Lo SCALPELLO Journal (2026) 40:46-54
doi number: 10.36149/0390-5276-366

Medial malleolar fractures: hook plates versus lag screws fixation. A prospective multicenter observational study

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Summary

Objective. This prospective multicenter observational study compares clinical, functional, and radiological outcomes of hook plate versus lag screw fixation for medial malleolar fractures.

Methods. Between June 1, 2019, and June 1, 2021, a prospective observational study was conducted across 5 hospitals. Sixty-one patients with isolated medial malleolar fractures or bimalleolar fractures were enrolled and assigned to two groups based on the treatment received: lag screw fixation (n = 30) or hook plate fixation (n = 31). Outcomes included AOFAS, OMAS, VAS scores and radiographic evaluations.

Results. Hook plate fixation yielded higher AOFAS (90.2 ± 9.7 vs 74.3 ± 13.8; p = 0.001), OMAS (85.7 ± 9.5 vs 71.0 ± 13.6; p = 0.002), healing rate (100% vs 86.6%; p = 0.050), and shorter time to union (9.7 vs 13.3 weeks; p = 0.044).

Conclusion. Hook plate fixation provides superior functional outcomes and higher healing rates compared to lag screws, particularly in osteoporotic or comminuted fractures. Careful patient selection and surgical technique are essential.

Key words: medial malleolar fractures, hook plate fixation, lag screw fixation, ankle fractures, functional outcomes

Received: March 24, 2026
Accepted: May 15, 2026
Published online: June 12, 2026

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How to cite this article: Suraci F, Benelli C, Carta B, et al. Medial malleolar fractures: hook plates versus lag screws fixation. a prospective multicenter observational study. Lo Scalpello Journal 2026;40:46-54. https://doi.org/10.36149/0390-5276-366

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Introduction

Ankle fractures are common in adults, with an incidence ranging from 107 to 187 cases per 100,000 individuals annually, a figure increasing due to demographic shifts and higher activity levels in the elderly [1,2]. The distribution of these fractures is varied: lateral malleolar fractures are the most frequent, accounting for 55-65% of all cases. Medial malleolar fractures occur in isolation less frequently, representing 5-15% of ankle fractures, while bimalleolar fractures, involving both medial and lateral malleoli, constitute 15-20% of cases. Trimalleolar fractures, involving the medial, lateral, and posterior malleoli, contribute to an additional 7-12% [5]. The medial malleolus plays a crucial role in maintaining ankle stability and ensuring

proper tibiotalar contact. Fractures in this area often reduce the articular contact area and increase joint pressure. If not properly managed, this can lead to post-traumatic arthritis [6,7]. Additionally, these fractures are often associated with syndesmotic injuries, dislocations, and ligament or tendon ruptures, complicating treatment and significantly impacting clinical outcomes. Moreover, the medial malleolus has limited overlying soft tissue, making surgical management challenging because of the risk of wound complications and hardware prominence [8].

Accurate classification of medial malleolar fractures is essential to guide treatment. The Herscovici classification system categorizes these fractures based on their location relative to the tibial plafond [9]. Type A fractures are avulsion injuries of the malleolar tip, Type B fractures occur between the tip and the plafond level, Type C fractures are at the level of the plafond, and Type D fractures are vertical and extend above the plafond. Understanding the fracture pattern aids in selecting the most appropriate fixation method.

Management options for medial malleolar fractures include conservative treatment and various surgical interventions. Surgical methods such as open reduction and internal fixation (ORIF) using lag screws, tension band wiring, or plate fixation are commonly employed [10,11]. ORIF with partially threaded cannulated screws is widely used due to its ability to provide interfragmentary compression and stability for bone healing [12]. Challenges particularly arise in osteoporotic or comminuted fractures where screw fixation may be insufficient, potentially leading to inadequate purchase and fixation failure [13,14].

Tension band wiring can be an effective alternative, particularly in small avulsion fractures or in osteoporotic bone. However, it has been associated with complications such as hardware irritation and prominence, leading to discomfort and the need for hardware removal [15]. Buttress or antiglide plating is another option, especially for vertical shear fractures, providing stable fixation and allowing for early mobilization [16].

Recently, hook plates have emerged as an alternative fixation method for medial malleolar fractures. Designed to securely capture the malleolar fragment, hook plates may enhance stability and promote healing, especially in fractures with small or osteoporotic fragments [17,18]. Biomechanical studies have suggested that hook plates provide higher stiffness and less bone destruction compared to traditional lag screws [19]. The potential advantages of hook plate fixation include better fragment control, angular stability, and the ability to convert shear forces into compression forces, which may accelerate the healing process [20].

This prospective multicenter observational study compares the clinical, functional, and radiological outcomes of lag screw fixation and hook plate fixation in medial malleolar fractures, particularly in patients with osteoporotic bone or comminuted fractures.

