Calcaneous interlocking nail treatment for calcaneous fracture: a multiple center retrospective study

Ye Peng¹, Junsong Wang¹,²†, Bo Feng³, Yunshou Li⁴, Yunlong Zhu⁵, Weiqing Yuan⁶, Lei Teng⁷, Chengming Zhu⁸, Bin Shi¹ and Lihai Zhang¹*

**Abstract**

**Background** Minimally invasive treatments for calcaneous fractures have the same outcomes and fewer complications. However, they are technically demanding, and there are a lack of reduction tools. To overcome these problems, a calcaneous interlocking nail system was developed that can make reduction and fixation minimally invasive and effective. We retrospectively studied the calcaneous fracture variables intraoperatively and followed up to evaluate the outcomes of patients treated with the calcaneous interlocking nail system.

**Methods** All patients in 7 institutions between October 2020 and May 2021 who had calcaneous fractures treated with calcaneous interlocking nails were retrospectively analyzed. The patient characteristics, including age, sex, injury mechanism, Sanders type classification, smoking status, and diabetes were recorded. The calcaneous interlocking nail and standard surgical technique were introduced. The intraoperative variables, including days waiting for surgery, surgery time, blood loss, incision length, and fluoroscopy time, were recorded. The outcomes of complications, AOFAS scores and VAS scores were recorded and compared with other similar studies.

**Results** Fifty-nine patients were involved in this study; 54 were male; 5 were female; and they had an average age of 47.5 ± 9.2 years (range 25–70). 2 of these fractures were Sanders type I, 28 of these fractures were Sanders type II, 27 of these fractures were Sanders type III, and 2 of these were Sanders type IV. The surgery time was 131.9 ± 50.5 (30–240) minutes on average. The blood loss was 36.9 ± 41.1 (1–250) ml. The average incision length was 3.5 ± 1.8 (1–8) cm; 57 were sinus tarsi incisions; and 2 were closed fixations without incisions. The average fluoroscopy time was 12.3 ± 3.6 (10–25) seconds during the surgery. The VAS score of patients on the day after surgery was 2.4 ± 0.7 (1–3). The AOFAS ankle-hindfoot score in patients who had a follow-up of at 12 months was 93.3 ± 3.6(85–99). During the follow-up, all patients’ functional outcomes were good. One patient had a superficial infection. The rate of complications of the 59 patients was 1.7% (1/59).

---

¹Ye Peng and Junsong Wang are co-first authors and contributed equally to this work.

*Correspondence:
Lihai Zhang
zhanglihai74@qq.com

Full list of author information is available at the end of the article
Introduction
Calcaneal fractures are common fractures in the foot [1]. More than 70% of calcaneal fractures are intra-articular fractures [2]. The treatment of displaced calcaneal fractures has been controversial in clinical practice. At present, there are three main treatment methods for calcaneal fractures: conservative treatment, open surgery, and minimally invasive treatment. Because of the reduced soft tissue cover, and the more likelihood of the patient’s smoking, having diabetes and having a high energy injury, open surgery has many complications, such as necrosis of the skin and infection [3–5]. For these reasons, minimally invasive treatments have been popular for calcaneous reduction and fixation. However, minimally invasive treatment is technically demanding and difficult to accomplish for satisfactory reduction and rigid fixation [6–8].

In this study, we try to solve the unsatisfactory percutaneous reduction and rigid fixation problems by calcaneous interlocking nail system. The calcaneous interlocking nail contains reduction tools and fixation system. These reduction tools can reduce the displaced cancellous fracture with traction, and the calcaneous interlocking nail can have rigid fixation of the fracture fragment. The retrospective outcomes of multiple medical centers were reported.

Materials and methods
Calcaneous interlocking nail, (Double Medical, China)
The calcaneous interlocking nail is a cannulated titanium alloy nail 65–80 mm long and 8.5 mm in diameter (Fig. 1A, B). The main nail was implanted from the posterior to anterior trough calcaneous tuberosity, which controls the calcaneous length. There are four locking screws for the nail. The anterior lock screw is transverse locking from lateral to medial and controls the rotation of the main nail. The articular fracture fragments have two locking screw fixations that can be implanted from the lower calcaneous tuberosity to the articular fracture fragments to support the fragments. The posterior lock screw is placed from medial superior to lateral inferior and can fix a tongue-type fracture. All locking screws have a target device that can be implanted with minimal invasiveness (Fig. 1C).

