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Open reduction and internal fixation of the posterior malleolus fragment frequently restores syndesmotic stability

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ABSTRACT

Aim: Comparison of unfixed, CRIF, and ORIF of the posterior malleolus fragment (PMF) regarding the frequency of trans-syndesmotic fixation and quality of reduction in trimalleolar (equivalent) fractures.
Material and Methods: Retrospective registry study. Patients with a trimalleolar (equivalent) ankle fractures were identified within the departments' fracture database. General demographics, treatment details, and fracture specific details (CT-scans) were assessed. Patients were grouped per the PMF treatment: not addressed, CRIF, ORIF.
Results: 236 patients (53.0 ± 18.3 (range: 18–100) years), 58.1% female were eligible. The mean size of the PMF was 21.4 ± 10.4% (range: 2.7–55.9%), 71.6% were ≤25% of the tibial plafond. PMF fixation: Untreated 48.3%, CRIF 18.6%, ORIF 33.1%. ORIF of the PMF significantly ($p < 0.001$) reduced the frequency of trans-syndesmotic fixation (25%) compared to CRIF (61%) or untreated PMF (63%) with no significant influence of the PMF size (≤25%/>25%). ORIF resulted in a significantly ($p < 0.001$) better quality of reduction (1.2 ± 1.1 mm (range: 0–5 mm)) compared to CRIF (2.5 ± 2.1 mm (range: 0–8 mm)) and untreated PMF (2.5 ± 2.3 mm (range: 0–20 mm)). Neither the frequency of trans-syndesmotic fixation nor the quality of reduction differed significantly between untreated PMF and CRIF.
Conclusion: All posterior malleolus fragments, independent of their size, should be treated by ORIF, as this restores syndesmotic stability significantly more often than untreated PMF or CRIF.

Introduction

With an annual incidence of 169/100,000, the treatment of ankle fractures is part of our daily routine [1]. Still, the intermediate clinical outcomes are discouraging with patient satisfaction rates decrease with fracture complexity. Whereas 80% of patients following uni-malleolar fractures report good outcomes, less than 50% of patients suffering a bi- or trimalleolar fracture are satisfied [2,3].

The current standard treatment approach for bi- or trimalleolar fractures with a fracture to the posterior malleolus (PM) is anatomical reduction and internal fixation of the lateral and/or medial malleolus. The fracture to the PM is not routinely addressed. Per to recommendation of the AO-Foundation and several authors, fractures to the PM are only fixed if its' size is greater than 25%–33% of the tibial plafond [4,5]. In case the PM is addressed, it most commonly is fixed indirectly by closed reduction and internal fixation (CRIF) using percutaneous anterior-to-posterior (AP) screws [6]. Then, the stability of the distal tibio-fibular joint is tested. In case of instability, a reduction clamp is applied, and a trans-syndesmotic fixation conducted [7]. Indirect reduction of the PM is supposingly achieved through ligamentotaxis by reducing the distal fibula and applying maximum ankle dorsiflexion [6]. Still, various studies, were able to demonstrate that CRIF by AP screws does not reproducibly result in anatomical reduction of the PM [7–9].

Considering the disillusioning results following complex ankle fractures, various authors have tried to identify factors associated with a poor outcome. These include severity of the fracture, insufficient reduction, and syndesmotic instability. Unsatisfactory reduction of the PM, as seen by CRIF, does not only affect the congruency of the tibio-talar, but also of the tibio-fibular joint, which possibly influences syndesmotic stability. Today, an increasing number of studies [10–14] argues for ORIF of the PM fragment independent of its size. PM fractures should be considered bony avulsions of the posterior tibio-fibular ligament (PTFL) [15] as it has been demonstrated that in case of a PM fracture the PTFL remains intact [15]. By anatomical reduction of PM fragment, the bony anatomy and length of the intact PTFL are restored. Thereby the fibula is reduced anatomically into the tibial groove [15,16]. Whether it also restores syndesmotic stability has not been evaluated yet [17–19].