Materials and methods

A prospective observational multicenter study was conducted over a 2-year period from June 1, 2019, to June 1, 2021. The study involved 5 hospitals in Italy: S. Andrea Hospital (Faculty of Medicine and Psychology, Sapienza University of Rome), C.T.O. Andrea Alesini (Traumatology and Orthopedic Center of Rome), San Camillo de Lellis Hospital (Traumatology and Orthopedic Center of Rieti), S. Spirito Hospital (Rome), and S. Pertini Hospital (Rome). Each center obtained ethical approval from its institutional review board, and written informed consent was obtained from all participants prior to inclusion in the study.

Both fixation techniques were available and routinely performed in all participating centers. Treatment allocation was not determined by institutional protocols but was based on individual surgeon preference and fracture characteristics. No center was restricted to a single fixation method.

Given the multicenter design, potential inter-center variability cannot be completely excluded; however, the availability of both techniques across institutions reduces the likelihood of center-driven treatment allocation bias.

Patients aged 18 years or older with a diagnosis of isolated medial malleolar fracture or bimalleolar fracture were eligible for inclusion. Fractures were classified preoperatively using standard ankle radiographs according to the Herscovici [9] and Danis-Weber classifications. Computed tomography was not routinely performed because fracture-dislocations and posterior malleolar involvement were excluded from the study population. In addition, fracture morphology was clearly identifiable on standard radiographs and did not require further CT-based characterization.

Exclusion criteria included also open fractures, polytrauma, previous ipsilateral ankle fractures, ankle dislocations, syndesmotic injuries, neurological or vascular insufficiency affecting the lower limb, inability to comply with follow-up protocols, and incomplete medical records or less than one year of follow-up.

Consecutive patients presenting to the participating centers with medial malleolar fractures were assessed for eligibility. A total of 61 patients met the inclusion criteria and were enrolled in the study. The decision for the type of surgical treatment—lag screw fixation or hook plate fixation—was determined based on the surgeon's preference, clinical judgment, and patient-specific factors. All surgical procedures were performed under spinal or general anesthesia with the patient in the supine position. Prophylactic antibiotics were administered prior to incision, and a tourniquet was applied to the thigh.

In the hook plate fixation group (n = 31), an anteromedial incision was made to expose the fracture site while carefully preserving the saphenous vein and nerve. After achieving anatomical reduction, the hook plate was positioned with the hooks engaging the distal fragment (Fig. 1). Reduction and implant



Figure 1. Surgical approach and positioning of the hook plate.

positioning were confirmed intraoperatively using fluoroscopic guidance in both fixation groups.

The plate was then secured proximally with 3.5-mm cortical screws, and locking screws were placed through the remaining holes to provide angular stability, as shown in Figure 2 for the initial placement and Figure 3 for the postoperative alignment (Figs. 2, 3) [17,18]. The hook plate used was a precontoured locking compression plate designed specifically for medial malleolar fractures (Hook Gorilla Plate, Paragon 28, Englewood, CO, USA).

In the lag screw fixation group (n = 30), an anteromedial approach over the medial malleolus was utilized. The fracture was reduced under direct visualization and confirmed with an image intensifier. Two partially threaded 4.0-mm cannulated screws (Stryker, Kalamazoo, MI, USA) were inserted perpendicular to the fracture line to provide interfragmentary compression [12,13]. In some cases, one screw and a Kirschner wire were used, depending on the fracture pattern and bone quality. All patients underwent fixation of the lateral malleolus if involved, using standard techniques. Syndesmotic injuries were ruled out intraoperatively by stress testing. Postoperative protocols were standardized across all centers. Early ankle mobilization was encouraged in both groups. Patients in the hook plate group remained non-weight-bearing for 2 weeks, followed by gradual weight-bearing as tolerated. Those in the lag screw group were non-weight-bearing for 4 weeks before initiating weight-bearing activities. Antithrombotic prophylaxis was administered according to standard hospital protocols [21] until full weight-bearing was achieved.

Data were collected prospectively at baseline and during follow-up visits at 2 weeks, at 1, 3, 6, and 12 months, and at 1, 2 and 3 years postoperatively. Demographic data included patient age, sex, body mass index (BMI), bone mineral density (BMD) assessed by dual-energy X-ray absorptiometry (DEXA), comorbidities, mechanism of injury, and physiological reserve, which was evaluated using the Charlson Comorbidity Index (CCI) [22]. Clinical assessments involved monitoring wound

