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Intramedullary nailing for calcaneal fractures: what are the available techniques? A review of the literature

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Summary

Objective. Displaced intra-articular fractures of the calcaneus (DIACF) may be treated in several ways. In recent years, intramedullary locking devices (ILD) have been proposed with the aim to reduce complications and improve long-term results. In this regard, we have reviewed the literature in order to identify devices currently available and evaluate their characteristics.

Methods. Following a PRISMA checklist, Medline, Scopus and EMBASE databases were searched to identify studies reporting use of ILDs to treat DIACFs. In this review, only technical notes were included. Manuscripts selected were critically analysed in order to highlight common points and differences among surgical techniques.

Results. Overall, four technical notes dealing with ILDs were found, of which two concerned the Calcanail® (FH Orthopedics, Heimsbrunn, France) and two the C-Nail® implant (Medin, Nov. Město n. Moravě, Czech Republic). While the Calcanail® is stabilised by two screws and allows indirect reduction of the posterior facet, the C-Nail® involves direct visualisation of the joint space and use of multiple multi-directional screws to achieve final stabilisation.

Conclusions. Although similar in the design, the Calcanail® and the C-Nail® lead to the reduction and stabilisation of fragments through different mechanisms. In both cases the restoration of heel height and anatomical reduction of the subtalar joint are the primary goals of surgery.

Key words: calcaneus, fracture, displaced, subtalar, nail

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Introduction

Calcaneal fractures are severe injuries, which represent 1 to 4% of all adult fractures [1,2]. If not diagnosed and treated promptly, they can cause long-term disability. In 60% to 80% of cases the fracture may present with an intra-articular pattern, ending up in joint incongruity which in turn may lead to functional impairment [1,2]. It has been clearly shown that adequate restoration of the articular surface is mandatory in order to increase the chances of a positive outcome [3-6].

The best treatment of displaced intra-articular calcaneus fractures (DIACF) is still debated [1,7-10]. The high rate of associated complications (hematoma, skin necrosis, soft tissue infection and osteitis), which has been reported in up to 35% of cases [5,9,11-15] has

increased the interest towards techniques involving a percutaneous reduction and fixation [16-19].

Among the possible treatments, intramedullary nailing has been advocated as a possible option. The first description of an intramedullary locking device (ILD) for treating DIACFs was published in 2012 by Goldzak et al. [20]. There have subsequently been a few studies showing encouraging results of ILDs for DIACFs which theoretically combine the advantages of minimally invasive surgery with stable fixation [21-30]. A recent review has reported that treating DIAFCs with ILDs leads to satisfactory clinical outcomes at short-term follow-up, enabling restoration of calcaneal height and improved subtalar joint congruency [1]. However, multiple devices have been introduced on the market, based on similar principles but different surgical techniques.

With this background, our aim was to identify the different surgical techniques proposed so far and to highlight similarities and differences between ILDs.

Methods

This review was designed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. This project was a sub-section of a larger investigation prospectively registered on the PROSPERO database of systematic reviews (CRD42019147815).

Eligibility criteria

We included technical notes reporting the use of ILD for treating DIACF, in English, French, Spanish, German and Italian. We excluded biomechanical studies, prospective or retrospective clinical studies, case reports, letters to the editor and studies on animals. Reviews were also excluded.

Data sources and search

A comprehensive electronic search of the current literature was performed using Medline, Scopus and EMBASE databases, from the earliest records through October 11, 2021. Additional studies were identified by checking the bibliographies of the articles selected. If full texts were not available, the authors were contacted. Using Boolean operators, the following search terms were used: calcane* AND fractur* AND fixat* AND nail*.

Study selection

Results were managed using Endnote. Duplicates and studies without abstracts were excluded. Titles and abstracts were screened by two authors (AB and FRT). After applying exclusion criteria, eligible studies were selected. Disagreements were resolved through discussion and consensus. Studies were critically analysed.

Summary measures and synthesis of results

As a narrative review, no formal statistical analysis was performed in this study.

Results

Four technical notes dealing with ILDs were found [20,23,24], of which two concerned the Calcanail® (FH Orthopedics, Heimsbrunn, France) [20,23] (Fig. 1A) and two the C-Nail® implant (Medin, Nov. Město n. Moravě, Czech Republic) [24] (Fig. 1B).