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Therefore, the aim of this study was to investigate the frequency of trans-syndesmotic fixation in patients suffering a trimalleolar or trimalleolar equivalent fracture treated without fixation of the PM (Group 1), CRIF by AP screws (Group 2), or ORIF (Group 3). It is hypothesized, that ORIF of the PM will significantly reduce the need for a trans-syndesmotic fixation. The secondary purpose was to analyse the quality of reduction between the three groups. The study was approved by the local ethics committee (#-500-15).

Patients and methods

The herein presented study is a retrospective database study investigating the frequency of trans-syndesmotic fixation and the quality of reduction of the PM fragment in patients following operative treatment of a trimalleolar or trimalleolar equivalent fracture.

Patient selection

Patient selection was based on the departments ankle fracture database. It includes all patients treated surgically for any type of ankle fracture between 01/2010 and 12/2016, comprising of 648 consecutive patients older than 18 years. The database was searched for trimalleolar (equivalent) fractures (AO 44-A2.3, A3.3, B1.3, B2.3, B3.1-3, C1.3, C2.3, C3.3), treated operatively, with either pre- or postoperative computer tomography scans (CT-scans). The phrase "trimalleolar equivalent" describes a bimalleolar fracture with a fracture of the PM and medial or lateral malleolus as well as an injury to the deltoid ligament complex / lateral ankle ligament complex.

Treatment strategy

At the author's level one trauma centre, treatment approaches for PM fractures can be categorized into three groups. Group 1 (Fig. 1A): The PM fracture is not fixed; Group 2 (Fig. 1B): The PM is fixed by CRIF using AP screws; Group 3 (Fib. 1C): ORIF of the PM by screw(s) or plate osteosynthesis through a posterolateral approach. The decision which treatment approach for the PM fracture was used was made by each surgeons individually. Treatment strategies for the lateral and medial malleolus fractures did not differ between the groups. After fracture fixation stability of the syndesmosis was tested using either the "hook test" or "external rotation test" [20]. Any widening of the medial or tibio-fibular clear space was held evidentiary for distal tibio-fibular joint instability. In case of instability, the distal tibio-fibular joint was reduced using a reduction clamp in neutral axis [21] and either a trans-syndesmotic screw or a suture-button fixation was applied.

Data assessed

Next to general demographics (age, sex), the fractures were classified according the AO classification. Furthermore, the PM fractures were classified according to Haraguchi et al. [22] (Fig. 2), their location (lateral, central, medial, total posterior rim), number of fragments (single / commuted), and displacement. The size of the PM fragment was assessed as percentage of the maximum pilon depth. All classifications were conducted on CT scans. Treatment details assessed, included the fixation strategy and necessity of trans-syndesmotic fixation. The postoperative images were evaluated for the quality of reduction of the PM, the medial (perpendicular; MCS) [23], and tibiofibular [24] clear space (TFCS) [25]. All measurements were conducted by two investigators independently on Syngo Studio (Vs. VB36E; Siemens Healthcare GmbH, Erlangen, Germany). In case of disagreement, each case was discussed until an agreement was reached.

Outcome parameters

The primary outcome was the need for trans-syndesmotic fixation per the three PM treatment groups. The secondary outcome was the degree of reduction (posterior malleolus, MCS, and TFCS) per the three different groups. Furthermore, it was tested whether these outcome parameters were influenced by any of the other parameters assessed.

Statistics

A sample size calculation was not conducted due to the observational nature of this retrospective registry study. Descriptive statistics included mean values, frequencies, and proportions. Group comparisons were conducted either by a paired-sample T Test, Chi-squared, or ANOVA using the Bonferroni post-hoc test. Due to multiple testing, an alpha level correction (Bonferroni) was conducted, setting the level of significance to $p < 0.005$. All statistics were computed using SPSS Vs. 21 (IBM Company). In the following the results are displayed as mean ± standard deviation (range).

Results

Out of 648 patients in the departments' ankle fracture database, 236 patients were included in the final analysis. The patient selection flow chart is presented in Fig. 3. Patients were on average 53.0 ± 18.3 (range: 18–100) years, 58.1% were female and the left ankle fractured in 45.3%.