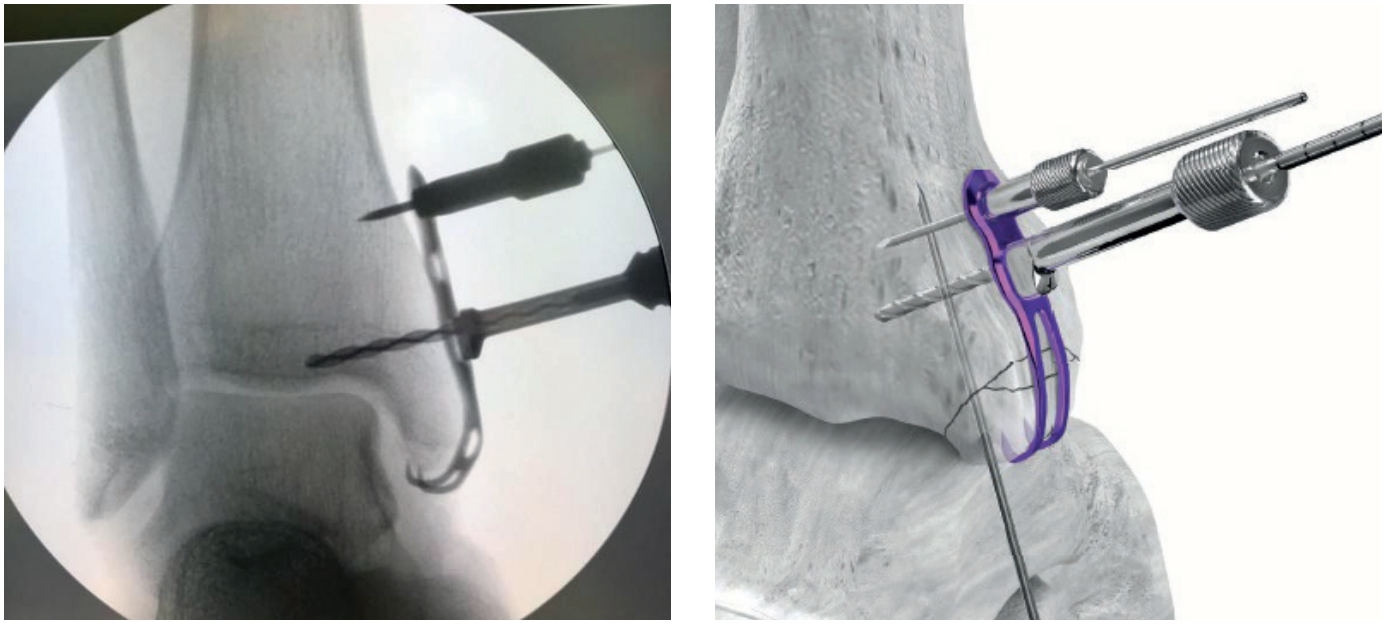


Figure 2. Application of hook plate. First the inserting of K wire on the proximal hole, and then the tighten of compression screw.

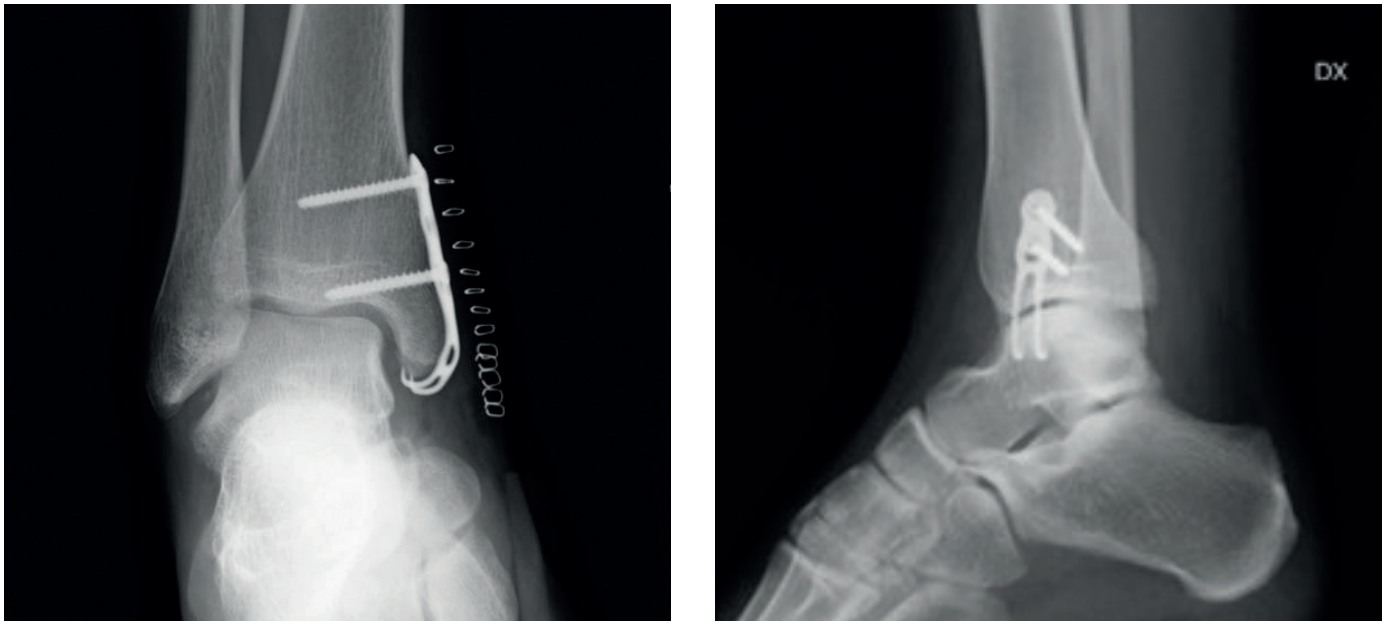


Figure 3. Postoperative radiographic evaluation illustrating the alignment and fixation of the hook plate in the medial malleolus.