Standard operative technique
The patients were positioned in a prone position for percutaneous reduction and interlocking nail percutaneous fixation. The prone position can be used for bilateral surgeries, and a calcaneous axial view is easy to obtain in this position. After routine surgical draping, two 2.5 mm K-wires perpendicular to the talus neck and calcaneous tuberosity were penetrated laterally to medially sequence under a fluoroscope. Then, the two traction devices on both sides of the calcaneus were assembled and were gradually tracted simultaneously to recover the calcaneous shape and create the space for reduction (Fig. 2A, B). The sinus tarsi approach was used, and the subtalar joint and compressed articular fragment were exposed. The compressed articular surface and lateral wall were lifted by a bone elevator. The temporary K-wires were implanted to fix the articular fragment from lateral to medial. For some comminuted fractures, some hollow screws could be implanted for articular surface fixation. The varus and valgus angles of the calcaneous were adjusted by bilateral traction devices under axial view fluoroscopy. The width of the calcaneous was reduced by special-made compression clamps. The calcaneous interlocking nail and four locking screws were implanted in sequence. For severely compressed fractures, bone graft or bone graft substitutes were used to fill the defect space. Finally, the sinus tarsi incision was closed with sutures.

A retrospective analysis was conducted and included 67 patients with displaced intra-articular calcaneal fractures who were treated with calcaneous interlocking nails at 7 institutions between October 2020 and May 2021. The inclusion criteria were patients older than 18 who underwent surgical treatment of a calcaneal closed fracture without other associated fractures. The exclusion criteria were patients who were treated conservatively. Due to the retrospective design of this study, we had no standardized postoperative follow-up protocol, and all the follow-ups were at least 12 months. In total, 59 patients were involved in this study, 54 were male, 5 were female, and they had an average age of 47.5±9.2 years (range 25–70). The injury mechanism, Sanders type classification, smoker, diabetes, days waiting for surgery, surgery time, blood loss, incision length, fluoroscopy time, complications and AOFAS score and VAS score after one year were recorded. X-rays and CT scans were obtained before the surgery: 2 of the fractures were Sanders type I, 28 of the fractures were Sanders type II, 27 were Sanders type III fractures, and 2 were Sanders type IV fractures. The patient characteristics are shown in Table 1.

All the patients underwent surgery by surgeons who had more than 5 years of experience with calcaneous fractures, even in Sanders type IV. The outcomes of follow-up showed good function. The calcaneous interlocking nail could be an alternative method for minimally invasive calcaneal fracture fixation.

Keywords
Calcaneal fracture, Sinus tarsi approach, Calcaneal interlocking nail

Conclusion
The calcaneous interlocking nail system can have satisfactory reduction and fixation in calcaneal fractures, even in Sanders type IV. The outcomes of follow-up showed good function. The calcaneous interlocking nail could be an alternative method for minimally invasive calcaneal fracture fixation.
fracture fixation. The surgeons were trained for this new calcaneous interlocking nail fixation and reduction. All patients were undergoing surgery according to the standard operative technique.

**Postoperative management**

After surgery, full range of ankle motion was permitted the next day, but no weight-bearing was permitted until 4 weeks. During weeks 4–8, patients could start weight-bearing, as tolerated, up to full weight-bearing with a walking stick after surgery. After 8 weeks, the patients were allowed to do some light work without walking sticks. X-rays of the lateral view and axial view were obtained 1 month and 3 months after surgery. All patients were followed up for more than 12 months. The standardized follow-up protocol modified based on Paley and Hall [9] includes radiographic reduction evaluation, incision infection, incision necrosis, peroneal impingement, fracture non-union, fracture malunion, return to work, subtalar joint motion, arthrosis of subtalar and calcaneocuboid joints, footwear problem.

**Statistical analysis**

The SPSS statistical software package for Windows (22.0) was used for statistical analysis. Student’s t test was used. Statistical significance was defined as P < 0.05.