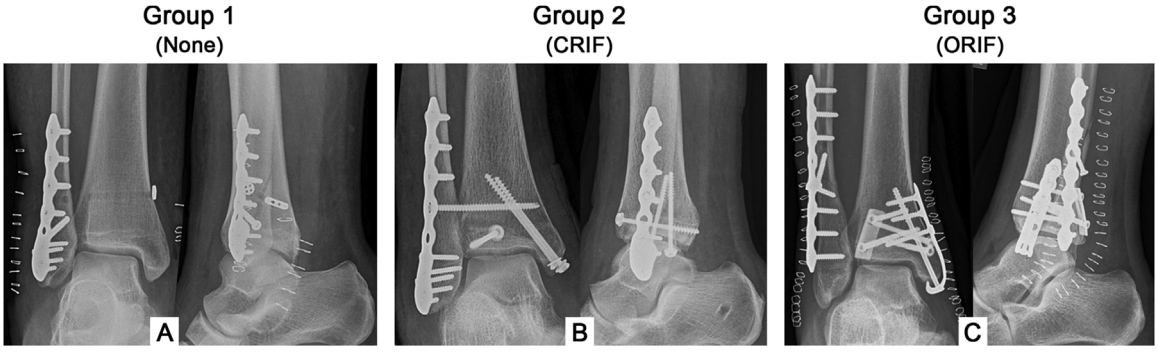

Fig. 1. Illustration of the three different treatment groups for the posterior malleolus fragment. A) The posterior malleolus (PM) fracture was not fixed; (Group 1); B) The PM was fixed by CRIF using AP screws (Group 2); C) ORIF of the PM by screw(s) or plate osteosynthesis (Group 3).

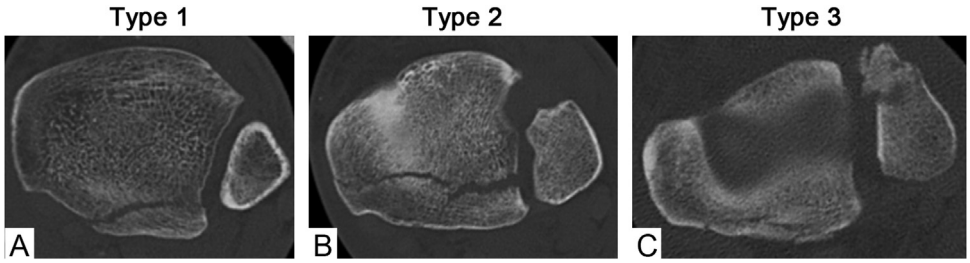

Fig. 2. Illustration of the Haraguchi classification [22]. Fractures are illustrated on transverse computed tomographic scans. A) Triangular fragment of the posterolateral corner of the tibial plafond (Type 1); B) Fracture extents across the entire posterior tibial plafond (Type 2); C) Small shell-shaped fragments of the posterior lip of the tibial plafond (Type 3).