healing, the presence of complications, and length of hospitalization. Functional outcomes were measured using the AOFAS ankle-hindfoot score and the Olerud-Molander Ankle Score (OMAS) at 12 months [23,24]. Pain assessment was performed using the VAS for pain on palpation of the medial malleolus at 12 months. Radiographic evaluations were conducted with standard ankle radiographs, including anteroposterior, lateral, and mortise views, to assess fracture healing and alignment. Fracture healing was assessed based on the presence of bridging trabeculae across the fracture site on at least three of four cortices in two orthogonal planes [25]. Nonunion was defined as the absence of radiographic healing at 6 months postoperatively. Malunion was defined as more than 2 mm of articular step-off or gap on postoperative radiographs.

The primary outcome was functional outcome measured by the AOFAS ankle-hindfoot score at 12 months. Secondary outcomes included pain level assessed by the VAS at 12 months, radiographic healing, and complications such as infections (superficial and deep), nonunion, malunion, hardware irritation, fixation failure, and the need for revision surgery.

Statistical Analysis

Data were analyzed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA) and SPSS Version 25.0 (IBM Corp., Armonk, NY). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. The Shapiro-Wilk test was used to assess the normality of continuous variables. Comparisons between groups were made using independent samples t-tests for normally distributed continuous variables and Mann-Whitney U tests for non-normally distributed variables. Chi-square or Fisher's exact tests were used for categorical variables. Multivariate regression analyses were performed to adjust for potential confounders such as age, sex, BMI, BMD, comorbidities, fracture type, and fracture comminution. Complementary categorical outcomes (union and nonunion rates) were derived from a single 2×2 contingency analysis, and only one p-value is reported to avoid redundancy. p-value < 0.05 was considered statistically significant.

Results

Participant Flow and Baseline Characteristics (Tab. I)

A total of 61 patients were enrolled, with 31 in the hook plate group and 30 in the lag screw group. There were no significant differences between the groups regarding age, sex, BMI, BMD, comorbidities, mechanism of injury, or CCI scores. The mean age was 76.1 ± 6.7 years in the hook plate group and 75.3 ± 5.6 years in the lag screw group. The sex distribution was similar, with 16 males and 15 females in the hook plate group, and 14 males and 16 females in the lag screw group. The mean BMI and BMD were comparable between the two groups. Comorbidities such as diabetes, hypertension, and peripheral vascular disease were evenly distributed.

Table I. Baseline Demographic and Clinical Characteristics.

Characteristic	Hook Plate Group (n = 31)	Lag Screw Group (n = 30)	p-value
Mean Age (years)	76.1 ± 6.7	75.3 ± 5.6	0.65
Sex (Male/Female)	16/15	14/16	0.88
Mean BMI (kg/m^2)	25.4 ± 3.2	24.9 ± 3.5	0.72
BMD (T-score)	-2.5 ± 0.6	-2.4 ± 0.7	0.80
Comorbidities (n)	18	17	0.90
Charlson Comorbidity Index	4.2 ± 1.3	4.1 ± 1.5	0.85

Fracture Classification

According to the Danis-Weber classification, in the hook plate group 10 patients (n = 10/31) had isolated medial malleolus fractures, and 21 patients (n = 21/31) had bimalleolar fractures. Among the bimalleolar fractures, the distribution was Type A (n = 1/21), Type B (n = 16/21), and Type C (n = 4/21). In the lag screw group, 4 patients (n = 4/30) had isolated medial malleolus fractures, and 26 patients (n = 26/30) had bimalleolar fractures, with the following distribution: Type A (n = 3/26), Type B (n = 15/26), and Type C (n = 8/26). According to the Herscovici classification (Tab. II), in the hook plate group, there were Type A fractures in 2 patients (n = 2/31, 6%), Type B fractures in 12 patients (n = 12/31, 39%), Type C fractures in 11 patients (n = 11/31, 35%), and Type D fractures in 6 patients (n = 6/31, 20%). In the lag screw group, there were Type A fractures in 4 patients (n = 4/30, 13%), Type B fractures in 5 patients (n = 5/30, 17%), Type C fractures in 18 patients (n = 18/30, 60%), and Type D fractures in 3 patients (n = 3/30, 10%). In addition, 18/31 fractures (58%) in the hook plate group and 8/30 fractures (27%) in the lag screw group were comminuted, with these characteristics distributed across fracture Types A, B, C, and D.

