International Journal of Research in Orthopaedics
Elshahhat A et al. Int J Res Orthop. 2022 Nov;8(6):660-667
http://www.ijoro.org

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20222704

Original Research Article

Relevance of posterior malleolar fracture fixation to ankle syndesmotic reduction, a comparative study

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Received: 13 September 2022
Revised: 07 October 2022
Accepted: 12 October 2022

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ABSTRACT

Background: Appropriate distal tibiofibular syndesmotic reduction is crucial to restore ankle stability, guard against future arthrosis with worse functional outcome. Optimal technique for syndesmotic reduction has been a matter of debate. This study aimed at radiological evaluation of syndesmotic integrity following two methods of reduction (posterior malleolar fixation and trans-syndesmotic screw fixation), additionally, correlating the posterior malleolus size to the radiological results of both techniques.
Methods: Syndesmotic integrity was compared after each technique as per translational and rotational fibular positions. Utilizing, preoperative and postoperative computed tomography scans of injured ankle, the fibular antero-posterior and Medio-lateral translation distances were measured. Additionally, the fibular rotation angle was calibrated. Incidence of inadequate reduction in each group was reported. Preoperative and postoperative radiological findings were compared and correlated to posterior malleolus size in relation to tibial articular distance.
Results: A significant difference between both techniques was noted in term of fibular rotation. In patients with PM < 10% of tibial articular surface, a significant difference was obvious in postoperative AP-translational and rotational findings between both techniques. Overall malreduction incidence rate of 68.9% was reported in this study, with 84.7% rate in patients managed with SS-fixation, whilst 51.2% rate in those managed via PM-fixation.
Conclusions: Posterior malleolar fixation could limit syndesmotic malreduction risk whatsoever it's size. Approaching CT reference values for syndesmotic reduction might benefit preoperative planning and detect intraoperative malreduction. Further future clinical studies correlating these findings to clinical outcome would be more helpful.

Keywords: Syndesmosis, Radiological, Computed tomography, Posterior malleolus

INTRODUCTION

Posterior malleolar (PM) fractures are present in 10% to 44% of all ankle fractures. It's presence negatively impacts the clinical outcome of ankle fractures.[1,2] PM is attached to posterior tibiofibular (TF) ligament which forms the main resistance against syndesmotic diastasis. Biomechanical studies suggest the restoration of the posterior aspect of the TF ligament with the fixation of PM might obviate the need for syndesmotic stabilization with trans-syndesmotic screws.[3] Syndesmotic malreduction ends with worse functional outcomes, however, the threshold at which a malreduction becomes clinically relevant remains controversial.[4,5] Syndesmotic malreduction has been reported as high as 52%, leading to abundant research and innovation regarding the optimal technique for syndesmotic reduction.[6] This study aimed at radiological evaluation of syndesmotic integrity in ankle fracture management, following either via anatomic reduction with PM fixation or through indirect reduction with trans-syndesmotic screw (SS) fixation. We hypothesized that incidence of syndesmotic malreduction in ankle fracture management might be lower with PM-fixation to the SS-fixation.

METHODS

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the institutional research board of the authors' affiliated institution. This comparative cohort study included all skeletally mature patients with acute PM fractures associated with distal TF syndesmotic injury admitted and managed at trauma and emergency hospital related to the authors' institution, at the period from January 2018 to February 2022. Patients' records were checked for complete radiological data, including bilateral preoperative ankle X-rays (anteroposterior (AP), mortise, lateral), ipsilateral postoperative ankle X-rays, ipsilateral preoperative and postoperative ankle computed tomography (CT) scans. Included patients should have postoperative reduced syndesmosis evident on X-rays as per the Keller criteria of syndesmotic integrity.[7] On comparing postoperative X-rays to contralateral non-injured ankle 1cm proximal to the joint line., patients could not have AP-TF clear space more than 6 mm, AP-TF overlap less than 6mm, mortise-TF overlap lessthan 1mm, and mismatch difference more than 2 mm between both ankles as accepted limit values for radiographic syndesmotic instability. Incongruities in any of the above parameters were judged as evidence of diastasis.[8,9] Our study excluded patients with non-reduced syndesmosis evident in post-operative X-rays as forementioned Keller criteria, pregnant females, skeletally immature patients, patients with previous ankle injuries, associated anterior malleolar fracture or superior syndesmotic injury (Maisonneuve fracture), conservatively managed cases, patients with incomplete radiological data. Patients' selection process was illustrated with a flow chart in (Figure 1).