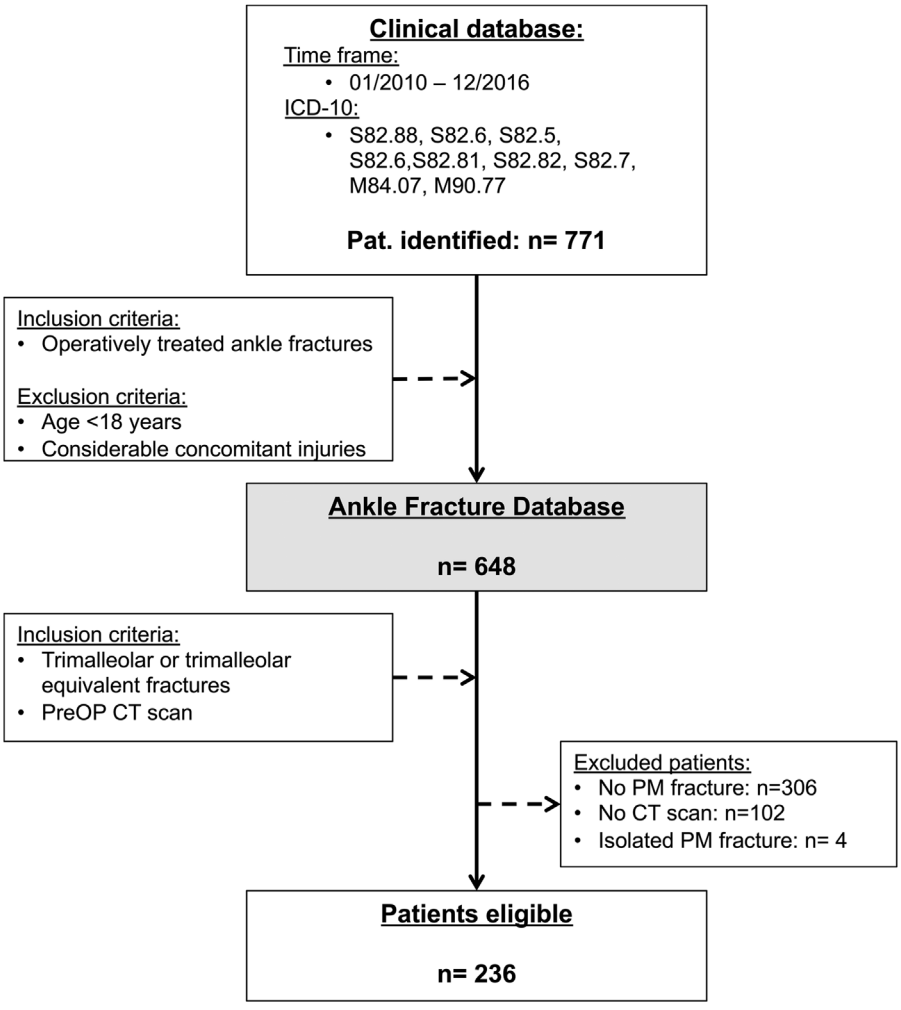

Fig. 3. Flow-chart illustrating patient selection based on the departments' ankle fracture database.

Fracture details

39.4% of the fractures were initially displaced. According to the AO Classification, 1.7% suffered a 44-A (A2: 0.4%; A3: 1.3%), 77.5% a 44-B (B1: 0.8%; B2: 0.4%; B3.1: 20.3%; B3.2: 19.5%; B3.3: 36.4%), and 11.9% a 44-C fracture (C1: 1.3%; C2: 6.8% C3: 3.8%). 8.9% could not be classified according to the AO classification with 2.5% suffering a fracture of the medial and PM and 6.4% a type Weber C and PM fracture. Per Haraguchi et al. [22], 47.9% suffered a Type 1, 33.9% a Type 2 and 18.2% a Type 3 fracture. The characteristics of the PM fractures are outlined in Table 1. The PM was initially displaced 6.6 ± 6.1 mm (range: 0–30 mm) and comprised on average 21.4 ± 10.4% (range: 2.7–55.9%) of the tibial plafond.

Treatment strategy and radiographic outcome

In 27.1% an external fixator was applied initially. The lateral malleolus was treated using a $1/3^{rd}$ tubular plate in 43.6%, a locking plate in 45.8%, an intramedullary nail in 3.1%, and 7.6% did not necessitate any stabilization. In 65.3% an osteosynthesis of the medial malleolus was performed. Of those, 67.5% were treated using lag screws, 17.5% a plate, and 14.9% a tension band wiring. In 8.1% an open reconstruction of the deltoid ligament was conducted.

Table 1
Characteristics of the posterior malleolus fractures per Haraguchi type [22].

