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PERONEUS BREVIS FLAP IN ORTHOPLASTIC APPROACH FOR CALCANEAL OSTEOMYELITIS WITH MALUNION: A CASE REPORT

Daniele Santoro[1], Agnese Battista[1], Giulia Nicolaci[1], Alessandro Massè[1], Davide Ciclamini[2]

[1] Department of Orthopaedics and Traumatology, School of Medicine, University of Turin, Turin, Italy; [2] Reconstructive Microsurgery Unit, Traumatologic Hospital, A.O.U. City of Health and Science of Turin, Italy

Summary

Introduction. Calcaneal osteomyelitis is a demanding lesion for orthopaedic and plastic surgeons, requiring advanced surgical solutions and sometimes driving to a below-the-knee amputation. A soft tissue covering of the residual bone and dead space filling is often necessary after complete resection of the septic bone (and osteotomy when needed to correct deformities). A variety of local or free flaps must be in the plastic surgeon's portfolio. This case report presents the pedicled peroneus brevis flap as a versatile tool to fill calcaneal bone loss dead space while covering the exposed bone.

Case. A 31-year-old female sustained a multi-fragmentary closed calcaneal fracture, initially managed with percutaneous pinning. Skin necrosis around K wires resulted in nascent malunion, soft tissue loss and osteomyelitis with sequestrum. After multidisciplinary planning, we performed en-bloc excision of the osteomyelitic bone (resulting in bone loss and medium-sized posterior dead space), k-wire reduction and pinning of the subtalar joint, dead space-filling and bone coverage with a peroneus brevis flap. At three-year follow-up, the clinical evaluation shows no restriction in daily activities, bone healing, complete restoration of soft tissues and no signs of infection.

Conclusions. Complex ortho-plastic cases need to be evaluated in a multidisciplinary centre to set a shared management protocol that allows a proper surgical strategy intending to address both the soft tissues and the bone and to reduce post-operative complications. The pedicled peroneus brevis muscle flap is a versatile and relatively fast-to-dissect tool for covering medium-sized loss of substance of the soft tissues around the calcaneal bone and Achilles tendon area. It can also obliterate any small to medium-sized dead space from removed cancellous bone. No significant function loss in pronation and ankle stability typically develops.

Key words: case report, osteomyelitis, calcaneum, flap, peroneus brevis, orthoplastic surgery

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Correspondence
Davide Ciclamini
Reconstructive Microsurgery Unit, Traumatologic Hospital, A.O.U. City of Health and Science of Turin, Corso Bramante 88, 10126, Turin, Italy
E-mail: davide.ciclamini@gmail.com

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INTRODUCTION

The calcaneus is the most frequently fractured tarsal bone [1], and its injury often occurs in young adults after a fall from a height. Displaced intra-articular calcaneal fractures are known to be challenging to manage, frequently leading to multiple acute and chronic complications. Furthermore, the calcaneal and distal Achilles tendon area is one of the most critical areas of the body in terms of soft tissue coverage. In the case of osteomyelitis, the necessity of bone resections complicates the treatment, requiring enough vascularised tissue to cover the area [2] and to fill the residual dead space after bone resection.
The decision between different strategies depends on the fracture pattern, the surrounding soft tissue's condition, the calcaneal bone's entity to be resected, and the patient characteristics and comorbidities [3]. Although other authors accept different surgical methods, minimally invasive orthopaedic surgical techniques in the acute setting have become widespread because of the reported comparable clinical results with a lower rate of significant complications [4-6]. However, despite those data, significant sequelae are still observed [7,8], usually associated with insufficient fracture reduction: this mainly occurs if the mandatory pre-operative CT-scan planning is not executed [9].
From a reconstructive perspective, choosing between local or free flaps for bone coverage in this area is tricky [10-12]. While local flaps may appear as a faster and technically easier solution for small to medium-size loss of substance, they are often afflicted by a higher rate of complications, especially in patients with severe comorbidities like diabetes or infection. Conversely, a free flap seems excessively complex when applied to medium or small-size wounds. In young and healthy patients, a local flap does not present a higher rate of complications and offers a fast and more straightforward surgical solution. The sural adipofascial flap [13] and peroneus brevis muscle flap [14] are optimal for medium substance loss at the calcaneal level. A muscle flap is sometimes preferred to bring what seems to be a more vascularized contact tissue to cover the bone in case of infection. Also, at the foot and ankle level, a pure muscle flap with split-thickness skin graft is preferred to a musculocutaneous flap to get a less bulky reconstruction, especially in the shoe area [11,13]. In the case of calcaneal bone resection, a presumptive area of bone loss with residual dead space is expected after removing the sequestrum. Obliterating this dead space with well-vascularized tissue [15] is essential, not necessarily with bone. Muscular tissue is ideal for such a function. Avoiding foreign materials is mandatory.
Finally, complications prevention and management are essential goals [16,17]; if major sequelae occur, the decision planning remains complex and controversial [18,19] regardless of the initial surgical strategy, often requiring a multidisciplinary approach.
We present the case of a complex calcaneal malunion with deep skin necrosis (fistula) and osteomyelitis, sequestrum with the necessity of medium-sized bone resection, and residual dead space. This case highlights the importance of shared decision-making between the patient, the orthopaedic, and the plastic surgeon.

