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ORIGINAL ARTICLE

CT controlled results of direct reduction and fixation of posterior malleolus in ankle fractures

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Abstract

Purpose The aim of this study was to present outcomes of operative treatment of the posterior malleolus fractures of type four of the Bartoníček/Rammelt classification.

Methods In 19 patients, direct reduction and fixation of the posterior malleolus was performed from the posterolateral or posteromedial approaches. The accuracy of reduction was assessed with the use of postoperative CT scans.

Results The mean size of the avulsed articular surface carried by posterior malleolus amounted to 36%. Reduction of the posterior malleolus fracture was assessed as anatomical in 14 cases and as satisfactory in five cases. Position of the distal fibula was assessed as anatomical in 15 cases. The mean AOFAS score was 89.4 points. All nine patients with anatomical reduction of all lesions achieved the mean AOFAS score of 93.1 points, five patients with malposition of posterior malleolus 89.1 points and five patients with malposition of the fibula in the fibular notch 87.8 points. A total of six patients developed osteoarthritic changes of grades one and two according to the Kellgren and Lawrence classification.

Conclusions Outcomes of the study demonstrated good mid-term results in type four fractures of the posterior malleolus treated by direct reduction from posterior approaches. Postoperative CT examination allowed evaluation of the accuracy of reduction of all fractures and reduction of the distal fibula into the fibular notch. Based on postoperative CT examination, it will be possible to assess the effect of reduction of individual lesions on the functional results.

Keywords Ankle fractures · Trimalleolar fractures · Posterior malleolus · Posterior approaches · Classification

Introduction

Fractures of the posterior malleolus (PM) have been investigated intensively over the recent years, particularly in terms of diagnosis [1], classification [2, 3, 4] and primarily clinical outcomes [5–21]. However, the studies dealing with functional outcomes show conflicting results in a number of aspects and their conclusions are controversial. Their detailed analysis has shown that in a majority of them diagnosis and classification of fractures, as well as accuracy of reduction, were based on radiographs alone [4, 8, 11, 13, 20].

Another weakness of these studies was the fact that the analyzed cohort comprised various types of PM fractures which were evaluated in summary. Only a few studies dealt with a particular pattern of a PM fracture, namely the Haraguchi 1 [11, 20] or Haraguchi 2 [4, 8, 22] types.

The aim of the present study was to present the outcomes of operative treatment of PM fractures of type 4 of the Bartoníček/Rammelt classification [2], i.e. a large triangular posterolateral fragment, where both the fracture type and accuracy of reduction were assessed with the use of pre- and postoperative CT scans.

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Material and methods

Material

The study included patients operated on between January 2010 and December 2017 for a fracture–dislocation of the ankle associated with a type four PM fracture according to the Bartoníček/Rammelt classification [2]. This type has been defined as a large posterolateral triangular fragment of the distal tibia carrying up to the posterior half of the fibular notch and approximately one-third of the articular surface of the distal tibia [23].

All of the patients enrolled in the study were skeletally mature and underwent pre- and postoperative CT examination of the ankle, including a 3D CT reconstruction. Another prerequisite for enrolment was direct reduction and internal fixation of the PM fracture from the posterolateral or posteromedial approach and a minimum follow-up of 1 year postoperatively. Exclusion criteria included a previous injury or arthritic changes of the ankle at the time of injury.

Inclusion criteria were met by 19 patients (1 man and 18 women), with the mean age of 58 years (range 20–76). The mean follow-up was 35 months (range 14–72). Prior to its launching, the study was approved by the institutional ethical board. Patients were asked for their consent to participate in the study at the last follow-up in 2018. The study was reviewed and approved by the local ethics committee.

Methods

Upon admission to the hospital, radiographs in three, i.e. ap, mortise and lateral views were performed in all patients. Where necessary, ap and lateral views of the lower leg were obtained to exclude a Maisonneuve fracture [24]. All patients underwent CT examination prior to operation, i.e. scans in the axial, frontal and sagittal planes, followed by 3D CT reconstructions in the posterior, medial, anterior and lateral aspects, with subtraction of the fibula to show the fibular notch in nine cases.

The size of the fragment of the posterior malleolus was assessed on the axial CT section 2 mm above the ankle joint line. Based on the medial propagation of the fracture line, the fragment size was classified into three subtypes [25, 2]:

1. the fracture line passed lateral to the malleolar groove,
2. the fracture line involved the malleolar groove,
3. the fracture line involved posterior colliculus or intercollicular grove.