		Type 1	Type 2	Type 3
Total		47.9%	33.9%	18.2%
Location	Lateral	100%	0%	30.2%
	Central	0%	0%	46.5%
	Medial	0%	0%	9.3%
	Total PM	0%	100%	14.0%
Fragments	Single Fragment	59.8%	3.7%	23.3%
	Commuted	40.2%	96.3%	76.7%
Size [percent tibial plafond depth]		21.0 ± 8.8% (6.7-55.9%)	27.2 ± 10.9% (8.3-51.3%)	11.7 ± 4.3 (2.7-21.0%)
Initial displacement [mm]		5.9 ± 5.2 (0-30)	10.0 ± 7.0 (1-27)	2.2 ± 1.7 (0-7)

Values are presented as percentage and/or mean ± standard deviation (range).

The posterior malleolus was not addressed in 48.3% (Group 1), by CRIF using AP screws in 18.6% (Group 2), and by ORIF using a plate or screw(s) in 33.1%. A trans-syndesmotic fixation was necessary in 50.0% of all cases, either using a trans-syndesmotic screw (56.8%), a tight rope (36.4%), or an internal brace (6.8%). According to the postoperative imaging, the above outlined treatment resulted in a displacement reduction of the posterior malleolus from 6.6 ± 6.1 mm (range: 0–30 mm) preoperatively to 2.0 ± 2.1 mm (range: 0–20 mm; $p < 0.001$) postoperatively overall. The postoperative medial clear space was 3.2 ± 1.0 mm (range: 2–8 mm), the tibio-fibular clear space 4.3 ± 1.5 mm (range: 2–9 mm).

Outcome

Table 2 depicts the fracture characteristics of the PM per treatment group. The Haraguchi classification [22] ($p < 0.001$), the location ($p < 0.001$), and the size of the PM ($p < 0.001$) differed significantly between the three Groups. The initial displacement did not differ between Group 2 and 3 ($p = 1.0$), the PM was significantly less displaced in Group 1 when compared to Group 2 ($p < 0.001$) and 3 ($p < 0.001$).

Further, the choice of treatment strategy and implants did no not differ significantly between the three groups. Neither the initial application of an external fixator ($p = 0.024$), nor the choice of fixation of the lateral malleolus ($p = 0.016$), medial malleolus ($p = 0.090$), or reconstruction of the deltoid ligament ($p = 0.918$) differed significantly between the three groups.

The primary outcome of this study was the frequency of trans-syndesmotic fixation in regard to the method of fixation of the PM fragment. A trans-syndesmotic fixation was necessitated significant less frequent ($p < 0.001$) in patients undergoing ORIF for the PM (Group 3: 25%) compared to CRIF (Group 2: 61%) and untreated PM fractures (Group 1: 63%). Moreover, the size of the PM fragment (≤25%/>25%) had no significant influence on the frequency of trans-syndesmotic fixation within the three Groups (Fig. 4). None of the demographic parameters (age: $p = 0.581$; sex: $p = 0.383$) or general fracture characteristics (side: $p = 0.186$; displacement: $p = 0.107$; AO-classification: $p = 0.358$) differed significantly between the three groups.

Table 2
Fracture characteristics of the PM per treatment Group.

		Group 1 (None)	Group 2 (CRIF)	Group 3 (ORIF)
Total		114 (48.3%)	44 (18.6%)	78 (33.1%)
Haraguchi classification [22]	Type 1	53 (46.5%)	15 (34.1%)	44 (56.4%)
	Type 2	19 (16.7%)	28 (63.6%)	34 (43.6%)
	Type 3	42 (36.8%)	1 (2.3%)	0 (0%)
Location PM	Lateral	66 (57.9%)	15 (34.1%)	44 (56.4%)
	Central	20 (17.5%)	0 (0%)	0 (0%)
	Medial	3 (2.6%)	1 (2.3%)	0 (0%)
	Total PM	25 (21.9%)	28 (63.6%)	34 (43.6%)
Size [percent tibial plafond depth]		15.6 ± 6.2%	30.3 ± 11.9%	24.7 ± 9.4%
PM Fragment ≤ 25%		107 (94 %)	14 (32 %)	48 (62 %)
PM Fragment > 25%		7 (6 %)	30 (68 %)	30 (38 %)
Initial displacement PM [mm]		4.6 ± 5.0 (0-26)	9.0 ± 5.6 (1-26)	8.3 ± 6.9 (1-30)

Values are given either as total number (percentage) or mean ± standard deviation (range).