Table II. Fracture Classification According to Herscovici.

Fracture Type	Hook Plate Group (n = 31)	Lag Screw Group (n = 30)
Type A	2/31 (6%)	4/30 (13%)
Type B	12/31 (39%)	5/30 (17%)
Type C	11/31 (35%)	18/30 (60%)
Type D	6/31 (20%)	3/30 (10%)
Comminuted	18/31 (58%)	8/30 (27%)

Functional Outcomes (Tab. III)

At the 12-month follow-up, patients treated with hook plates demonstrated significantly higher functional scores compared to those treated with lag screws, irrespective of whether they had bimalleolar or isolated medial malleolar fractures. The mean AOFAS score in the hook plate group was 90.2 ± 9.7, while in the lag screw group it was 74.3 ± 13.8 (p = 0.001). Similarly, the OMAS was higher in the hook plate group (85.7 ± 9.5) compared to the lag screw group (71.0 ± 13.6, p = 0.002). Pain assessment using the VAS showed no significant difference between the groups. The hook plate group had a mean VAS score of 2.8 ± 2.7, and the lag screw group had a mean score of 2.9 ± 2.1 (p = 0.60).

Table III. Functional Outcomes at 12 Months.

Outcome Measure	Hook Plate Group (n = 31)	Lag Screw Group (n = 30)	p-value
AOFAS Score	90.2 ± 9.7	74.3 ± 13.8	0.001*
OMAS	85.7 ± 9.5	71.0 ± 13.6	0.002*
VAS Pain Score	2.8 ± 2.7	2.9 ± 2.1	0.60
*Statistically significant.			

Radiographic Healing (Tab. IV)

Radiographic evaluations demonstrated that the hook plate group achieved a 100% healing rate, with all patients (n = 31/31) showing evidence of fracture union. In contrast, the lag screw group had a healing rate of 86.6%, with 26 of 30 patients achieving union. This difference was statistically significant (p = 0.050). This corresponds to a nonunion rate of 0% versus 13.3%, respectively.

Furthermore, the mean time to union was significantly shorter in the hook plate group, averaging 9.7 ± 7.0 weeks, compared to 13.3 ± 6.7 weeks in the lag screw group (p = 0.044).

Table IV. Radiographic Healing and Time to Union.

Parameter	Hook Plate Group (n = 31)	Lag Screw Group (n = 30)	p-value
Healing Rate (%)	100% (n = 31/31)	86.6% (n = 26/30)	0.050*
Nonunion Rate (%)	0% (n = 0/31)	13.3% (n = 4/30)	0.050*
Time to Union (weeks)	9.7 ± 7.0	13.3 ± 6.7	0.044*
* Statistically significant.			

Complications (Tab. V)

Analysis of complications revealed a lower overall complication rate in the hook plate group compared to the lag screw group, although the difference was not statistically significant. The overall complication rate was 16.1% (n = 5/31) in the hook plate group and 20% (n = 6/30) in the lag screw group (p = 0.12). Nonunion was observed exclusively in the lag screw group, with an incidence of 13.3% (n = 4/30; p = 0.050). The fixation failure rate was 3.2% (n = 1/31) in the hook plate group compared to 10.0% (n = 3/30) in the lag screw group, although this difference was not statistically significant (p = 0.15). In the hook plate group, one patient developed superficial infection associated with early fixation failure. The patient underwent revision surgery consisting of hardware removal, surgical debridement, and repeat fixation. Subsequent radiographs demonstrated complete fracture union without residual complications. In the lag screw group, three revision surgeries were required, all for nonunion. Two of these cases involved fixation failure, and all three were associated with superficial wound infections. No statistically significant differences were found for superficial wound infections (p = 0.81), hardware irritation (p = 0.92) and revision surgeries (p = 0.31).

Table V. Complications.

Complication	Hook Plate Group (n = 31)	Lag Screw Group (n = 30)	p-value
Total Complications (%)	16.1% (n = 5/31)	20% (n = 6/30)	0.12
Nonunion	0% (n = 0/31)	13.3% (n = 4/30)	0.050*
Fixation Failure	3.2% (n = 1/31)	10.0% (n = 3/30)	0.15
Hardware Irritation	9.7% (n = 3/31)	10.0% (n = 3/30)	0.92
Superficial Wound Infection	12.9% (n = 4/31)	10.0% (n = 3/30)	0.81
Revision Surgery Needed	3.2% (n = 1/31)	10.0% (n = 3/30)	0.31
* Statistically significant.			