Fibular fractures were classified into 16 cases as Weber type B and in three cases as Weber type C, including two cases of Maisonneuve fracture (MF). Medial lesion was in ten cases assessed as a bicollicular fracture with an intact deltoid ligament, in six cases as a lesion of the deltoid ligament and in three cases as an osteoligamentous lesion, i.e. a combination of a fracture of the anterior colliculus and rupture of the tibiotalar portion of the deltoid ligament.

The operative procedure was determined based on all identified lesions, including surgical approaches and sequence of treatment of individual injuries. Only three patients were operated on within 24 h of the injury; the remaining 16 patients were treated within the interval of 5–17 days post-injury. The whole cohort was operated on by eight experienced trauma surgeons.

All procedures were performed with the use of tourniquet and under fluoroscopy. A posterolateral approach to PM and to the distal fibula with the patient in the prone or semiprone position was used in 14 patients, of which in eight patients in combination with a medial approach to treat a fracture of the medial malleolus (MM). A posteromedial approach with the patient in the supine position allowing treatment of PM and MM was used in five patients, always in combination with the lateral approach to treat an accompanying fibular fracture. External rotation test was performed at the end of the operation in order to assess syndesmotic stability after fixation of all bony injuries.

In 11 cases, the PM fracture was managed first, followed by the fracture of the distal fibula and the MM fracture (five patients). In eight cases, the bicollicular fracture of the medial malleolus was first reduced and fixed, which was followed by treatment of the PM fracture and a distal fibula fracture. Internal fixation of the fibula was always performed after fixation of the PM.

Direct reduction and fixation of the PM was always performed under visual control with a T- or L-shaped 3.5 mm plate, or a combination of a semitubular plate and 3.5 mm cortex screw. Screws were driven through the anterior cortex in order to increase stability of the construct.

After fracture fixation, the medial clear space was checked after completion of internal fixation of PM and the fibula. Revision of the deltoid ligament was not required in any of the six cases of rupture.

Stability of the tibiofibular mortise was confirmed after internal fixation by the hook test [14]. In four patients with a fibular fracture of Weber B type, instability of the mortise (tibiofibular clear space > 6 mm) was detected and treated with syndesmotic 3.5 mm cortex screw.

In two MF, internal fixation of PM was performed from the posterolateral approach, followed by stabilization of the tibiofibular mortise by two quadricortical syndesmotic screws. Accuracy of reduction of the distal fibula into the fibular notch was checked from a short anterolateral incision.

On the second postoperative day, radiographs of the ankle were performed in three views, in case of MF a radiograph of the lower leg in two views; and CT scans were used to assess the quality of reduction of all fractures and position of the distal fibula within the fibular notch. Reduction of PM was evaluated as excellent in case of a gap/step-off in the articular surface ≤ 1 mm, as satisfactory with displacement of 1–2 mm and as poor with displacement > 2 mm.

Position of the fibula in the fibular notch was evaluated according to Bartoníček et al. [24] and Boszczyk et al. [10]. A good position was considered with anteroposterior and mediolateral displacement < 2 mm or a rotational deviation < 5°.

The fractured leg was immobilized in a plaster cast for 6 weeks, with partial weightbearing (20 kg) being allowed from the 3rd week. After cast removal, patients underwent radiographic follow-up and ambulated with gradually increased weightbearing. Additional clinical and radiological follow-up was scheduled at 3, 6 and 12 months postoperatively.

The syndesmotic screw was removed at 8–10 weeks postoperatively in all six cases. Implants from the fibula and the medial malleolus were removed in 12 patients because of local pressure between 12 and 20 months postoperatively. Implants from the PM were removed only in one patient.

Evaluation

At the final follow-up between January and April 2019, clinical results of all patients were evaluated with the use of the AOFAS score. Radiographs of the ankle in three views. Patients with AOFAS score < 85 points were indicated for a follow-up CT examination.

Arthritic changes were classified according to the Kellgren and Lawrence scale[26]: Grade 0-normal, no changes; Grade 1-mild, small marginal osteophytes without narrowing of the joint space; Grade 2-moderate, small marginal osteophytes with definite narrowing of the joint space, with or without subchondral sclerosis; Grade 3-severe, multiple large osteophytes, complete loss of joint space, subchondral bone sclerosis, loss of joint contour.