Calcanail®

The technique utilising the Calcanail®, which includes intrafocal reduction and internal fixation, was reported in 2012 by Goldzak et al. from France, and subsequently by Saß et al. from Germany [20,23] (Fig. 1A). The first step of the procedure is the placement of two 3.2 mm K-wires, passing from lateral to medial, respectively in the posterior tuberosity and the lateral tubercle of the talus. A Caspar distractor is then fixed on these wires in order to mobilise the fragments bringing distally the great tuberosity and pushing proximally the subtalar fragment against the talar surface, therefore restoring the Bohler angle and facilitating reduction of the depressed calcaneal joint surface. A skin incision is made posteriorly and inferiorly at the heel and a K-wire is positioned aiming towards the posterior facet of the subtalar joint (in the sagittal plane) and the fourth metatarsal head (in the transverse plane). After removing a bone cylinder around the H-wire, a chamber is made, through which two specialised bone pushers (one straight and one curved) are passed. These are used to elevate the subchondral calcaneal side of the posterior subtalar facet against the talar facet and to restore joint congruency. The nail (available in three lengths: 45 mm, 50 mm and 55 mm, with a diameter of 10 mm) is introduced into the chamber and stabilised by two locking screws passing from lateral to medial (Tab. I). Additional potential screws and K-wires can be used outside the nail should some other fragments require stabilisation.

C-Nail®

The technique utilising C-Nail® was reported in German by Zwipp et al. in 2013 and then in English in 2017 [24] (Fig. 1B) to treat both intra- and extra-articular displaced calcaneal fractures. According to the technique, the subtalar joint is exposed through a 3-cm sinus tarsi incision that runs from the tip of the distal fibula to the base of the fourth metatarsal, which allows the reduction of the posterior facet under direct visualisation using elevators and K-wires to stabilised the fragments. Two 3.5 mm or 4 mm cancellous screws are positioned from the lateral joint fragment to the sustentaculum tali under the joint surface to prevent articular collapse. A 6.5 mm Schanz screw is then inserted through the posterior tuberosity to manage the valgus and varus angulation, translation and inclination of the

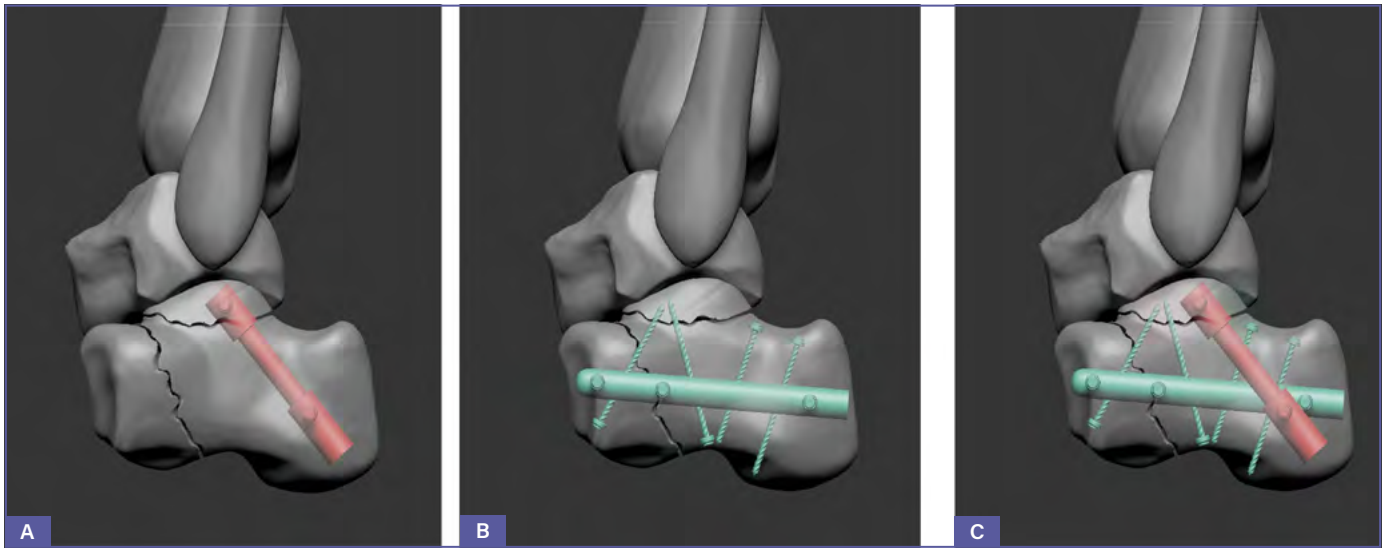

Figure 1. A) Three-dimensional illustration of a subthalamic calcaneal fracture stabilised using a Calcanail®; B) three-dimensional illustration of a subthalamic calcaneal fracture stabilised using a C-Nail®; C) superimpostion of two intramedullary locking devices (Calcanail® and C-Nail®) to illustrate the different positioning in the calcaneus.