Discussion

The medial malleolus is integral to ankle joint stability and function, contributing significantly to the congruency of the ankle mortise and distribution of load across the tibiotalar joint [6,7]. Untreated or poorly reduced medial malleolar fractures can lead to joint incongruity, malunion (Fig. 4), and post-traumatic arthritis, necessitating surgical intervention to restore alignment and function [10]. Traditional fixation methods, such as lag screws, have been the standard due to their ability to provide interfragmentary compression [12]. However, in osteoporotic or comminuted fractures, achieving stable fixation with lag screws can be challenging because of poor bone quality and small fragment size, often necessitating ORIF to achieve anatomical alignment [13,14].

In this prospective multicenter observational study, we found that hook plate fixation for medial malleolar fractures resulted in significantly better functional outcomes, higher fracture healing rates, and shorter time to union compared to lag screw fixation. Patients in the hook plate group exhibited higher AOFAS and OMAS scores at 12 months, indicating improved functional recovery. The healing rate was 100% in the hook plate group, while the lag screw group exhibited an 86.6% healing rate and a 13.3% nonunion rate.

A higher proportion of Herscovici Type C fractures was observed in the lag screw group (60% vs 35%). These fractures, located at the level of the tibial plafond, may involve greater vertical shear components and potentially the posterior colliculus, which could contribute to increased mechanical instability. This morphological characteristic may partially explain the higher nonunion rate observed in the lag screw group.

Although multivariate regression analysis adjusted for fracture type and comminution, residual confounding related to subtle

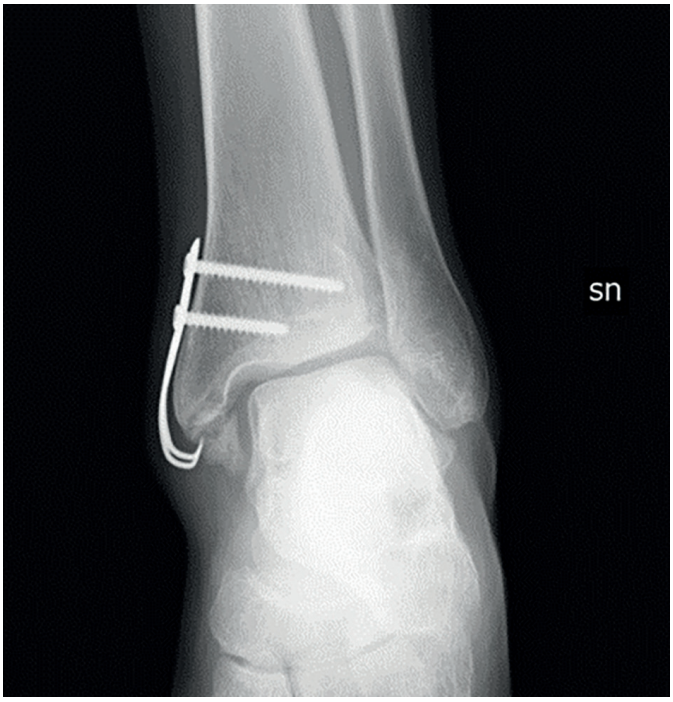


Figure 4. Malunion with hook plate fixation one month after surgery: the fracture was not adequately reduced, and the hook plate was malpositioned.

morphological differences not detectable on plain radiographs cannot be completely excluded.

These findings align with previous studies suggesting that hook plates offer biomechanical advantages over lag screws in certain fracture patterns [17,18]. The hook plate's design allows for secure capture of small or osteoporotic fragments, providing angular stability and converting shear forces into compression at the fracture site [20]. This improved stability likely contributed to the higher healing rates and quicker time to union observed in this study.

The significantly better functional outcomes in the hook plate group may be attributed to the ability of the hook plate to maintain stable fixation in osteoporotic bone, allowing for earlier mobilization and rehabilitation. Early weight-bearing and joint movement are critical to prevent stiffness and promote functional recovery. Conversely, the lag screw group required a longer period of non-weight-bearing, possibly contributing to the inferior functional outcomes.

Complication rates were comparable between the two groups, but the types of complications differed. Nonunion (Fig. 5) and fixation failure were more frequent in the lag screw group, both of which may necessitate revision surgery and impact long-term function. However, the difference in fixation failure did not reach statistical significance [7,13]. Hardware irritation was observed in both groups, likely resulting from the subcutaneous location of the medial malleolus and implant prominence in this region [5,15]. Although hardware irritation may lead to discomfort and require removal, it is generally a less severe complication compared to nonunion or fixation failure [17].