Statistical analysis was not performed due to the small number of patients and the range of variables (fracture patterns, ligamentous lesions, surgical approaches).

Results

Surgical wounds healed without complications in all patients. All fractures, i.e. those involving the fibula, PM and MM, healed within 3 months postoperatively.

Pathoanatomy of the fractured PM

The mean size of the avulsed articular surface carried by PM amounted to 36% (range 25–48%). Evaluation of medial propagation of the fracture line on CT axial scans proved a subtype 1 in 11 cases, subtype 2 in 4 cases and subtype 3 in 4 cases.

Reduction of the PM fracture

Sagittal CT scans showed anatomical reduction in 14 cases (Fig. 1) and satisfactory reduction in five patients. No cases were classified as having a poor reduction.

Reduction of the MM fracture

Frontal CT scans showed anatomical reduction in 12 cases and satisfactory reduction in 1 patient (Fig. 2).

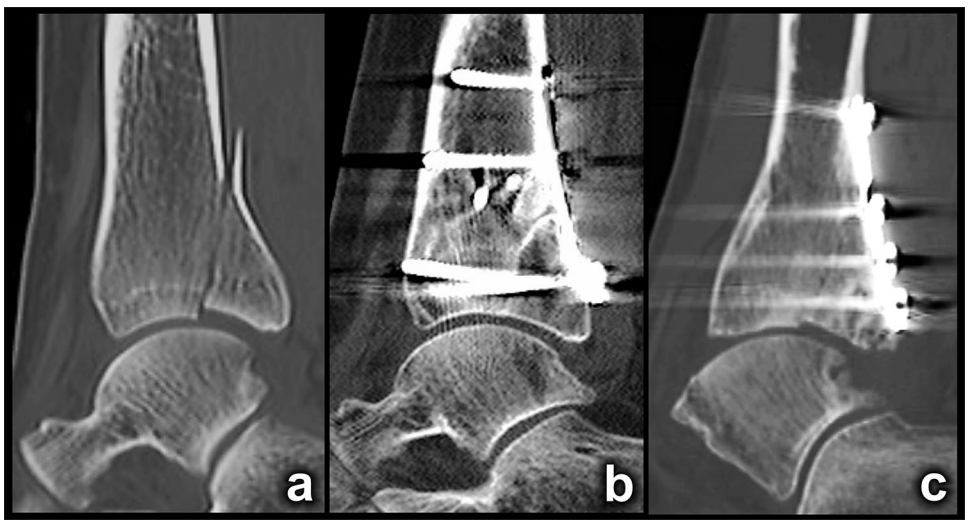

Fig. 1 Reduction of the PM fracture, sagital CT scan. **a** fracture sign, **b** anatomical reduction, **c** satisfactory reduction

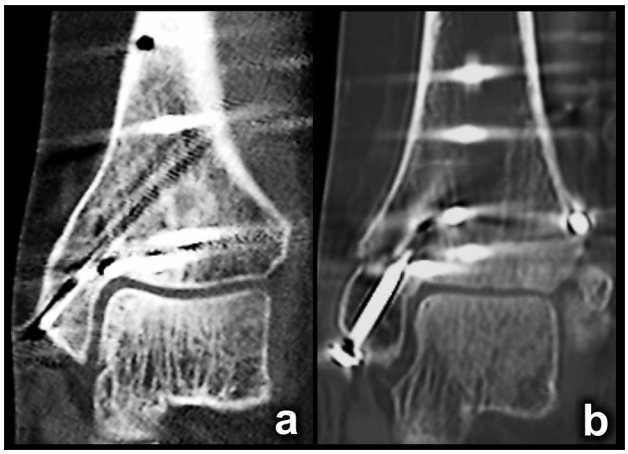

Fig. 2 Reduction of the MM fracture, frontal CT scan. **a** anatomical reduction, **b** satisfactory reduction

Reduction of the distal fibular fracture

Reduction was assessed as anatomical in all 17 cases.

Reduction of the distal fibula into the fibular notch

Position of the distal fibula was assessed as anatomical in 15 cases. In one case of MM malreduction the tibiofibular space was wider by 2 mm. In another case the distal fibula (Weber type B fracture) was displaced anteriorly by 2 mm. In two cases, the distal fibula (Weber type B fracture) showed external rotation by 10 and 15°, respectively, with the latter case only showing satisfactory reduction of PM (Fig. 3).