calcaneus. If the anterior calcaneus is involved, a third screw may be used parallel to the calcaneocuboid joint. Then the posterior tuberosity fragment may be reduced using the aforementioned Schanz screw against the articular block and anterior process. After stabilising this construct with K-wires, a 1-cm incision is placed infero-laterally to the Achilles tendon distal insertion, and a guide-wire is positioned aiming towards the calcaneocuboid joint. A reamer is passed over the wire to create a channel for the implant (available only in a diameter of 8 mm and length of 65 mm, which is extendable using a cap between 5 and 20 mm). Up to 7 locking screws are used to stabilise the implant depending on fracture characteristics (Tab. I).

Discussion

The traditional approach to DIACF involves direct visualisation of the lateral calcaneal wall and fracture, anatomical reduction of the fracture and restoration of Bohler's angle. The non-negligable risk of complications, such as wound infection, hematoma, sural nerve injury, fixation failure [15,31-33] and need for revision surgery in up to 35% of patients [5,11,13,34-37] has encouraged to develop minimally-invasive techniques, aiming to restore the anatomy of the calcaneus with greater respect of soft tissues.

According to what we found in this study, both commercially available ILDs have been thought to provide on-axis fixation, but they differ in a number of aspects. While the nail of the C-Nail® construct is not used to reduce the fracture (so that anatomical reduction is achieved with 3 or more locking screws through a mini lateral incision before the horizontal positioning of the nail [23,24], in the Calcanail® system the introduction of the nail itself should help reduce the articular surface and restore and maintain the correct joint height (Fig. 1C). Other relevant differences are represented by the positioning of the nail (horizontal in C-Nail®, oblique in Calcanail®), the number of locking screws (3 in C-Nail®, 2 in Calcanail®) and the possibility to convert the fixation of the fracture toa subtalar arthrodesis.

Looking at the current literature, a recent review which focused on biomechanical and clinical studies outlined how both ILDs seem to lead to good results [38]. Biomechanically, both commercially available ILDs achieve satisfactory primary stability and in terms of absolute values and when compared to locking plates [26,28]. From a clinical standpoint, after using ILDs partial weightbearing can be allowed after an average of 3 weeks, with short-term AOFAS-AHS and VAS scores similar to more 'traditional' surgery but with a reduced trauma for soft tissues [39,40]. From the radiographic viewpoint, surgery utilising ILDs restores a Böhler angle close to reference values (between 22° and 50°) [40], comparing well with values obtained after the extensile lateral approach (between 24° and 31°) [40]. The residual step-off of the posterior facet is reported as low as 0.8-1 mm, although this has only been assessed in two previous studies [24,30]. For what concerns the complication rate of ILDs, according to the literature it is between 6 and 30% with metalware irritation (including implant protrusion on the plantar aspect of the foot and lateral prominence of locking screw head causing either skin or peroneal tendon irritation) nerve entrapment symptoms (usually self-limiting) reported up to 20 and 30% of cases, respectively, and subtalar arthrodesis required in 4 to 6% of patients [38].

We acknowledge some limitations of this study. First, as a narrative review of surgical techniques, this study cannot pro-

Table I. Main differences between the Calcanail® and the C-Nail® in terms of surgical technique.