The secondary outcome was the quality of reduction of the PM fragment. Again, significant differences ($p < 0.001$) between the Groups were observed (Table 3). ORIF of the PM fragment (Group 3) resulted in a significantly superior reduction compared to CRIF (Group 2: $p = 0.002$) and untreated PM fractures (Group 1: $p < 0.001$). Similarly, the size of the PM fragment (≤25% / >25%) had no significant influence on the level of reduction within the three Groups (Table 3). Postoperatively, the medial ($p = 0.563$) as well as lateral clear space ($p = 0.929$) also did not differ between the Groups.

Factors influencing the necessity of trans-syndesmotic fixation

Despite the significant reduction of trans-syndesmotic fixation following ORIF of the PM fragment (Group 3), a quarter of these patients necessitated additional trans-syndesmotic fixation. Consequently, it was of interest, whether any factor could be identified predicting the need for trans-syndesmotic fixation. Overall, none of the parameters assessed differed significantly per the necessity of trans-syndesmotic fixation in Group 3 (Table 4).

Discussion

Syndesmotic malreduction is known to be a major factor leading to poor patient rated outcome following complex ankle fracture treatment [26,27]. Indirect reduction and trans-syndesmotic screw fixation has been reported to result in malreduction rates of up to 50% [28]. Today, a PM fracture is considered a bony avulsion of the PTFL [15]. Therefore, it can be hypothesized that ORIF of the PM fracture restores syndesmotic stability. This would decrease the need for indirect reduction and thereby the rate of malreduction. If this could be demonstrated it would argue for ORIF of PM fragments of any size, not only if comprising more than 25% of the tibial plafond.

To the authors' best knowledge this is the first study demonstrating that ORIF of the PM fragment, independent of its size, significantly reduced the necessity of trans-syndesmotic fixation by 60% compared to CRIF or untreated PM fragments. Further, ORIF resulted in a significantly superior quality of reduction of the PM fragment. Interestingly, neither the necessity of trans-syndesmotic fixation nor the level of reduction differed significantly between CRIF or untreated PM fragments.

ORIF of the PM has been shown to reduce the malreduction rate of the fibula in the fibula notch by a figure of 4.5 [27]. Various studies have compared the quality of reduction or the outcome of CRIF to ORIF of the PM [4,5,8,9,29,30]. Only three studies have reported on the frequency of trans-syndesmotic fixation (Table 5) [17–19].

O'Conner et al. [17] retrospectively compared CRIF to ORIF for the PM fragment in 27 patients and observed no significant differences for trans-syndesmotic fixation ($p = 0.19$). The value of this study is limited, not only as it was underpowered, but also because it was missing a group of unfixed PM. Miller et al. [18] reported on the results of 198 fractures. ORIF was only performed for fragments comprising more than 25% of the articular width. Surprisingly, only 27% of the patients with untreated and 2% following ORIF of the PM fractures required additional trans-syndesmotic fixation ($p < 0.001$), which is both remarkably low.