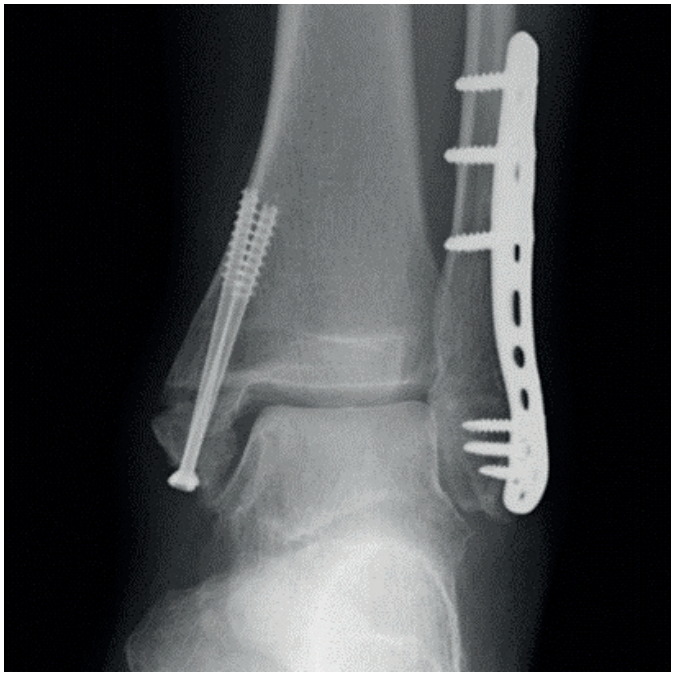


Figure 5. Nonunion with lag screws 12 months after surgery.

This study highlights the importance of selecting appropriate fixation methods based on patient-specific factors, including bone quality and fracture pattern. In elderly patients with osteoporotic bone or comminuted fractures, hook plates may provide superior outcomes due to their enhanced stability and ability to maintain reduction [19]. Earlier mobilization with hook plates can also contribute to better functional recovery, which is particularly important in elderly populations to prevent deconditioning and promote independence.

Limitations

This study has several limitations. The non-randomized design and reliance on surgeon preference for the choice of fixation method may introduce selection bias. Although baseline characteristics were similar between groups, unmeasured confounding variables could have influenced the outcomes. The sample size was relatively small, which may limit the generalizability of the findings and the statistical power to detect differences in complication rates. Future randomized controlled trials with larger sample sizes are warranted to validate these findings and assess long-term outcomes. Although this was a multicenter study, differences in surgical decision-making and perioperative management among centers may represent a source of variability. Nevertheless, since both fixation methods were routinely used in all institutions and baseline demographic and fracture characteristics were comparable between groups, a systematic center-related treatment bias is unlikely.

Conclusions

Hook plate fixation offers superior functional outcomes, higher fracture healing rates, and shorter time to union compared to lag screw fixation for medial malleolar fractures, particularly in elderly patients with osteoporotic bone or comminuted fractures. Although not entirely free from complications, the overall benefits of improved healing and function suggest that hook plates are a viable and potentially preferable alternative to lag screws, enabling earlier mobilization and faster recovery. Careful patient selection and meticulous surgical technique are essential to maximize outcomes and minimize complications. Future research should focus on developing strategies to mitigate hardware-related complications, and expanding the evidence base to a wider patient population.

Acknowledgements

The authors thank all the staff of the participating centres for their support in patient care and data collection.

Conflict of Interest Statement

The authors declare no conflicts of interest related to this study.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' contributions
C.B., F.S., B.C., E.L.: data collection, literature review, manuscript drafting. A.P.V., R.L., D.T., R.D.S.: study design, supervision, critical revision of the manuscript. All authors read and approved the final manuscript.

Ethical Consideration
This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the institutional review boards of all participating centers. Written informed consent was obtained from all participants after explaining the study procedures and potential risks. Patient confidentiality and data protection were maintained throughout the study.