	C-Nail®	Calcanail®
Decubitus of the patient	Lateral; contralateral knee flexed	Lateral or prone (if bilateral)
Articular reduction	3-cm sinus tarsi approach	Indirect, through Caspar distractor and graft pusher in the working channel; sinus tarsi approach only if needed
Hematoma	Cleared out	Usually not cleared
Posterior tuberosity	6.5-mm cancellous Shanz screw on a T-handle	Calcaneal tuberosity pin
Temporary stabilisation	K-wires	K-wires
Final stabilisation of the posterior facet	3.5 or 4.0-mm cancellous steel screws	Nail
Calcaneocuboid joint stabilisation (if needed)	3.5 or 4.0-mm cancellous steel screws	NA
Nail		
Sizes	Diameter 8 mm Length 65 mm, extendable using an end cap of 5 to 20 mm	Diameter 10 mm Lengths 45, 50 and 55 mm (for subtalar joint arthrodesis: diameter 12 mm, lengths 65, 75 and 85 mm)
Insertion point	10-mm vertical incision below the attachment of the Achilles tendon, slightly lateral	'through-the-heel-approach, 2 cm incision posterioly and inferiorly to the calcaneal tuberosity
Direction	Towards the center of the calcaneocuboid joint	Towards the base of the fourth metatarsal
Reaming	8-mm drill over a guidewire	10-mm trephine over the central drill guide
Potential issues	Introduce the K-wires so that there is no interference with the introduction of the nail	Introduce the K-wires so that there is no interference with the introduction of the nail
Rotation	In the correct position, the first K-wire positioned through the aiming device hits the sustentaculum tali	In the correct position, the target device allows to position 2 locking screws from lateral up to the medial wall
Locking	Up to 2 locking screws via the sustentaculum arm, 2 locking screws via the superior arm, and 2 to 3 locking screws via the lateral arm	2 double-threaded locking screws
Post-operative management	Range of motion exercises on post-operative day 2 Partial weightbearing of 20 kg for 6 to 10 weeks in normal shoes	Foot circle movements, weightbearing with crutches for 6 weeks

vide a high level of evidence. However, although ILDs were introduced in practice almost a decade ago, their use is not widespread and we believe that our work could be useful to those with an interest in these techniques. Second, although we adopted a critical approach to the studies identified, we could compare the techniques only indirectly since we did not retrieve any previous direct comparative study. Third, in this study no statistical analysis was performed, which however could be expected given the narrative design of the analysis.

In conclusion, Calcanail® and C-Nail® can be used in the treatment of DIAFCs with the aim to restore the calcaneal height and improve subtalar joint congruency. Although different in

their design and surgical technique, they both provide the opportunity to reduce the stress on soft tissues (as compared to traditional lateral approaches) and to anticipate rehabilitation. Additional screws and/or K-wires can be used with both techniques to stabilise fragments not directly fixed by the nail itself.

Highlights

- Intramedullary locking nailing has been advocated as an option for treating displaced intra-articular fractures of the calcaneus.
- Two devices are currently available on the market: Calcanail® and C-Nail®.
- In both cases, the aim of surgery is to reduce the fracture and to restore the anatomy of the subtalar joint.
- Although different in design and surgical technique, they both provide the opportunity to reduce the stress on soft tissues compared to traditional lateral approaches.

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Conflict of interest statement

The Authors declare no conflict of interest.

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Authors' contributions

FRT: write the paper, study conception and design, generate figures; AB: write the paper, study conception and design, overall guidance. AI: revise draft; AC, FS, GB, MM: study conception.

Ethical consideration

The Ethics Committee approval was not requested for this review.

References

1 Epstein N, Chandran S, Chou L. Current concepts review: intra-articular fractures of the calcaneus. Foot Ankle Int 2012;33:79-86. https://doi.org/10.3113/FAI.2012.0079

2 Wei N, Zhou Y, Chang W, et al. Displaced intra-articular calcaneal fractures: classification and treatment. Orthopedics 2017;40:e921-e929. https://doi.org/10.3928/01477447-20170907-02

3 Potter MQ, Nunley JA. Long-term functional outcomes after operative treatment for intra-articular fractures of the calcaneus. J Bone Jt Surgery-American Vol 2009;91:1854-1860. https://doi.org/10.2106/JBJS.H.01475

4 Makki D, Alnajjar HM, Walkay S, et al. Osteosynthesis of displaced intra-articular fractures of the calcaneum: a long-term review of 47 cases. J Bone Joint Surg Br 2010;92:693-700. https://doi.org/10.1302/0301-620X.92B5.23542

5 Rammelt S, Zwipp H, Schneiders W, et al. Severity of injury predicts subsequent function in surgically treated displaced intra-articular calcaneal fractures. Clin Orthop Relat Res 2013;471:2885-2898. https://doi.org/10.1007/s11999-013-3062-z

6 Sanders R, Vaupel ZM, Erdogan M, et al. Operative treatment of displaced intra-articular calcaneal fractures. J Orthop Trauma 2014;28:551-563. https://doi.org/10.1097/BOT.0000000000000169