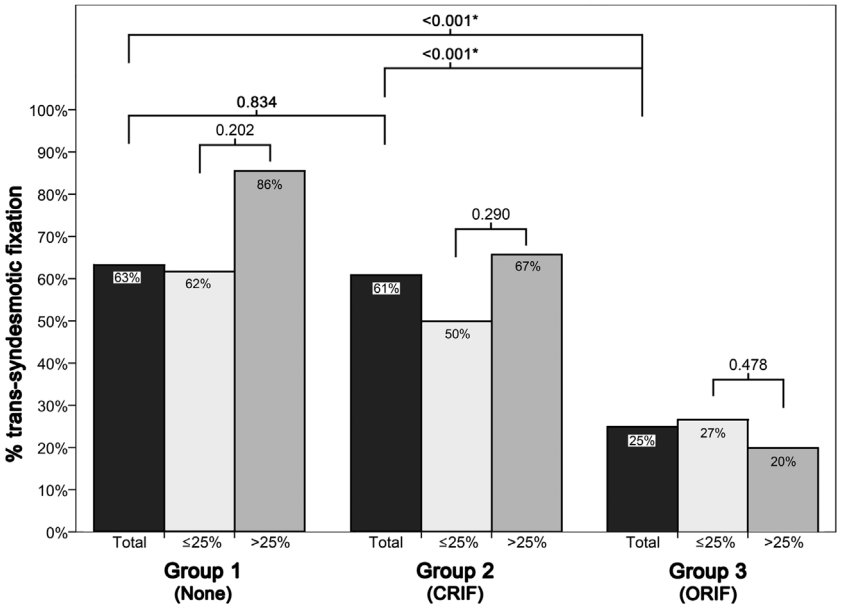

Fig. 4. Frequency of trans-syndesmotic fixation per group and size of the PM fragment.

Table 3
Quality of reduction per treatment group and PM fragment size.

	Group 1 (None)			Group 2 (CRIF)			Group 3 (ORIF)		
	Total	≤25%	>25%	Total	≤25%	>25%	Total	≤25%	>25%
Reduction PM [mm]	2.5 ± 2.3 (0-20)	2.5 ± 2.4 (0-20)	2.3 ± 0.8 (1-3)	2.5 ± 2.1 (0-8)	2.4 ± 1.8 (0-7)	2.5 ± 2.3 (0-8)	1.2 ± 1.1 (0-5)	1.4 ± 1.3 (0-5)	0.9 ± 0.8 (0-3)
p-value		0.852			0.837			0.042	
% anatomical reduction (≤1 mm)	38%	38%	14%	36%	29%	40%	73%	65%	87%
p-value		0.187			0.463			0.032	

Values are given as percentage or mean ± standard deviation (range).

Table 4
Parameters possibly affecting the necessity of trans-syndesmotic fixation.

	Group 3 (ORIF)	
	No Trans-syndesmotic fixation	Trans-syndesmotic fixation
Total	58 (75%)	20 (25%)
Age	p = 0.645	
Sex	p = 0.011	
Side	p = 0.012	
Displacement	p = 0.349	
AO Classification	p = 0.179	
Haraguchi classification	p = 0.225	
PM location	p = 0.225	
PM comminution	p = 0.262	
PM displacement	p = 0.306	
PM size	p = 0.227	
PM reduction	p = 0.335	
Medial clear space	p = 0.112	
Tibio-fibular clear space	p = 0.467	
Treatment external fixator	p = 0.960	
Treatment lateral malleolus	p = 0.017	
Treatment medial malleolus	p = 0.117	
Treatment Deltoid ligament	p = 0.141	

Values are given as number (percent) or p-value.

Table 5
Overview of studies reporting on the frequency of trans-syndesmotic fixation with regard to different treatment strategies for PM fractures.

Study	n	% Trans-syndesmotic Screw			
		Group 1 None	Group 2 CRIF	Group 3 ORIF	Sig
O'Conner et al. [17]	27	–	45% (5 out of 11)	13% (2 out of 16)	0.190
Miller et al. [18]	198	27% (41 out of 151)	–	2% (1 out of 47)	<0.001
Li et al. [19]	97	57% (36 out of 63)	47% (7 out of 15)	0% (0 out of 19)	<0.001
Current study	236	63% (72 out of 114)	61% (27 out of 44)	25% (19 out of 78)	<0.001*

* Significant reduction between Group 3 and Group 1 as well as Group 2.