CASE REPORT

A 31-year-old overweight (BMI: 29) female sustained a multi-fragmentary closed calcaneal fracture (Sanders 2b) following a fall from height (2.5 m).She was a smoker with a history of deep venous thrombosis (DVT) complicated by pulmonary embolism (PE). The patient's history did not provide evidence of other underpinning health issues apart from that. She was initially managed in a very acute setting (2 days after the trauma) with percutaneous pinning in a peripherical hospital.
She was referred to our hospital 20 days after the first surgery, reporting persistent pain and swelling of the heel associated with a deep eschar of about 3 x 3 cm located in the posterior calcaneal region (Fig. 1) between the 3-pin insertion points. Pins were not displaced; hypoesthesia in the plantar area of the toe and finger was present; there were no clinical signs of deep venous thrombosis (DVT).
A multidisciplinary team of orthopaedic and plastic surgeons assisted by a clinical infectious disease specialist managed the case. Radiological analysis showed a Bohler angle of -26° (Fig. 2) and a Gissane angle of 152° (Fig. 3).
An ankle-foot CT scan showed fracture nascent-malunion and malalignment (Fig. 4). The subsequent MRI revealed ischaemia of the surrounding soft tissue, necrosis, with concurrent stage 3 osteomyelitis of the posterior pole of the calcaneus (Fig. 5). The osteomyelitis

Figure 1. Deep eschar located in the posterior calcaneal region, between the 3-pin insertion point (removed).

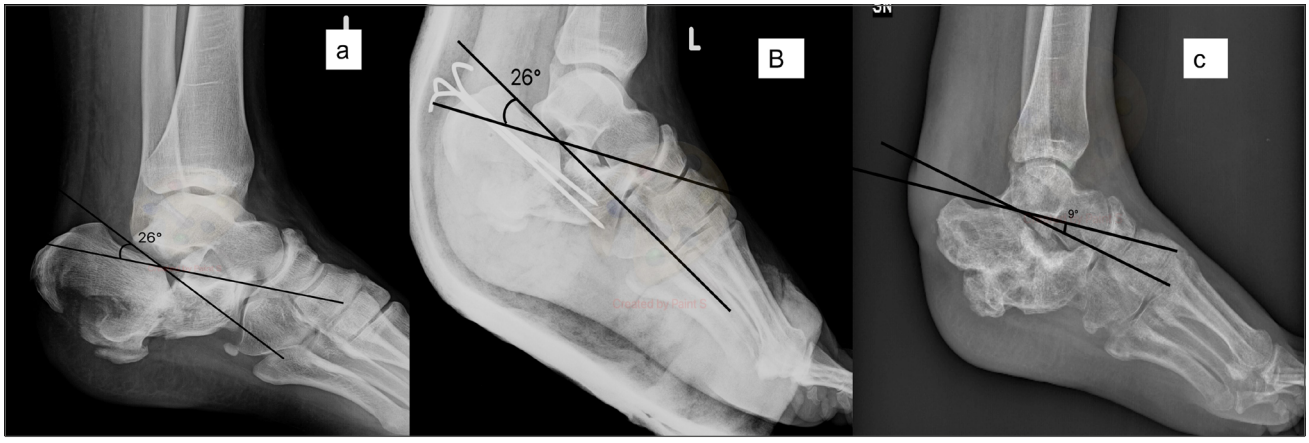

Figure 2. Bohler angle comparison. **A)** pre-operative (-26°); **B)** after first mini-invasive surgery (-26°); **C)** angle at one year follow up after definitive surgery (9°).