**Clinical outcome results**

The surgery time was 131.9 ± 50.5 (30–240) minutes on average. The blood loss was 36.9 ± 41.1 (1–250) ml. Two patients with Sanders type I underwent closed fixation without an incision. The average incision length was

---

**Fig. 1** The calcaneous interlocking nail and minimally invasive target device

A Lateral view of calcaneous interlocking nail
B Posterior view of calcaneous interlocking nail
C Target device of calcaneous interlocking nail
3.5±1.8 (1–8) cm; 57 were sinus tarsi incisions, and 2 were closed without incisions. The average fluoroscopy time was 12.3±3.6 (10–25) seconds during the surgery. The VAS score of patients on the day after surgery was 2.4±0.7 (1–3). A total of 59 patients reached full weight-bearing, and a calcaneal fracture healing rate of 100% was found by the follow-up. The AOFAS ankle-hindfoot score in patients who had a follow-up of at 12 months was 93.3±3.6(85–99).

During the follow-up, all patients’ functional outcomes were good. One patient had a superficial infection. The rate of complications of 59 patients was 1.7% (1/59). The patients had dressing changes, and the wounds had healed after one month. No additional surgery was needed. There is no hardware removed. In the follow-up, the radiographic reduction evaluation results showed 89.8%(53/59) anatomic reduction(<2 mm), 1 patient had incision infection, no patient had incision necrosis, peroneal impingement, fracture non-union, fracture mal-union and footwear problems. 54 patients returned to same work and 5 patients changed to light work, average subtalar joint motion 80–95% compared to the opposite one, 1 Sanders type IV patient development arthrosis of subtalar joints. There were some classical cases below (Figs. 3 and 4).

The CT scan showed a depressed fragment with articular steps greater than 2 mm (C-H).

X-ray showed calcaneal fracture reduction and fixation by calcaneal interlocking nail (I-J) sinus tarsi skin incision (3.5 cm).

The CT scan showed a severely depressed articular fragment with widened calcification (C-E).

X-ray showed the calcaneal fracture reduction and fixation by calcaneal interlocking nail (F-G).

**Discussion**

Calcaneal fracture treatment is still controversial. Non-operatively treated calcaneal fractures are often associated with hindfoot deformities, hindfoot biomechanical disturbances, lateral wall fibular impingement, and peroneal tendon dysfunction. Patients without surgery are 6 times more likely to have their fractures result in late subtalar fusion than patients who had surgery [10]. Open surgery is often associated with the lateral extensile approach, which has great opportunity to cause incision complications, especially with diabetes smokers and high-energy soft tissue injuries. The complication rate of the lateral extensile approach is 20–37% [11–16]. Minimally invasive treatment of calcaneal fractures has gradually become mainstream because it is associated with more rapid healing, lower complication rates, shorter hospital time and less pain [17–19]. To date, many studies

![Fig. 2 The traction and reduction tools for calcaneal fracture](image)

A Lateral view of traction and reduction tools

B Posterior view of traction and reduction tools

| Table 1 Patient characteristics |
|----------------------------------|
| Age(years) | 47.5±9.2(25–70) |
| Gender | 5 female, 54 male |
| Sanders type classification | Number of cases |
| I | 2 |
| II | 28 |
| III | 27 |
| IV | 2 |
| smokers | 23/59 |
| diabetes | 2/59 |
| days waiting for surgery(days) | 7.5±3.2(1–16) |
Fig. 3  Case 1. Male, 39 years old, who fell from a ladder
X-ray showed a calcaneous fracture. Later view (a) Axial view (b)
Fig. 4 Case 2. Male, 43 years old, who fell from a roof.
X-ray showed a calcaneous fracture. Later view (a) Axial view (b).
have shown that minimally invasive reduction and percutaneous fixation provide the same long-term function and fewer complications [17–19]. However, minimally invasive fixations are technically demanding, and fewer tools and nails have been designed for reduction and fixations. Many minimally invasive methods of calcaneus fixation exist [20–24], but a system that can have easy reduction and fixation is still needed.

For these reasons, we designed a calcaneal interlocking nail system for calcaneal fracture reduction and fixation to overcome the disadvantage of traditionally minimally invasive surgery. The calcaneal interlocking nail system has specially made traction devices, reduction tools and target devices that can make the whole procedure in sequence. Compared to traditionally minimally invasive reduction and fixation, it overcomes the difficulty of free hand reduction, maintains reduction, and implants an accurate screw with the right position under fluoroscopy. The calcaneal interlocking nail system is effective and easy to handle, which lowers the learning curve. All kinds of calcaneal fracture types can be fixed by the calcaneal interlocking system.

