA) further supported the benefits of STA.

Stability of locking plates versus locking nails

a) Calcanail® versus AO Locking Plate

In a cadaveric study [40] using Sanders IIB fracture models, Calcanail showed significantly higher stiffness ($p=0.001$) and load-bearing capacity ($p=0.003$) compared to AO locking plates. While some specimens failed at loads below 200 N, the Calcanail provided superior stability.

b) Calcanail versus C-nail versus rimbus locking plate

A comparative study [41] using fresh frozen human calcanei found that both Calcanail and C-Nail were equal to Rimbus locking plates. The C-Nail exhibited superior performance in dynamic failure testing, with a failure rate of 14%, compared to 87.5% for Calcanail and 66% for Rimbus.

c) Modified calcanail test

A finite element study [42] demonstrated that adding a 3.5 mm screw to the Calcanail increased stability in Sanders IIB fracture models, effectively stabilizing the construct in the second plane.

d) Ni-Nail versus C-Nail

Following the modified Calcanail test findings, a new Ni-Nail design was developed. In a study using Sanders IIB fracture models [44], the Ni-Nail, featuring a third proximal hole to improve fixation of the sustentacular fragment, demonstrated comparable stability to the C-Nail. The von Mises stress on the screws was 27.92 MPa for Ni-Nail and 57.42 MPa for C-Nail, while the Ni-Nail showed 15.6% greater fracture displacement.

Early and late complications with ELA and plate fixation

Early complications: ELA and plate fixation are associated with a range of complications. Wound edge necrosis occurs in 2% to 25% of cases, superficial soft tissue infections in 2.5% to

20.1%, and deep infections in 0.9% to 13.6% [2-17]. Sural nerve damage is reported in up to 19% of cases [3]. Even with long-term follow-up, these methods yield an average AOFAS score of 75 points [5], but up to 12.0% of patients require additional surgical intervention for complications [10].

Late complications: In large patient series, Rammelt et al. [4] reported a 6.0% incidence of subtalar arthritis requiring secondary arthrodesis after 7.9 years, while Sanders et al. [5] found that 29% of patients needed subtalar fusion within 10 to 20 years post-surgery.

Complications associated with CRIF (K-wire or screw fixation)

Minimally invasive procedures like CRIF with K-wires have a 7% incidence of pin-tract infections and a 1.7% risk of deep bone infections [20]. When CRIF is combined with percutaneous screw fixation, the rate of deep infection ranges between 0% and 4% [21-27].

Complications with locking nails

a) Calcanail®

Studies on Calcanail have reported varying complication rates. Simon et al. [30] found an 18.5% rate of subtalar fusion at 12.3 months, while Fourgeaux et al. [34] reported a 23% complication rate over a 2.8-year follow-up, including osteomyelitis (3.8%) and Complex Regional Pain Syndrome (CRPS). Herlyn et al. [33] found significantly fewer complications with Calcanail (5%) compared to locking plates (50%).

b) C-Nail®

In a multi-center study of 108 cases treated with C-Nail, the complication rate was 2.8%, with superficial infections (1.9%) and deep infections (0.9%) [29]. More recent studies showed even lower complication rates, with Veliceasa et al. [36] reporting a 1.3% incidence of superficial infections and no deep infections or nerve damage in 75 cases. Pompach et al. [35] reported similar findings: superficial infections in 0.8% and deep infections in 0.4% of 265 cases.

Steinhausen et al. [37] compared C-Nail to ELA with plate fixation, finding a significantly lower complication rate in the C-Nail group (25%) versus the ELA group (51%). The C-Nail group had fewer cases of wound edge necrosis (6% vs. 37%, $p<0.001$), although the rates of superficial and deep infections (10% and 8%, respectively) were higher than in other studies.

Timing of C-nail surgery

In this study, C-Nail surgery was performed an average of 5 days post-injury, approximately 6 days earlier than typical ELA and plate fixation [2-17]. In cases of emergency, such as open fractures or acute compartment syndrome, immediate debridement and fixation were performed. This differs from the two-stage approach often used with ELA and plate fixation, potentially reducing the risk of compartment syndrome and soft tissue necrosis. If soft tissues are compromised (e.g., with blisters), surgery is delayed until the swelling subsides.

Comparison of outcomes: Calcanail versus C-Nail

a) C-Nail

In the present study of 308 cases treated with STA and C-Nail, no patients required primary fusion, and only 0.5% needed secondary subtalar fusion within a year. Similar

studies [29,35,36] reported AOFAS scores ranging from 90.2 to 92.6 after 12 months, with improvements in Böhler's angle comparable to the current findings (from 7.3° preoperatively to 31.2° postoperatively).

b) Calcanail

In contrast, studies on Calcanail [30,34] showed significantly higher subtalar fusion rates (18.5% within a year). This difference may be attributed to the routine use of STA or arthroscopy for joint inspection during C-Nail procedures, which allows for more precise anatomic reduction.

Outcomes related to Bohler's angle, AOFAS scores, and subtalar fusions

Herlyn et al. [33] reported an average postoperative Böhler's angle of 29.0° with Calcanail, decreasing to 23.9° over 1.6 years. In comparison, the present study showed a smaller decline from 29.8° to 27.5° at 12 months with C-Nail, indicating better maintenance of fracture reduction. Additionally, AOFAS scores were consistently higher for C-Nail (90.2–92.6) compared to Calcanail (70.3–79) [33,34].

Evidence in the treatment of DIACFs

A systematic review and meta-analysis [48] found no significant differences between ELA and STA in restoring Bohler's angle, calcaneal dimensions, or complication rates. However, two meta-analyses [46,47] demonstrated that STA significantly reduced complications. Biomechanical studies also supported the use of STA, particularly with the C-Nail's sustentacular screw positioning, which enhances construct stability.

Bernasconi et al.'s Coleman Methodological Score (CMS) analysis [49] found that studies on C-Nail had lower complication rates (5.2–6.0%) compared to Calcanail (19.6% on average), further supporting the use of STA with locking nails in DIACF treatment.

Conclusion

Over the past 12 years, minimally invasive interlocking nail systems like the Calcanail and C-Nail have gained popularity for treating Displaced Intraarticular Calcaneal Fractures (DIACFs). This shift in preference is mainly due to the significantly lower complication rates associated with the Sinus Tarsi Approach (STA) and percutaneous nail insertion compared to the Extended Lateral Approach (ELA) with plate fixation. The emergence of new systems, such as the Ni-Nail in China, further underscores the trend toward using locking nail technology.

The present study demonstrated that the C-Nail is a versatile and effective treatment for 308 DIACFs, encompassing all Sanders classification types (I–IV), open fractures (Gustilo-Anderson Types I–IIIb), and complex closed fractures (Tscherne-Oestern Type C3). At the 12-month follow-up, the American Orthopaedic Foot and Ankle Society (AOFAS) scores ranged from 86.8 to 94.5, correlating directly with the severity of the fracture based on the Sanders classification. The low incidence of complications, including superficial infections (1.4%), deep infections (0.3%), hardware-related issues (1.6%), sural nerve damage (0%), and subtalar fusion (0.5%), highlights the benefits of a minimally invasive approach combined with the stable fixation provided by the C-Nail.

The outcomes are particularly noteworthy given the patient cohort's risk factors: 49.0% were smokers, 8.6% had diabetes, and 1.9% of the fractures were open injuries. These results

indicate that the C-Nail, a minimally invasive technique, provides a reliable and effective solution for treating various DIACF types, even in patients with high-risk factors.

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