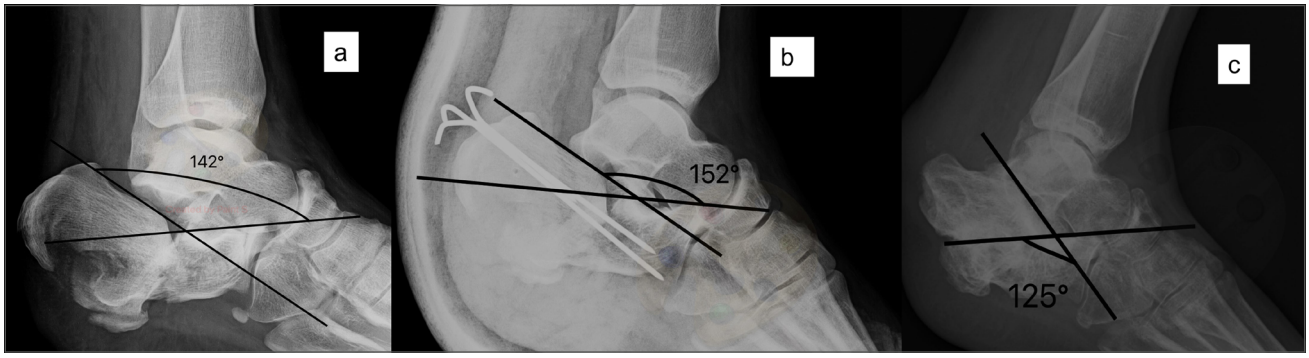

Figure 3. Gissane angle comparison. **A)** pre-operative (142°); **B)** after first mini-invasive surgery (152°); **C)** angle at one year follow up after definitive surgery (125°).

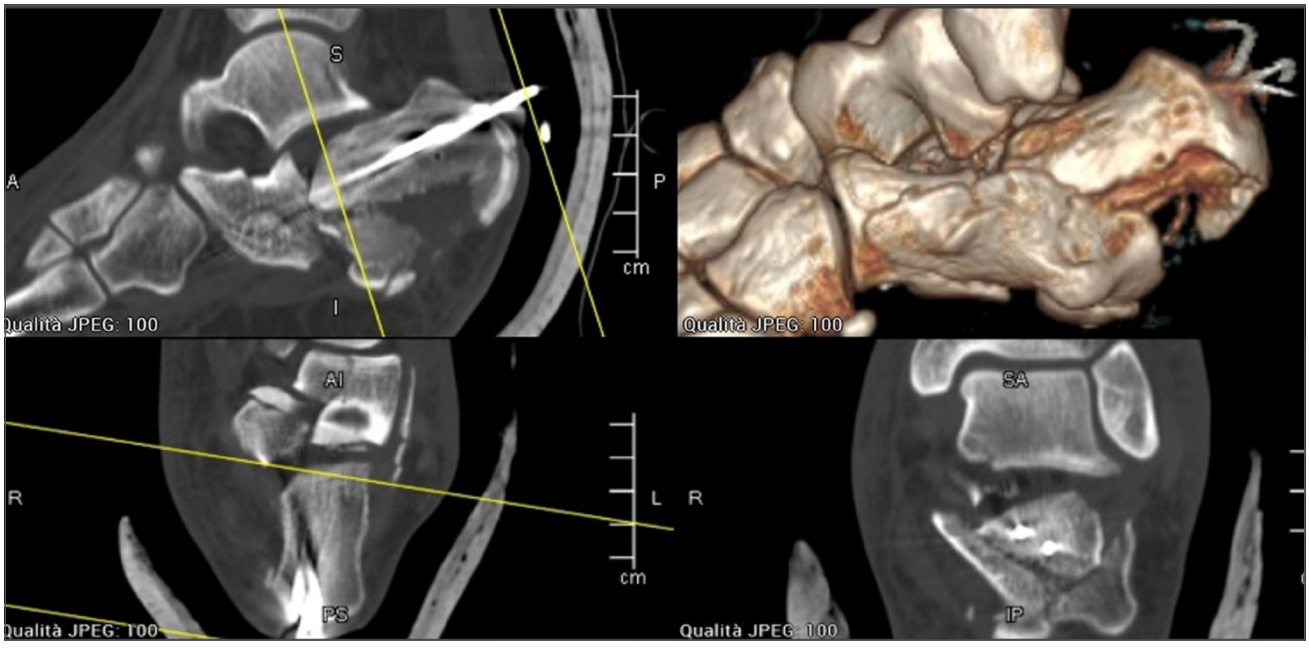

Figure 4. Ankle-foot CT scan that showed fracture nascent-malunion/malalignment.