AOFAS score

The mean score in the whole series was 89.4 points (range 73–100). All nine patients with anatomical reduction of all lesions achieved the mean AOFAS score of 93.1 points: five patients with malposition of PM 89.1 points, four patients with malposition of the fibula in the fibular notch 87.8 points. The mean outcomes differed in terms of the type of lesion of the fibula, damage to the medial structures and the choice of the surgical approach (Table 1). The lowest mean AOFAS score, i.e. 84.8 points, was identified in five patients who developed osteoarthritic changes. A predisposition was incorrect reduction and older age (Table 2).

Table 1 Characteristics of the series, functional results

Characteristics /AOFAS score	Value
Overall	89.4 (73–100)
Trimalleolar fracture	89.8 (73–100)
Bimalleolar fracture	88.5 (73–100)
Posterolateral approach	88.8 (73–100)
Posteromedial approach	91.0 (86–95)
Excellent reduction	93.1 (85–100)
PM satisfactory reduction	89.1 (73–100)
Malreduction of the distal fibula into the fibular notch	87.8 (73–100)
Osteoarthritis	84.8 (73–96)

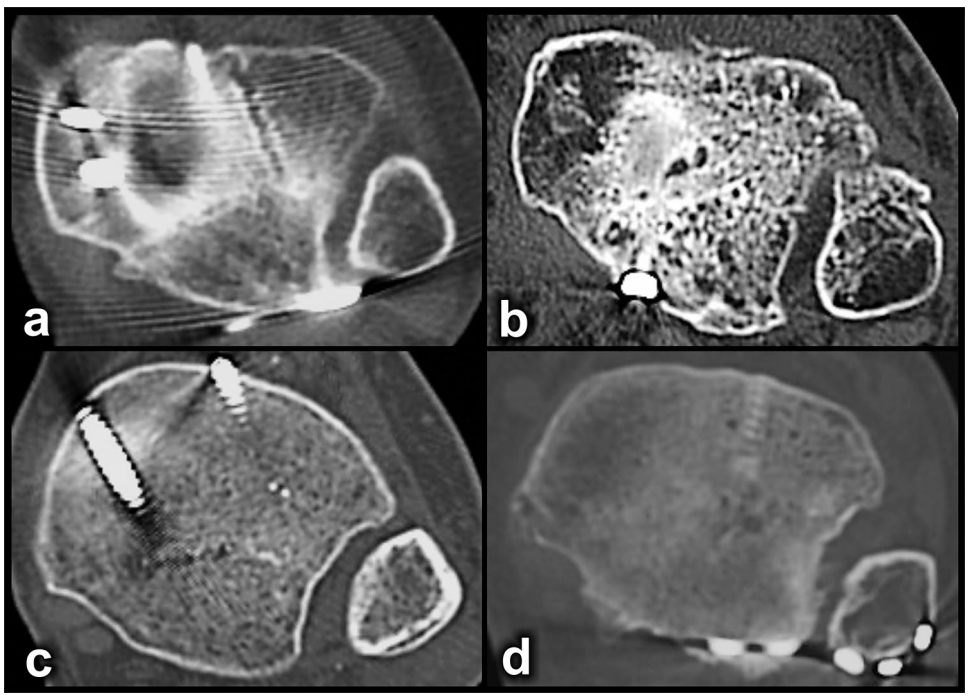

Fig. 3 Reduction of the distal fibula into the fibular notch, axil CT scan. **a** anatomical reduction, **b** widening by 2mm, **c** anterior dispacement, **d** external rotational malposition

Table 2 Characteristics of patients with AOFAS score below 85 points

	AOFAS	Age	F–U	Fracture	Reduction	Osteoarthritis
P1	73	59	72 M	WB, DL, PM 4–3	External malrotation 15	Grade 2
P2	73	67	55 M	WB, BMM, PM 4–1	PM satisfactory reduction	0
P3	80	76	34 M	WB, DL, PM 4–3	Correct	Grade 2
P4	82	55	61 M	WB, MOL, PM 4–3, Chaput	Correct	Grade 2
P5	85	58	28 M	WB, MOL, PM 4–1	MM 1 mm step-off, widening of syndesmosis	0

WB Weber type B fibular fracture, *DL* deltoid ligament, *BMM* bicollicular fracture of medial malleolus, *MOL* medial osteoligamentous lesion

Range of motion

The range of motion (flexion/extension) of the affected and unaffected extremity was symmetrical in six patients; in 13 patients it was reduced on the affected side by 5–30°.