A retrospective study from multiple centers showed that 59 patients with calcaneus fractures treated with the calcaneal interlocking nail system had a lower complication rate of 1.6%, which was similar to the 1.9% complication rate of the c-nail [25]. The blood loss was 36.9 ± 41.1 ml using a tourniquet, and most of the blood loss occurred during reduction. The Sanders type I fractures were closed and fixed without an incision. During the reduction, the lateral and axial views of fluoroscopy was used to ensure the articular surface and varus valgus reduction by lateral view and axial view. Many authors use the VAS (visual analog scale) scores and the AOFAS ankle-hindfoot scores to assess the outcomes [26–29]. The next day, the VAS scores were 2.4 ± 0.7, indicating that patients could start rehabilitation exercises as soon as possible. At 12 months of follow-up, the average calcaneus AOFAS ankle-hindfoot score was 65–89. Our study showed that the AOFAS scores were 93.3 ± 3.6, which could be related to very few Sanders type IV fractures. Compared to other studies of calcaneaus fractures, Yavuz Akalin [30] reported that 61 patients calcaneus fracture treated with locking plate fixation, the AOFAS average score were 84.7 ± 12.4 (t = -5.122 P < 0.001). Wound problems were observed in 15 (28.6%) patients (Z = 3.689, P < 0.001). Eva Steinhausen [31] reported that 33 patients calcaneus fractures treated with C-nail fixation, the AOFAS average score were 80 ± 17 (t = -5.805 P < 0.001). Wound problems were observed in 15 (28.6%) patients (Z = 2.116, P = 0.034). Takuya Sugimoto [32] reported that 32 patients calcaneus fractures treated with cannulated screw fixation, the AOFAS average score were 90. There was 1 patient had skin necrosis problems in 32 (3%) patients. In summary, the calcaneus interlocking nail for calcaneus fractures showed preferable peri-operation data and lower complications and good functional outcomes during the follow up compared to other studies.

There were some limitations to this study. First, the number of cases was limited, particularly for Sanders type IV fractures. This study is the early experience and applications for calcaneus interlocking nails. Second, the results from reduction, as determined by CT scan, need to be further study. Third, a control group and matched subtype of Sanders classifications should be designed in future studies. Finally, a multicenter randomized comparative study and biomechanical study were not available, which should be performed in the near future.

**Conclusion**

This study focused on introducing the calcaneal interlocking nail system and the applications for calcaneus fractures. With the use of this calcaneal interlocking nail system, the surgeons can make minimally invasive reduction and fixation effectively and easily. All procedures can be performed by the target device with minimal invasive incisions. The functional outcome assessments showed that the patients had lower VAS scores and better AOFAS scores after surgery and a lower complication rate. We believe that this calcaneus interlocking nail system could be an alternative method for calcaneal fracture.

**Acknowledgements**

Not applicable.

**Authors' contributions**

Lihai Zhang and Ye Peng contributed to conception and design and surgery. Lihai Zhang, Ye Peng, Junsong Wang, Bo Feng, Yunzhou Li, Yunlong Zhu, Weiqing Yuan, Lei Teng, Chengming Zhu contributed to the analysis and interpretation of data before and after surgery. Ye Peng, Bin Shi and Junsong Wang contributed to the acquisition of surgery data. Ye Peng, Bin Shi and Junsong Wang contributed to the analysis and interpretation of data before and after surgery.

**Funding**

This research received grant from funding agencies in the public. National Key Research and Development Program of China (No. 2020YFC2004900). Beijing Natural Science Foundation-Haidian original Innovation Joint Foundation(L1919016). National Natural Science Foundation of China (U21A20489).

**Table 2. Clinical results of interlock nails for calcaneal fractures**

| surgery time (mins) | 131.9 ± 50.5 (30–240) |
|---------------------|------------------------|
| blood loss (ml)     | 36.9 ± 41.1 (1–250)    |
| incision length (cm)| 3.5 ± 1.8 (1–8)        |
| fluoroscopy time (s)| 12.3 ± 3.6 (10–25)     |
| complications rate  | 1/59                   |
| AOFAS               | 93.3 ± 3.6 (85–99)     |
| VAS                 | 2.4 ± 0.7 (1–3)        |
Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

The treatment was approved from the People’s Liberation Army General Hospital’s Ethics Committee. Informed consent, including publication, was obtained from the patient.

Consent for publication

For manuscripts that include details, images, or videos relating to an individual person, written informed consent for the publication of these details was obtained from the patient.

Competing interests

There are no competing interests.