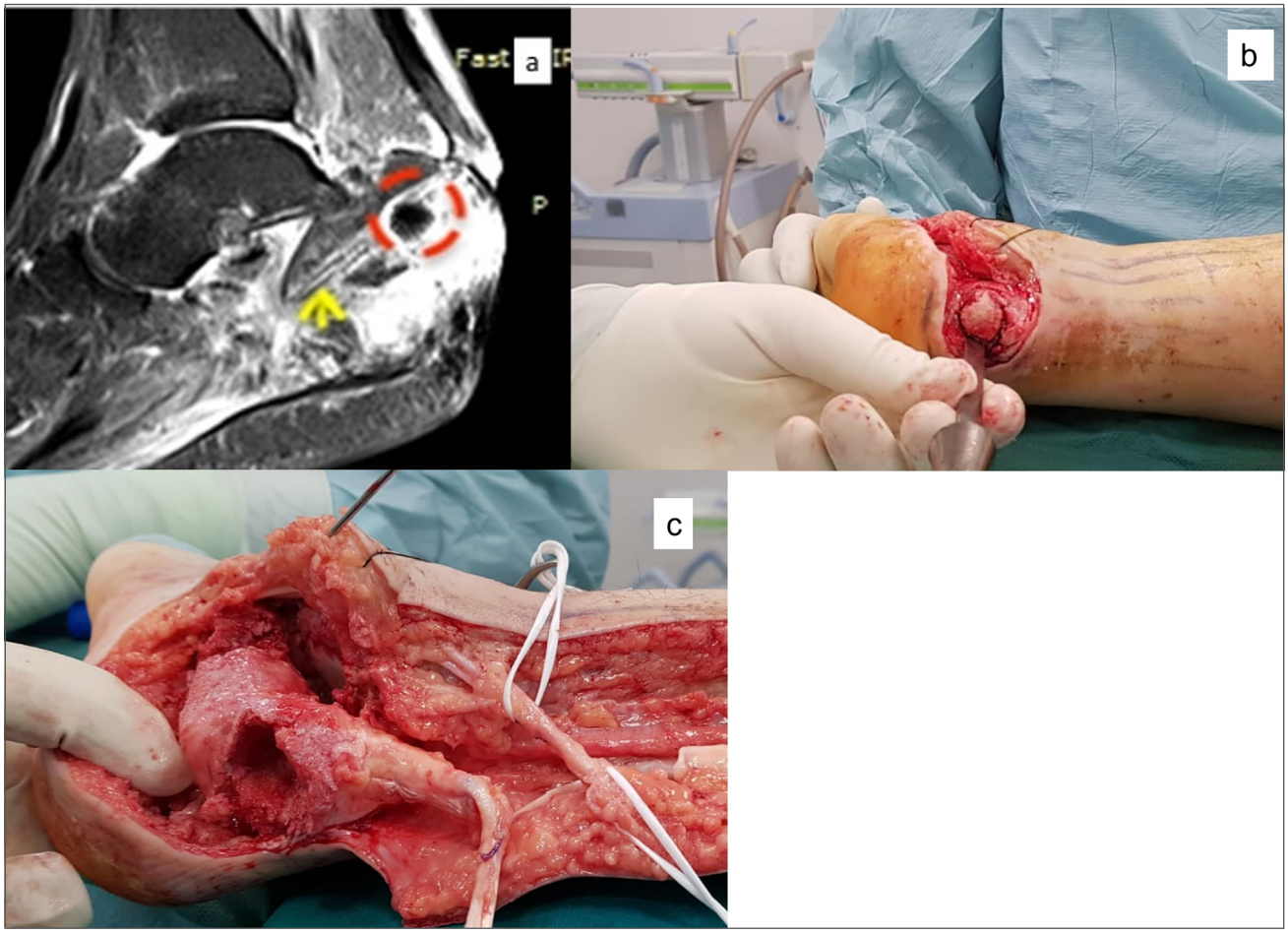

Figure 5. A) MRI preo-perative planning that shows osteomyelitis of the posterior pole of the calcaneus; **B-C)** En-bloc excision with macroscopic clear margins of the osteomyelitic bone.

sequestrum area was a sphere of about 3 to 5 cm of diameter.

The initial state of the soft tissues, with clear signs of active infection all around the eschar, precluded early operative intervention. At first, we removed the K-wires and placed a Vacuum Assisted Closure (VAC) device therapy on the area of loss of substance for ten days; after vacuum-assisted treatment and acute infection stabilization, a surgical treatment improved the chances of recovery.

Traditional "L" shaped lateral incision to the calcaneus, including the posterior eschar in the vertical branch of the lateral incision, was performed. Subsequently, we made an en-bloc excision with macroscopic clear margins of the osteomyelitic bone (about 4 cm of bone, in a spheric geometry, in the posterior part of the calcaneus). Multiple samples for bacterial analysis were collected. The malconsolidated fracture was carefully mobilized from the lateral approach, including the posterior apophysis associated with the lateral subtalar joint (Fig. 6). Since the apophysis was flexed and retracted, we performed a "Z" lengthening procedure at the Achilles tendon through the same surgical approach planned for the peroneus brevis flap. Reduction of the subtalar joint to the anatomical position and percutaneous K wires fixation followed the Achilles lengthening. The plantar bone fragment was deeply immersed in the scar, causing substantial plantar bone loss.

We raised a distal-based peroneus brevis flap [20,21] to fill the dead space and cover the posterior apophysis with the muscle through a proximal extension of the vertical approach. During the dissection, a good calibre perforator nourishing the flap appeared about 5 cm proximal to the distal apex of the lateral malleolus, making the flap's turning point relatively evident. The flap fully reached the calcaneal bone and filled it out without tension, covering the posterior calcaneal bone. The muscle belly of the peroneus comfortably filled and obliterated the 4 cm sferic loss of bone [22] by bending its structure softly inside the hole, leaving enough tissue to define the reconstruction as slightly bulky, with