7 Thermann H, Krettek C, Hfner T, et al. Management of calcaneal fractures in adults. Clin Orthop Relat Res 1998;353:107-124. https://doi.org/10.1097/00003086-199808000-00013

8 Thordarson DB, Krieger LE. Operative vs non-operative treatment of intra-articular fractures of the calcaneus: a prospective randomized trial. Foot Ankle Int 1996;17:2-9. https://doi.org/10.1177/107110079601700102

9 Sanders R. Displaced intra-articular fractures of the calcaneus*. J Bone Jt Surg 2000;82:225-250. https://doi.org/10.2106/00004623-200002000-00009

10 Rammelt S. An update on the treatment of calcaneal fractures. J Orthop Trauma 2014;28:549-550. https://doi.org/10.1097/BOT.0000000000000227

11 Abidi NA, Dhawan S, Gruen GS, et al. Wound-healing risk factors after open reduction and internal fixation of calcaneal fractures. Foot Ankle Int 1998;19:856-861. https://doi.org/10.1177/107110079801901211

12 Folk JW, Starr AJ, Early JS. Early wound complications of operative treatment of calcaneus fractures: analysis of 190 fractures. J Orthop Trauma 1999;13:369-372. https://doi.org/10.1097/00005131-199906000-00008

13 Buckley R, Tough S, Mccormack R, et al. Operative compared with nonoperative treatment of displaced intra-articular calcaneal fractures. J Bone Jt Surg 2002;84:1733-1744. https://doi.org/10.2106/00004623-200210000-00001

14 Howard JL, Buckley R, McCormack R, et al. Complications following management of displaced intra-articular calcaneal fractures: a prospective randomized trial comparing open reduction internal fixation with non-operative management. J Orthop Trauma 2003;17:241-249. https://doi.org/10.1097/00005131-200304000-00001

15 Backes M, Schepers T, Beerekamp MSH, et al. Wound infections following open reduction and internal fixation of calcaneal fractures with an extended lateral approach. Int Orthop 2014;38:767-773. https://doi.org/10.1007/s00264-013-2181-1

16 Stulik J, Stehlik J, Rysavy M, et al. Minimally-invasive treatment of intra-articular fractures of the calcaneum. J Bone Joint Surg Br 2006;88-B:1634-1641. https://doi.org/10.1302/0301-620X.88B12.17379

17 Weber M, Lehmann O, Sägesser D, et al. Limited open reduction and internal fixation of displaced intra-articular fractures of the calcaneum. J Bone Joint Surg Br 2008;90-B:1608-1616. https://doi.org/10.1302/0301-620X.90B12.20638

18 Schepers T. The sinus tarsi approach in displaced intra-articular calcaneal fractures: a systematic review. Int Orthop 2011;35:697-703. https://doi.org/10.1007/s00264-011-1223-9

19 Nosewicz T, Knupp M, Barg A, et al. Mini-open sinus tarsi approach with percutaneous screw fixation of displaced calcaneal fractures: a prospective computed tomography-based study. Foot Ankle Int 2012;33:925-933. https://doi.org/10.3113/FAI.2012.0925

20 Goldzak M, Mittlmeier T, Simon P. Locked nailing for the treatment of displaced articular fractures of the calcaneus: description of a new procedure with calcanail®. Eur J Orthop Surg Traumatol 2012;22:345-349. https://doi.org/10.1007/s00590-012-0968-1

21 Simon P, Goldzak M, Eschler A, et al. Reduction and internal fixation of displaced intra-articular calcaneal fractures with a locking nail: a prospective study of sixty nine cases. Int Orthop 2015;39:2061-2067. https://doi.org/10.1007/s00264-015-2816-5

22 Fascione F, Di Mauro M, Guelfi M, et al. Surgical treatment of displaced intra-articular calcaneal fractures by a minimally invasive technique using a locking nail: a preliminary study. Foot Ankle Surg 2018. https://doi.org/10.1016/j.fas.2018.08.004

23 Saß M, Rotter R, Mittlmeier T. Minimally invasive internal fixation of calcaneal fractures or subtalar joint arthrodesis using the Calcanail®. Oper Orthop Traumatol 2019;31:149-164. https://doi.org/10.1007/s00064-018-0576-2

24 Zwipp H, Paša L, Žilka L, et al. Introduction of a new locking nail for treatment of intra-articular calcaneal fractures. J Orthop Trauma 2016;30:e88-e92. https://doi.org/10.1097/BOT.0000000000000482