Pain

Pain at rest was not present in any patient, eight patients reported slight pain during longer distance walking or sports activities, two patients felt a certain discomfort when climbing stairs and one female patient was unable to walk in high heels.

Osteoarthritic changes

After 3–7 years of the injury, six patients developed osteoarthritic changes of Grade 1 and 2; of these, three female patients with Grade 1 osteoarthritis were pain free and achieved a good functional result (AOFAS 96, 90 and 88 points, respectively), and three female patients with Grade 2 osteoarthritis reported pain during activities of daily living and reduction of the range of motion by 10–30°.

A 79-year-old female patient with a rotational malposition of the fibula in the fibular notch achieved the final AOFAS score of 73 points. A 76-year-old female patient with anatomical reduction of all fractures was diagnosed 3 years postoperatively with Grade 2 osteoarthritis and the resulting AOFAS score was 80 points. Similarly, degenerative changes were found 5 years post-injury in a 55-year-old female patient with anatomical reduction of all fractures and the resulting AOFAS score of 82 points.

Discussion

Recent studies report better functional and radiological results of PM fractures treated from the posterior approach as compared to indirect reduction of the PM fragment and fixation by anteroposterior screws [7, 12, 15, 16, 18, 27–31].

In addition, a majority of these studies present the outcomes of direct PM reduction and fixation in cohorts of less than 10 patients. Studies conducted in the recent decade, with a higher number of patients, functional evaluation and treatment from the posterior approaches are listed in Table 3. Only five studies dealt with evaluation of a single PM fracture pattern; Choi et al. [11] and Wang et al. [20] focused on Haraguchi 1 fracture type, Bali et al. [8], Klammer et al. [4] and Wang et al. [22] on Haraguchi 2 fracture type. An exact determination of the PM fracture pattern is essential for evaluation of the treatment outcome. Studies

Table 3 Studies from the recent decade, functional evaluation, post. approaches

	No. of patients	PM fracture types	Surgical approaches	Imaging	F-U	Score
Bali (2017)	15	Haraguchi 2	PM	Radiograph	29 M	OM 72
Choi (2015)	50	Haraguchi 1 (21), 2 (29)	PL	Radiograph	26 M	AOFAS 90.6
Forberger (2009)	45	All types 24% (10–48)	PL	Radiograph	25 M	AAOS 93
Klammer (2013)	11	Haraguchi 2	PL	Radiograph	23 M	AOFAS 82
Levack (2018)	122	All types 12% (2–50)	PL	CT, Radiograph	16,3 M	FAOS 53–82*
Miller (2010)	17	All types	PL	CT, Radiograph	15 M	FAOS 49–87*
Wang (2011)	12	Haraguchi 1 (7), 2 (5)	PM + PL combined	Radiograph	19 M	AAOS 85.7
Wang (2016)	16	Haraguchi 2 31,6%	PM	Radiograph	30 M	AOFAS 85.6
Authors	19	Bartoníček/Rammelt 4	PL or PM	CT	35,3 M	AOFAS 89.4

OM Olerud and Molander score, * according to domain

by Haraguchi et al. [3] and Bartoníček et al. [2] proved a marked variability of these fractures.

No study has so far focused on PM type four fractures according to the Bartoníček/Rammelt classification. These highly unstable fractures present a transition to the partial fractures of the tibial pilon. A typical feature of this PM fracture pattern is a higher mean age of patients, namely by 8 years more than in patients with a type two fracture and by 14 years more than in patients with a type three fracture according to the Bartoníček/Rammelt classification [2]. Another characteristic feature is a high predominance of women as compared to type two and three fractures [23].

Fragment of PM type four fracture carries one-third of the articular surface of the distal tibia and its non-anatomic reduction poses a risk of residual subluxation, as well as incongruence of the tibiotalar joint. In addition, a part of the fragment is the posterior half of the fibular notch. All this highlights the importance of an accurate reduction and stable fixation of PM. An advantage of this type of fracture of PM is the PM size facilitating its reduction and stable fixation which not only restores the congruence and stability of the tibiotalar joint, but also stability of the tibiofibular mortise [34, 5, 6, 36, 10, 20– 22, 32]. Easier reduction in large PM fragments was mentioned also by McHale et al. [29].