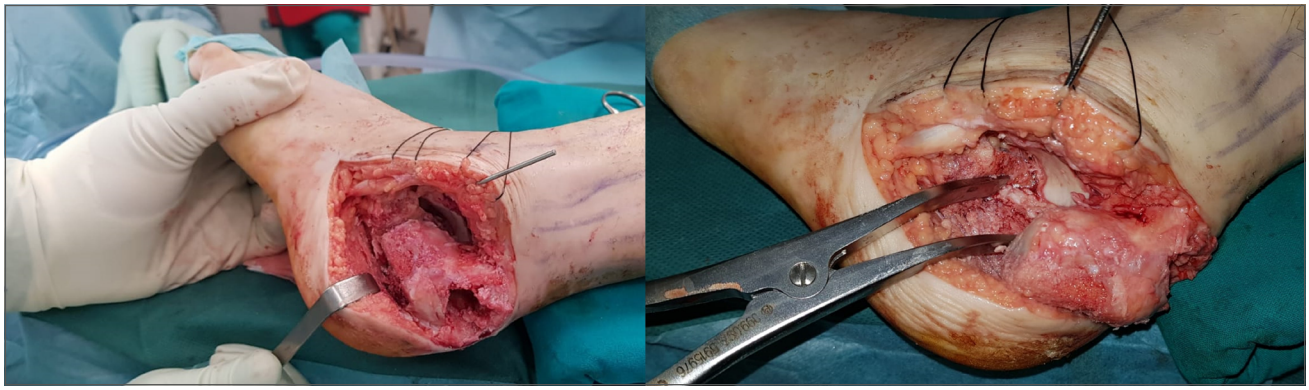

Figure 6. The mal-consolidated fracture was carefully mobilized including the posterior apophysis associated to the lateral subtalar joint.

Figure 7. The distal-based peroneus brevis flap raised to cover the posterior apophysis with the muscle. **A)** the flap was positioned deep to the peroneus longus tendon to avoid impingement with the saphenous nerve; **B)** the setting of the peroneus brevis obliterates the dead space left after resection of the osteomyelitis sequestrum.

no tension. The muscle was positioned deep to the peroneus longus tendon to avoid impingement with the sural nerve (Fig. 7A-B). Subsequently, we covered the flap with a split-thickness skin graft taken from the thigh. A trans-articular subtalar percutaneous K wire and a bridging external fixator (EF) were positioned at the end to stabilize the construct.

The laboratory tests on the resected bone found an Ampicillin oxacillin-resistant Staphylococcus Aureus pathogen and confirmed the diagnosis of osteomyelitis.

After surgery, antibiotic prophylaxis with Teicoplanin (600 mg/day) for eight weeks was started based on the recommendation of the infectious diseases consultant. Post-surgery prescriptions included a softly compressing medication of the flap and the graft for five days (Moulage) and the following: 1) no weight bearing for 90 days; 2) removal of EF after 30 days; 3) removal of superficial K wires after 60 days and surgical removal of deep K wires after four months. The surgical wound and local skin wholly healed in 15 days. Graft take was 95%. The post-operative consultations (follow-up) were at weeks one, two, three and four. Then, at months one, two, three, four and five. The patient reached full weight bearing in August 2019 (5 months after surgery) and followed up at one year, 18 months, two and three years after surgery. After one year, she walked without crutches and climbed the stairs without aid. We measured the clinical results through the American Foot and Ankle Society Score (AOFAS score of 79) and the Foot and Ankle Disability Index Score (FADI score of 89.4), and they appeared comparable to the main results obtained in the literature. Radiological analysis at one-year follow-up showed a Bohler angle of 9° and a Gissane angle of 125° (Figs. 2-3).

Eighteen months, two and three years after surgery, the patient had mild, occasional pain and could walk with no distance limitation and without ordinary activities restriction. No significant limping remained, but some residual difficulty walking on uneven ground. She lost weight (BMI 28), ceased smoking, and ran 20 minutes 3 days/week. At clinical examination, the skin had no sign of suffering; the ankle showed normal motion in the sagittal plane (flexion/extension: 20°-0-50°); the inversion/eversion of the ankle was reduced (eversion 0°, inversion 20°); The subtalar joint was fixed but painless. The ankle-hindfoot alignment was adequate (5°), and the podoscope analysis showed a standard footprint