References

1 Lin CW, Hiller CE, de Bie RA. Evidence-based treatment for ankle injuries: a clinical perspective. J Man Manip Ther. 2010;18(1):22-28. https://doi.org/10.1179/106698110X12595770849574
2 Jain S, Haughton BA, Brew C. Intramedullary fixation of ankle fractures: a systematic review. Foot Ankle Int. 2018;39(6):743-751. https://doi.org/10.1177/1071100718762101
3 Thur CK, Edgren G, Jansson KA, et al. Epidemiology of adult ankle fractures in Sweden between 1987 and 2004: a population-based study of 91,410 Swedish inpatients. Acta Orthop. 2012;83(3):276-281. https://doi.org/10.3109/17453674.2012.672091
4 Zaghloul A, Haddad B, Barksfield R, et al. Early complications of surgery in operative treatment of ankle fractures in those over 60: a review of 186 cases. Injury. 2014;45(5):780-783. https://doi.org/10.1016/j.injury.2013.11.008
5 Ebraheim NA, Ludwig T, Weston JT, et al. Comparison of surgical techniques of 111 medial malleolar fractures classified by fracture geometry. Foot Ankle Int. 2014;35(5):471-477. https://doi.org/10.1177/1071100714524553
6 Lareau CR, Bariteau JT, Paller DJ, et al. Contribution of the medial malleolus to tibiotalar joint contact characteristics. Foot Ankle Spec. 2015;8(1):23-28. https://doi.org/10.1177/1938640014546862
7 Hu J, Zhang C, Zhu K, et al. Adverse radiographic outcomes following operative treatment of medial malleolar fractures. Foot Ankle Int. 2018;39(10):1199-1207. https://doi.org/10.1177/1071100718785943
8 Barnes H, Cannada LK, Watson JT. A clinical evaluation of alternative fixation techniques for medial malleolus fractures. Injury. 2014;45(9):1365-1367. https://doi.org/10.1016/j.injury.2014.05.031
9 Herscovici D Jr, Scaduto JM, Infante A. Evaluation and treatment of isolated medial malleolar fractures. J Foot Ankle Surg. 2007;46(2):123-127. https://doi.org/10.1053/j.jfas.2006.12.002
10 Carter TH, Duckworth AD, White TO. Medial malleolar fractures: current treatment concepts. Bone Joint J. 2019;101-B(5):512-521. https://doi.org/10.1302/0301-620X.101B5.BJJ-2019-0070.R1
11 Verhage SM, Schipper IB, Hoogendoorn JM. Long-term functional and radiographic outcomes in 243 operated ankle fractures. J Foot Ankle Res. 2015;8:45. https://doi.org/10.1186/s13047-015-0098-1
12 Parker L, Garlick N, McCarthy I, et al. Screw fixation of medial malleolar fractures: a cadaveric biomechanical study challenging the current AO philosophy. Bone Joint J. 2013;95-B(12):1662-1666. https://doi.org/10.1302/0301-620X.95B12.32086
13 Bulut T, Gursoy M. Isolated medial malleolus fractures: conventional techniques versus headless compression screw fixation. J Foot Ankle Surg. 2018;57(3):552-556. https://doi.org/10.1053/j.jfas.2017.12.005
14 Ebraheim NA, Weston JT, Ludwig T, et al. The association between medial malleolar fracture geometry, injury mechanism, and syndesmotic disruption. Foot Ankle Surg. 2014;20(4):276-280. https://doi.org/10.1016/j.fas.2014.08.002
15 Ricci WM, Tornetta P, Borrelli J Jr. Lag screw fixation of medial malleolar fractures: a biomechanical, radiographic, and clinical comparison of unicortical partially threaded lag screws and bicortical fully threaded lag screws. J Orthop Trauma. 2012;26(9):602-606. https://doi.org/10.1097/BOT.0b013e3182404512
16 Wegner AM, Wolinsky PR, Robbins MA, et al. Antiglide plating of vertical medial malleolus fractures provides stiffer initial fixation than bicortical or unicortical screw fixation. Clin Biomech. 2016;31:29-32. https://doi.org/10.1016/j.clinbiomech.2015.10.005
17 Vajapey SP, Harrison RK. Hook plate fixation of medial malleolar fractures: a comparative study of clinical outcomes. J Foot Ankle Surg. 2020;59(5):969-971. https://doi.org/10.1053/j.jfas.2018.12.048
18 Gao Z, Shi Z, Yan W, et al. Efficacy of hook type locking plate and partially threaded cancellous lag screw in the treatment of displaced medial malleolar fractures in elderly patients. Arch Orthop Trauma Surg. 2021;141(9):1521-1528. https://doi.org/10.1007/s00402-021-03945-6
19 Jiang D, Zhan S, Wang Q, et al. Biomechanical comparison of locking plate and cancellous screw techniques in medial malleolar fractures: a finite element analysis. J Foot Ankle Surg. 2019;58(2):235-240. https://doi.org/10.1053/j.jfas.2018.10.005
20 Fowler TT, Pugh KJ, Litsky AS, et al. Medial malleolar fractures: a biomechanical study of fixation techniques. Orthopedics. 2011;34(6)-e355. https://doi.org/10.3928/01477447-20110627-09
21 Geerts WH, Bergqvist D, Pineo GF, et al. Prevention of venous thromboembolism: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines (8th Edition). Chest. 2008;133(6 Suppl):381S-453S. https://doi.org/10.1378/chest.08-0656

[22] Charlson ME, Szatrowski TP, Peterson J, et al. Validation of a combined comorbidity index. J Clin Epidemiol. 1994;47(11):1245-1251. https://doi.org/10.1016/0895-4356(94)90129-5

[23] Kitaoka HB, Alexander IJ, Adelaar RS, et al. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. 1994;15(7):349-353. https://doi.org/10.1177/107110079401500701

[24] Olerud C, Molander H. A scoring scale for symptom evaluation after ankle fracture. Arch Orthop Trauma Surg. 1984;103(3):190-194. https://doi.org/10.1007/BF00435553

[25] Whelan DB, Bhandari M, Stephen D, et al. Development of the Radiographic Union Score for Tibial fractures (RUST). J Bone Joint Surg Am. 2010;92(1):192-197. https://doi.org/10.2106/JBJS.I.00973