Ethical approval and consent to participate

The treatment was written with authorization from the People’s Liberation Army General Hospital’s Ethics Committee. All methods were carried out in accordance with relevant guidelines and regulations (declaration of helsinki).

Author details

1Department of Orthopaedic Surgery, General Hospital of Chinese People’s Liberation Army, Beijing, China

2Department of Joint Surgery, Beijing Shijitan Hospital Capital Medical University, Beijing, China

3Department of orthopaedic clinical medicine, the Third Affiliated Medical College of Inner Mongolia Medical University, Baotou, China

4Department of Hand and Foot Surgery, People’s Hospital of Juxian, Rizhao, China

5Department of Orthopaedic Surgery, Beijing fengtai hospital of traditional Chinese and western medicine, Beijing, China

6Department of Orthopaedic Surgery, Guangxi Orthopedic Hospital, Nanning, China

7Department of Orthopedics, Mayang County People’s Hospital, Huaihua, China

8Department of Orthopedics, Liuzhou workers hospital orthopedic/ the fourth affiliated hospital of guangxi medical university orthopedic, Liuzhou, China

Received: 10 June 2022 / Accepted: 4 October 2022

Published online: 13 October 2022

References

1. Zwipp H, Rammelt S, Barthel S. Calcaneal fractures—the most frequent tarsal fractures. Ther Umsch. 2004 Jul;61(7):435–50.

2. Bajammal S, Tornetta PR, Sanders D, Bhandari M. Displaced intra-articular calcaneal fractures. J Orthop Trauma. 2005;19:360–4.

3. Al-Mudhaﬀar M, Prasad CV, Mohﬁ A. Wound complications following operative ﬁxation of calcaneal fractures. Injury. 2000;31(6):461–4.

4. Shuler FD, Conti SF, Gruen GS, Abidi NA. Wound-healing risk factors after open reduction and internal ﬁxation of calcaneal fractures: does correction of Bohler’s angle alter outcomes? Orthop Clin North Am. 2001;32(1):187–92.

5. Assous M, Bhrma MS. Should calcaneus fractures in smokers be ﬁxed? A review of 40 patients. Injury. 2001;32(8):631–2.

6. Biggi D, Di Fabio S, D’Antimo C, Isoni F, Salfi C, Trevisani S. Percutaneous calcanearoplasty in displaced intra-articular calcaneal fractures. J Orthop Traumaol. 2013 Dec;14(4):307–10.

7. Arastu M, Sheehan B, Buckley R. Minimally invasive reduction and ﬁxation of displaced calcaneal fractures: surgical technique and radiographic analysis. Int Orthop. 2013;37:359–45.

8. Kikuchi C, Chaffron TP, Thorndason DB. Limited sinus tarsi approach for intra-articular calcaneal fractures. Foot Ankle Int. 2013;34:1689-94.

9. Paley D, Hall H. Calcaneal fracture controversies. Can we put Humpty Dumpty together again? Orthop Clin North Am. 1989;20(4):665–77.

10. Cszyz M, Buckley R, Tough S, Leighton R, Smith J, McCormack R, Pate G, Petrie D, Galpin R. Displaced intra-articular calcaneal fractures: variables predicting late subtalar fusion. J Orthop Trauma. 2003 Feb;17(2):106–12.

11. Bozes H, Massant P, Delvaux D, Fouquet JP, Tazi F. The operative treatment of intra-articular calcaneal fractures: indications, technique, and results in 257 cases. Clin Orthop Relat Res. 1999;360:55–9.

12. Zwipp H, Tischer H, Therrmann H, Weber T. Osteosynthesis of displaced intra-articular fractures of the calcaneus: results in 123 cases. Clin Orthop Relat Res. 1993;290:76–86.

13. Abdii NA, Dhawan S, Gruen GS, Vogt MT, Conti SF. Wound-healing risk factors after open reduction and internal ﬁxation of calcaneal fractures. Foot Ankle Int. 1998;19:856–61.

14. Harvey EJ, Grujic L, Early JS, Benirschke SK, Sangeorzan BJ. Morbidity associated with ORIF of intra-articular calcaneal fractures using a lateral approach. Foot Ankle Int. 2001;22:868–73.

15. Folk JW, Starr AJ, Early JS. Early wound complications of operative treatment of calcaneal fractures: analysis of 190 fractures. J Orthop Trauma. 1999;13:369–72.