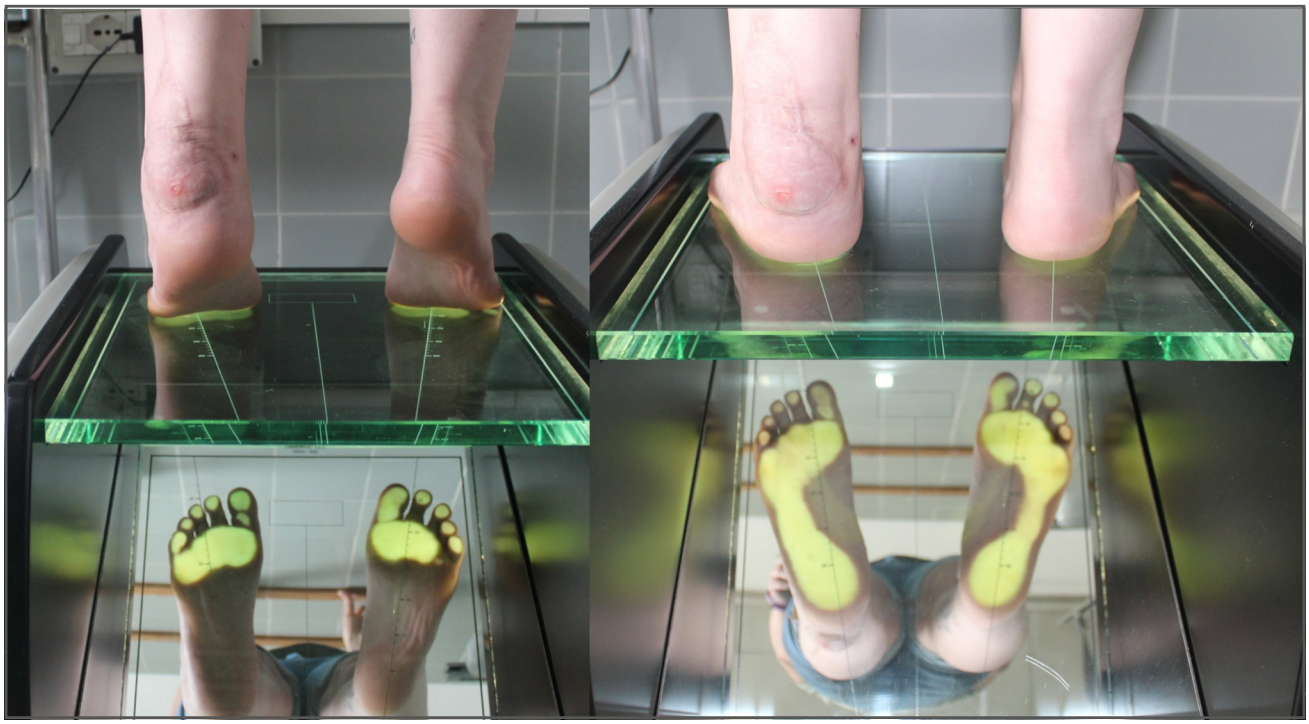

Figure 8. Hill rise test: the podoscope analysis that shows normal footprint.

(Fig. 8). Clinically, ankle-hindfoot was stable (anteroposterior, varus-valgus). The AOFAS and FADI scores were 84/100 and 95/105 at three years, respectively.
No sign of local infection at three years follow-up. The posterior calcaneal skin was closed entirely, with no sign of ulcers. We assessed a moderate posterior bulk of the flap, with no shoe discomfort. The flap donor site had a normal scar with no pain. Foot pronation was 0° but stable, with no passive supination.

DISCUSSION

The management of intra-articular calcaneal fractures complicated by osteomyelitis remains a significant debate among orthopaedic and plastic surgeons [23,24]. The outcomes depend on the fracture pattern, the patient's comorbidities, the stage and size of the osteomyelitis and the experience of the institution where the patient obtains treatment.
From an orthopaedic point of view, recent systematic reviews describe comparable clinical results between operative and non-operative treatment for a displaced intra-articular calcaneal fracture, especially in complex patients with associated comorbidities or dangerous habits.
Operative treatment with open reduction and internal fixation (ORIF) has been performed for decades and is currently the standard treatment option; recently, techniques that use percutaneous reduction and screw osteosynthesis or minimally invasive open approaches have been widespread. Conversely, external fixation and other methods, such as Kirschner wire fixation, have not proven satisfying results when used as first-line treatment.
The chosen treatment should focus on restoring the anatomy by correcting the varus/valgus deformity of the heel, the Bohler angle, the lateral wall blowout, and subtalar joint congruity [25]. Post-traumatic arthrosis development makes it easier to perform subtalar fusion if we have an excellent calcaneal shape and dimensions [26,27]. Furthermore, calcaneal malunion may shorten the injured extremity and change the motion axis of the foot, ankle, and even the entire lower limb, leading to dysfunction. Such a condition provides a strong reason for open or mini-open operative treatment in appropriate cases.
Furthermore, patient selection, specifically skilled surgeons, and adequate follow-up are crucial: Vasukutty [28] pointed out the importance of managing those fractures in a foot and ankle unit with a multidisciplinary environment.
In this case, the fracture was initially managed in the very acute setting in a peripherical hospital mini-invasively with K-wires to ideally fasten the patient's recovery and reduce soft tissue complications. This approach, as reported by Epstein [3], may be technically demanding, and the quality of the reduction achieved

may be lower, increasing the chances of secondary arthrodesis. Moreover, the patient's characteristics had not been previously considered, raising the chances of soft tissue complications. As a result, the supposed sufficient reduction with minimal complications was a non-reduction with significant soft tissue and bone complications.