Despite their large sample size, they missed a CRIF group and all parameters were assessed on plain radiographs only. Therefore, the PM fractures were not be sufficiently classified, and the influence of various fracture characteristics could not be assessed. Most importantly, the effect of ORIF on fragments smaller than 25% was not evaluated. The only study comparing all three treatment strategies was published by Li et al. [19]. Trans-syndesmotic fixation was necessary in 57% of patients with untreated PM fragment, in 47% following CRIF, and 0% following ORIF. Unfortunately, the authors did not measure the fragment size but only distinguished "flake" and "sizable" fragments. Again, no CT scans but only plain radiographs were analysed. Consequently, PM fractures were neither classified, nor their characteristics assessed. Further, the size of the CRIF and ORIF group was limited. Even though these studies report comparable results, the herein presented study is the first to actually asses the frequency of trans-syndesmotic stability per PM fracture treatment group in a large sample. Moreover, it is the only study to analyse the PM fractures in detail based on CT scans.

Noteworthy, a quarter of the patients necessitated trans-syndesmotic stabilization despite ORIF of the PM fracture. This could be attributed to numerous reasons, including stretching or partial tear of the PTFL as well as multi-ligamentous lesions. Although anatomical reduction of the PM fracture will restore the PTFL, it has no impact on lesions to the AITFL (anterior-inferior tibiofibular ligament), IOL (interosseous ligament), or deltoid ligament. The stress tests applied in this study for the assessment of syndesmotic stability have been proven to detect instability of the syndesmotic complex of two or more ligaments [20]. Consequently, patients necessitating trans-syndesmotic stabilization in addition to ORIF of the PM fragment might have suffered more complex ligamentous injuries to the syndesmotic complex.

From our understanding, ORIF of the PM leads to increased syndesmotic stability by anatomical reduction of the bony PTFL lesion. The herein presented data revealed a significantly better quality of reduction in the ORIF, compared to the CRIF or untreated group. Several studies have assessed the degree of reduction comparing CRIF to ORIF of the PM, all of which demonstrated superior results for ORIF [7–9,17,31]. However, only one of these studies did assess the quality of PM reduction on postoperative CT scans. Shi et al [8] conducted an RCT comparing the quality of reduction in 52 patients treated by CRIF and 64 patients by ORIF of the PM fragment. All PM fractures involved more than 25% of the articular surface. Again, the degree of reduction was significantly better in the ORIF compared to the CRIF group ($p = 0.038$). Still, neither did they report on the frequency of additional trans-syndesmotic fixation, nor did they classify the PM fractures.

Although this study was the first to assess the effect of different treatment strategies for PM fractures in regard to syndesmotic stability, several limitations have to be mentioned. First, the registry study design was retrospective, including all patients from a level I trauma centre. Whether this has an impact on the parameters assessed remains a matter of debate. Another limiting factor could be that the indication for trans-syndesmotic fixation was made by several surgeons based on two different intra-operative tests. Nevertheless, both tests are well accepted in literature and all surgeons were board-certified trauma surgeons. Finally, no patient rated outcome measures were assessed. Therefore, the clinical impact of the different treatment strategies remains unclear. Despite these limitations, this study has two major positive aspects. First, PM fracture characteristics were all assessed based on CT imaging. Previous studies relied predominantly on plain radiographs [17–19], which have been shown insufficient to assess the frequency, size, morphology and reduction of the PM fragment [12,32,33]. Second, previous studies were considerably limited by either not including all three treatment arms, or insufficient sample size per arm [17–19]. This is the first study presenting the frequency of trans-syndesmotic fixation for all three surgical approaches to PM fractures with a sufficient patient number per treatment arm.

Conclusion

Missed syndesmotic instability or malreduction are among the most determinant factors for a poor outcome following complex ankle fracture treatment. As PM fractures should be considered bony avulsions of the posterior tibio-fibular ligament, anatomical reduction of PM fragment has been hypothesized to restore syndesmotic stability. This study, for the first time, demonstrated a 60% decrease in trans-syndesmotic fixation following ORIF of the PM fragment and a significantly superior quality of reduction compared to CRIF by AP screws or untreated PM fractures. These findings were consistent for all PM fragments independent of their size ($\leq$25%/>25%). Interestingly, CRIF and untreated PM fractures did not differ in regard to the high frequency of trans-syndesmotic fixation and the low quality of reduction. Future studies should focus on the clinical benefit of ORIF of the PM fragment including the quality of reduction of the distal tibio-fibular joint.

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