Large PM fragments were traditionally subjected to indirect reduction and ap fixation with screws. Indirect reduction and fixation, however, carries the risk of malreduction. This can be avoided in some instances by transfibular reduction of the PM under direct vision—"Weber's trick" [14, 30]. Outcomes of recent studies, however, favor direct reduction and internal fixation from the posterior approach [25, 7, 8, 9, 11, 13, 15, 17, 19, 21, 27–29, 33], similarly to the findings of our CT analysis of accuracy of PM reduction and the clinical results. Based on our experience, we consider the posterolateral approach to be preferable if permitted by the overall injury pattern and soft tissue status. The posteromedial approach is preferred in some type 3 PM fractures with dislocation of the MM [23, 25, 30].

Studies using AOFAS or AAOS score to evaluate fractures report the mean values in the range of 82–93 points [4, 11, 13, 20, 22]. Our results (89 points) compare favourably with these studies (Table 3).

We have recorded neither delayed wound healing nor sural nerve irritation in our series. The same experience was reported by other authors [11, 27, 33]. Only Forberg et al. [13] described soft tissue problems in 11% and superficial infection in 9% of their patients. Klammer et al. [4] operated on 11 patients for four complications in the region of the approach to PM (sural nerve decompression, exostectomy, osteophyte excision and Achilles tendon lengthening).

It should be noted that the final outcome is influenced also by the position of the distal fibula in the fibular notch, particularly in Weber C type fractures of the fibula. Accurate reduction is more difficult to achieve in these fractures and their share in the analyzed series may influence also the final outcome [25, 5, 6,7].

Size of PM fragment, fracture dislocations, malreduction, cartilage damage, female gender or a higher age have been discussed as risk factors for development of osteoarthritic changes [34, 9, 12], which is consistent with our findings related to PM fractures. However, in this small cohort we have identified osteoarthritic changes in all four patients with subtype 3 fractures and the age of female patients with osteoarthritic changes was higher than the mean age of the series.

A strength of our study is preoperative CT examination in all patients allowing for an exact assessment of the PM fracture pattern, as well as other lesions. The importance of CT for an exact determination of the PM fracture type, evaluation of the position of the fibula in the fibular notch and preoperative planning has been confirmed by a number of authors [23, 25, 35, 34, 6, 36, 1, 10, 29, 32].

Another strength of our study are postoperative CT scans allowing an exact evaluation of PM reduction and reduction of the distal fibula into the fibular notch. Postoperative CT examination was performed as a standard only in a few recent studies [5, 6]. Levack et al. [5] found a 25.4% rate of articular incongruence the cause of which they saw in "comminution or impaction at the level of the joint despite otherwise adequate cortical reduction and intraarticular loose body ". The same authors found malreduction of the distal fibula into the fibular notch in 27.8% of patients with and in 10% of patients without the use of a syndesmotic screw (SER IV 114, PER IV 8). In our series we encountered a postoperative step-off on articular surface of the distal tibia in five patients (26% of cases) and malposition of syndesmosis in four patients (21% of cases).

Klammer et al. [4] evaluated reduction of PM fracture type three according to the Bartoníček/ Rammelt classification on the basis of radiographs as good in seven of 11 cases. The remaining four patients showed less than 2 mm of articular incongruence. McHale et al. [29] reported anatomical reduction in 91% of fragments carrying more than 30% of the articular surface of the distal tibia ($N = 10$).

Choi et al. [11] found on the basis of follow-up radiographs an accurate reduction (< 1 mm of displacement) of the tibial surface with the resulting AOFAS score of 90.6 points in 96% of patients (50 patients).

Conclusion

In trimalleolar fractures of the ankle with a type 4 PM fracture according to the Bartoníček/Rammelt classification, anatomical reduction and stable fixation, and consequently also good functional results, were achieved by direct

reduction and fixation of the posterior fragment, with the mean follow-up of 35 months. Of essential importance for an exact identification of all lesions and preoperative planning was preoperative CT examination, whereas postoperative CT examination allowed evaluation of the accuracy of reduction of all fractures and reduction of the distal fibula into the fibular notch. Based on postoperative CT examination it will be possible to assess the effect of reduction of individual lesions on the functional results.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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