After a multidisciplinary evaluation, we excluded subtalar fusion as the first-line treatment because of potential poor residual bone stock after the planned osteomyelitis excision. We decided to manage the nascent malunion with open reduction (OR) to obtain an anatomical reduction of the subtalar joint and restore the calcaneus shape. In addition, this approach might improve short- and long-term clinical results because of the young patient's age and the expected long-term high functional requests: even if an OR involves an increased risk of local complications in the short-time, it decreases long-term complications like arthrosis, the necessity of subtalar fusion or failure to resume pre-injury work. We then stabilized the reduction with Kirshner Wires Pinning and External Fixation.

From a reconstructive perspective, managing osteomyelitis is always challenging and requires complete infected tissue excision and reconstruction [29]. The complete resection of the osteomyelitis sometimes causes an extensive loss of substance of the calcaneus, needing a reconstruction with vascularized bone graft or considerable size of soft tissue. Free vascularized bone graft from the iliac crest is an option in extensive resections. Ghods et al. [22] describe a quite inspiring surgical technique: a free gracilis muscle flap to fill the gap is a reliable alternative when a large size of cancellous calcaneal bone is excised without primary cortical resection. Since a small-medium bone gap was to be filled, the peroneus pedicled flap was a practical alternative to apport soft vascularized viable tissue without needing microsurgical anastomosis. In our case report, the infected bone was confined in the central and posterior area of the calcaneum, requiring a limited bone resection with no need for a bone graft. Laub et al. [15] describe a similar tool (gracilis free flap) for the more significant demand for dead-space obliteration, which is essential after sequestrum resection. We also considered the need for orthopaedic surgeons for an open reduction and stabilization with K-wires, and we finalized our choice of the peroneus muscle pedicled flap as an easy-to-raise and minimally invasive procedure when compared to a free flap, considering the size of the defect. Furthermore, muscle flaps offer abundant, pliable, well-vascularized tissue to cover infection sites. The surgical technique of the peroneus flap is well described in the literature.

CONCLUSIONS

This case report emphasizes the importance of setting the management of complex cases in a multidisciplinary "orthoplastic" centre where different clinical and surgical skills work together to develop a shared management protocol that allows a proper patient and surgical strategy selection to reduce post-operative complications [30]. The pedicled peroneus brevis muscle flap is a versatile, relatively effortless and fast-to-dissect tool for covering slight to medium-sized loss of substance of the soft tissues around the calcaneal bone and Achilles tendon area. It is also suitable to obliterate [15,22] any small to medium-sized posterior dead space from removed cancellous bone by simply bending its shape into the holes. No significant function loss in pronation and ankle stability typically develops.

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Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

DS: A and W
AB: D and S
GN: DT and S
AM: O (coordinator)
DC: A and W

Abbreviations

A: conceived and designed the analysis
D: collected the data
DT: contributed data or analysis tool
S: performed the analysis
W: wrote the paper
O: other contribution (specify contribution in more detail)

Ethical consideration

Not applicable.

References

1 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

2 Pierazzi DM, Arleo S, Faini G. Combination of LICAP and IMAP flap for treatment of long-lasting cutaneous fistulas of the chest wall with osteomyelitis. Plast Reconstr Regen Surg 2022:20-23. https://doi.org/10.57604/PRRS-003

3 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

4 Walde TA, Sauer B, Degreif J, et al. Closed reduction and percutaneous Kirschner wire fixation for the treatment of dislocated calcaneal fractures: surgical technique, complications, clinical and radiological results after 2-10 years. Arch Orthop Trauma Surg 2008;128:585-591. https://doi.org/10.1007/s00402-008-0590-1

5 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

6 Ebrahimpour A, Kord MHC, Sadighi M, et al. Percutaneous reduction and screw fixation for all types of intra-articular calcaneal fractures. Musculoskelet Surg 2021;105:97-103. https://doi.org/10.1007/s12306-019-00635-w

7 Lim EV, Leung JP. Complications of intraarticular calcaneal fractures. Clin Orthop 2001;391:7-16. https://doi.org/10.1097/00003086-200110000-00003

8 Li Y, Bao RH, Jiang ZQ, et al. Complications in operative fixation of calcaneal fractures. Pak J Med Sci 2016;32:857-862. https://doi.org/10.12669/pjms.324.10225

9 Benirschke SK, Kramer PA. Wound healing complications in closed and open calcaneal fractures. J Orthop Trauma 2004;18:1-6. https://doi.org/10.1097/00005131-200401000-00001

10 Monticelli A, Ciclamini D, Boffano M, et al. Lower limb core scale: a new application to evaluate and compare the outcomes of bone and soft-tissue tumours resection and reconstruction. BioMed Res Int 2014;2014. https://doi.org/10.1155/2014/652141