25 Falis M, Pyszel K. Treatment of displaced intra-articular calcaneal fractures by intramedullary nail. Preliminary report. Ortop Traumatol Rehabil 2016;18:141-147. https://doi.org/10.5604/15093492.1205021

26 Goldzak M, Simon P, Mittlmeier T, et al. Primary stability of an intramedullary calcaneal nail and an angular stable calcaneal plate in a biomechanical testing model of intra-articular calcaneal fracture. Injury 2014;45:S49-S53. https://doi.org/10.1016/j.injury.2013.10.031

27 Ni M, Wong DW-C, Niu W, et al. Biomechanical comparison of modified calcanail system with plating fixation in intra-articular calcaneal fracture: a finite element analysis. Med Eng Phys 2019;70:55-61. https://doi.org/10.1016/j.medengphy.2019.06.004

28 Reinhardt S, Martin H, Ulmar B, et al. Interlocking nailing versus interlocking plating in intra-articular calcaneal fractures. Foot Ankle Int 2016;37:891-897. https://doi.org/10.1177/1071100716643586

29 Fourgeaux A, Estens J, Fabre T, et al. Three-dimensional computed tomography analysis and functional results of calcaneal fractures treated by an intramedullary nail. Int Orthop 2019;43:2839-2847. https://doi.org/10.1007/s00264-019-04381-3

30 Herlyn A, Brakelmann A, Herlyn PK, et al. Calcaneal fracture fixation using a new interlocking nail reduces complications compared to standard locking plates – preliminary results after 1.6 years. Injury 2019;50(Suppl 3):63-68. https://doi.org/10.1016/j.injury.2019.07.015

31 Rammelt S, Amlang M, Barthel S, et al. Minimally-invasive treatment of calcaneal fractures. Injury 2004;35(Suppl 2):SB55-SB63. https://doi.org/10.1016/j.injury.2004.07.012

32 Zwipp H, Rammelt S, Barthel S. Calcaneal fractures – open reduction and internal fixation (ORIF). Injury 2004;35(Suppl 2):SB46-SB54. https://doi.org/10.1016/j.injury.2004.07.011

33 Chen L, Zhang G, Hong J, et al. Comparison of percutaneous screw fixation and calcium sulfate cement grafting versus open treatment of displaced intra-articular calcaneal fractures. Foot Ankle Int 2011;32:979-985. https://doi.org/10.3113/FAI.2011.0979

34 Benirschke SK, Sangeorzan BJ. Extensive intra-articular fractures of the foot. Surgical management of calcaneal fractures. Clin Orthop Relat Res 1993:128-134.

35 Zwipp H, Tscherne H, Thermann H, et al. Osteosynthesis of displaced intra-articular fractures of the calcaneus. Results in 123 cases. Clin Orthop Relat Res 1993:76-86.

36 Ding L, He Z, Xiao H, et al. Risk factors for post-operative wound complications of calcaneal fractures following plate fixation. Foot Ankle Int 2013;34:1238-1244. https://doi.org/10.1177/1071100713484718

37 Sanders R, Fortin P, DiPasquale T, et al. Operative treatment in 120 displaced intra-articular calcaneal fractures. Results using a prognostic computed tomography scan classification. Clin Orthop Relat Res 1993:87-95.

38 Amlang M, Zwipp H, Pompach M, et al. Interlocking nail fixation for the treatment of displaced intra-articular calcaneal fractures. JBJS Essent Surg Tech 2017;7:e33. https://doi.org/10.2106/JBJS.ST.17.00015

39 Bernasconi A, Iorio P, Ghani Y, et al. Use of intramedullary locking nail for displaced intra-articular fractures of the calcaneus: what is the evidence? Arch Orthop Trauma Surg 2021;May 11. https://doi.org/10.1007/S00402-021-03944-7

40 Griffin D, Parsons N, Shaw E, et al. Operative versus non-operative treatment for closed, displaced, intra-articular fractures of the calcaneus: randomised controlled trial. BMJ 2014;349:g4483. https://doi.org/10.1136/bmj.g4483

41 Bai L, Hou Y-L, Lin G-H, et al. Sinus tarsi approach (STA) versus extensile lateral approach (ELA) for treatment of closed displaced intra-articular calcaneal fractures (DIACF): a meta-analysis. Orthop Traumatol Surg Res 2018;104:239-244. https://doi.org/10.1016/j.otsr.2017.12.015