16. Hsu AR, Anderson RB, Cohen BE. Advances in surgical management of intra-articular calcaneal fractures. J Am Acad Orthop Surg. 2015;23:399–407.

17. Kline A, Anderson RB, Davis WH, et al. Approach for intra-articular calcaneal fractures. Foot Ankle Int. 2013;34(6):773-80.

18. Xia S, Lu Y, Wang H, et al. Open reduction and internal ﬁxation with conventional plate via L-shaped incision versus internal ﬁxation with percutaneous plate via a sinus tarsi approach for calcaneal fractures – a randomized controlled trial. Int J Surg. 2014;12(5):475–80.

19. Peng Y, Liu J, Zhang G, Ji X, Zhang W, Zhang L. Tang P. Reduction and functional outcome of open reduction plate ﬁxation versus minimally invasive reduction with percutaneous screw ﬁxation for displaced calcaneal fractures: a retrospective study. J Orthop Surg Res. 2019 May 9;14(1):124.

20. Cao L, Weng W, Song S, Xiao N, Li H, Cai Y, Zhou Q, Ju S. Surgical treatment of calcaneal fractures of Sanders type II and III by a minimally invasive technique using a locking plate. J Foot Ankle Surg. 2015 Jan-Feb;54(1):76–81.

21. Battaglia A, Catania P, Giumma S, Carbone S. Early Minimally Invasive Percutaneous Fixation of Displaced Intra-Articular Calcaneal Fractures. Foot Ankle Int. 2015 Jan-Feb;54(1):51-6.

22. Dayton P, Feilmeier M, Hensley NL. Technique for minimally invasive reduction of calcaneal fractures using small bilateral external ﬁxation. J Foot Ankle Surg. 2014 May-Jun;53(3):376–82.

23. Goldmark M, Wittmeeier T, Simon P. Locked nailing for the treatment of displaced articular fractures of the calcaneus: description of a new procedure with calcanæal™. Eur J Orthop Surg Traumatol. 2012;22:345–9.

24. Reinhardt S, Martin H, Ullmar B, Döbelö S, Zwipp H, Rammelt S, et al. Interlocking nailing versus interlocking plating in intra-articular calcaneal fractures. Foot Ankle Int 37:891-897.

25. Zwipp H, Pasa L, Zilika L, Amlang M, Rammelt S, Pompach M. Introduction of a new locking nail for treatment of intraarticular calcaneal fractures. J Orthop Trauma. 2016;30(3):e88–92.

26. Sceat A, Christopher S. Lateral Extensile Approach Versus Minimal Incision Approach for Open Reduction and Internal Fixation of Displaced Intra-articular Calcaneal Fractures: A Meta-analysis. J Foot Ankle Surg. 2020;59(2):356–66.

27. Kline A, Anderson RB, Davis WH, Jones CP, Cohen BE. Minimally invasive technique versus an extensile lateral approach for intra-articular calcaneal fractures. Foot Ankle Int. 2013;34(6):773–80.

28. Yeo JH, Choi HJ, Lee KB. Comparison of two surgical approaches for displaced intra-articular calcaneal fractures: sinus tarsi versus extensile lateral approach. BMC Musculoskeletal Disorders. 2015;16:63.

29. De Groot R, Frima AJ, Schepers T, Roendink WH. Complications following the extended lateral approach for calcaneal fractures do not inﬂuence mid- to long-term outcome. Injury. 2013;44(11):1596–600.

30. Akalin Y, Cansuabucu G, Yetkin E, Acik O, Aktumu O, Öztürk A. An evaluation of the results of locked plate osteosynthesis applied without the use of bone graft in Sanders type III and IV intra-articular calcaneal fractures. Int Orthop. 2020;44(2):2753–60.

31. Steinhausen E, Martin W, Lefering R, Lundin S, Gombritza M, Mester B, Brinkmann N, Dudda M. C-Nail versus plate osteosynthesis in displaced intra-articular calcaneal fractures—a comparative retrospective study. J Orthop Surg Res. 2021;16:203.

32. Takuya Sugimoto K, Tokutake Y, Takegami NO, Kanayama Y, Inoue H, Sugimoto R, Kagami Y. Shiro Imagama. Plate ﬁxation through the lateral extensile approach for calcaneal fractures do not influence mid- to long-term outcome. J Orthop Sci. 2020;25(7):733-84.
Publisher's note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.