11 Battiston B, Ciclamini D, Tang JB. Compound or specially designed flaps in the lower extremities. Clin Plast Surg 2020;47:535-546. https://doi.org/10.1016/j.cps.2020.06.006

12 Battiston B, Ciclamini D, Tang JB. Compound or specially designed flaps in the lower extremities. Clin Plast Surg 2017;44:287-297. https://doi.org/10.1016/j.cps.2016.11.006

13 Pignatti M, Tos P, Garusi C, et al. A sequence of flaps and dissection exercises in the living model to improve the learning curve for perforator flap surgery. Injury 2020;51:S22-S30. https://doi.org/10.1016/j.injury.2020.02.006

14 Jose J, Parameswaran SC, Rajappan A, et al. Surgical outcome of distally based peroneus brevis flap: a retrospective study. Cureus 2022;14:E26329. https://doi.org/10.7759/cureus.26329

15 Laub P, Vandevender J, Yang M, et al. Intramedullary free gracilis for dead-space obliteration and stump resurfacing in a transfemoral amputee with recurrent osteomyelitis. Eplasty 2023;23:E46.

16 Chen K, Balloch R. Management of calcaneal osteomyelitis. Clin Podiatr Med Surg 2010;27:417-429. https://doi.org/10.1016/j.cpm.2010.04.003

17 Reddy V, Fukuda T, Ptaszek AJ. Calcaneus malunion and nonunion. Foot Ankle Clin 2007;12:125-135. https://doi.org/10.1016/j.fcl.2006.12.004

18 Clare MP, Crawford WS. Managing complications of calcaneus fractures. Foot Ankle Clin 2017;22:105-116. https://doi.org/10.1016/j.fcl.2016.09.007

19 Ciclamini D, Antonini A, Tos P, et al. Treatment of chronic Osteomyelitis with vascularized bone flaps in one-stage-procedure. Handchir Mikrochir Plast Chir Organ Deutschsprachigen Arbeitsgemeinschaft Handchir Organ Deutschsprachigen Arbeitsgemeinschaft Mikrochir Peripher Nerven Gefasse Organ V 2020;52:116-122. https://doi.org/10.1055/a-1075-2402

20 Eren S, Ghofrani A, Reifenrath M. The distally pedicled peroneus brevis muscle flap: a new flap for the lower leg. Plast Reconstr Surg 2001;107:1443-1448. https://doi.org/10.1097/00006534-200105000-00020

21 Battiston B, Vasario G, Ciclamini D, et al. Reconstruction of traumatic losses of substance at the elbow. Injury 2014;45:437-443. https://doi.org/10.1016/j.injury.2013.09.029

22 Ghods M, Grabs R, Kersten C, et al. A modified free muscle transfer technique to effectively treat chronic and persistent calcaneal osteomyelitis. Ann Plast Surg 2012;68:599-605. https:/doi.org/10.1097/SAP.0b013e31821ee359

23 Arrigoni C, Vezza D, Crosio A, et al. Open G3 lower limb fracture management in an Italian trauma center: Comparison with international protocols. Minerva Ortop E Traumatol 2019;70:181-187. https://doi.org/10.23736/S0394-3410.19.03950-X

24 Felici N, Fulchignoni C, Ciclamini D, et al. Orthoplastic approach to leg and foot trauma. Minerva Orthop 2023;74:290-297. https://doi.org/10.23736/s2784-8469.23.04281-5

25 Radnay CS, Clare MP, Sanders RW. Subtalar fusion after displaced intra-articular calcaneal fractures: does initial operative treatment matter? Surgical technique. J Bone Joint Surg Am 2010;92(Suppl 1 Pt 1):32-43. https://doi.org/10.2106/JBJS.I.01267

26 Wei N, Yuwen P, Liu W, et al. Operative versus nonoperative treatment of displaced intra-articular calcaneal fractures: a meta-analysis of current evidence base. Medicine (Baltimore) 2017;96:E9027. https://doi.org/10.1097/MD.0000000000009027

27 Rammelt S, Sangeorzan BJ, Swords MP. Calcaneal fractures – should we or should we not operate? Indian J Orthop 2018;52:220-230. https://doi.org/10.4103/ortho.IJOrtho_555_17

28 Vasukutty N, Kumar V, Diab M, et al Operative treatment of calcaneal fractures: improved outcomes and low complications rates with a strict management protocol. Ann R Coll Surg Engl 2017;99:275-279. https://doi.org/10.1308/rcsann.2016.0259

29 Longo B, D'Orsi G, Orlando G, et al. Recurrent dermatofibrosarcoma protuberans of the clavicular region: radical excision and reconstruction with Latissimus Dorsi myocutaneous flap. Plast Reconstr Regen Surg 2022;1:14-19. https://doi.org/10.57604/PRRS-002

30 SIM Società Italiana di Microchirurgia. Acute Orthoplastic surgery treatment of open fractures of the lower leg and foot. Minerva Medica 2021.