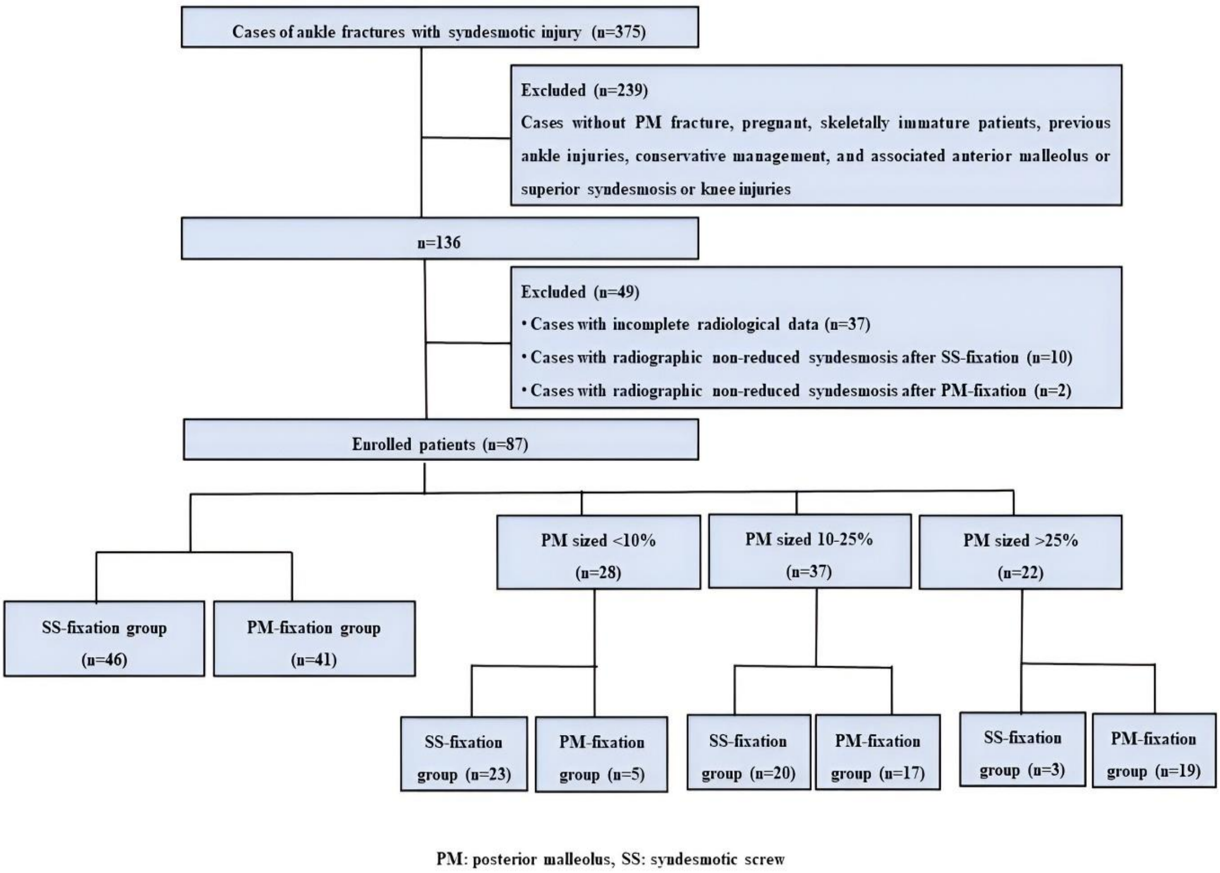

Figure 1: Flow chart for patient selection process.

The fracture pattern was noted among included patients, additionally, we classified PM injuries as per the Haraguchi classification into three types: type I, posterolateral-oblique; type II, medial-extension; and type III, small-shell.[10] Included patients were divided into two main groups. The first group (SS-fixation group): patients underwent indirect syndesmotic reduction with SS-fixation under fluoroscopic guidance, utilizing a 3.5 mm-cortical screw inserted 2cm above and parallel to ankle joint line with three-cortices fixation. SS was inserted as the last step of ankle fracture fixation. The second group (PM-fixation group): patients underwent syndesmotic reduction via open reduction and internal fixation (ORIF) of PM utilizing one third tubular plate or a 3.5 mm partial cancellous screw and a washer through posterolateral approach, ORIF of PM was done as the first step of ankle fracture fixation. In both groups, syndesmotic reduction was confirmed intraoperatively under fluoroscopic guidance. Selection of fixation technique was based upon the choice of the attendant orthopedic trauma surgeon. All fractures were surgically managed by a senior orthopedic trauma surgeon with at least five years' experience. We reported the radiological impact of each technique on syndesmotic integrity, comparing pre and postoperative ankle CT scans regards the following parameters: anterior and posterior TF-syndesmotic intervals, also, fibular AP and rotational displacement. CT scans were performed preoperatively and within 48 hours post-surgery. Scans were reformatted via the CT workstation (GE Optima CT520 16 slice) obtaining 2.5 mm-3 mm-thickness slices. The axial slices were standardized parallel to the ankle plafond in neutral rotation. The tibial vertical axis and the plafond horizontal axis were advocated as reference axes to ensure parallel axial images to the plafond. Neutral rotation was defined by the bimalleolar axis, a tangential line to the anterior aspects of the medial and lateral malleoli (Figure 2). Images were rotated to ensure the bimalleolar axis was parallel to horizontal axis of the axial image.[11]

For each scan, a single axial image located 1cm proximal to the plafond (three or four cuts above TF joint), was exploited for assessing fibular reduction within the tibial incisura as an indicator of TF joint congruency. Quality of syndesmotic reduction was judged in terms of translational and rotational fibular positions. Nault fibular AP translation was measured as a distance between two lines passing through the most anterior points of fibula and incisura. Both lines passed perpendicular to a vertical between anterior and posterior fibular aspect (Figure 3). Medio-lateral translations was interpreted by measuring three distances (Figure 4).

A-distance: between the most anterior point of incisura and nearest most anterior point of fibula, B-distance (Leporjärvi clear space): between tibia and fibula at the middle of incisura, and C-distance: between the most posterior point of incisura and the nearest most posterior point of fibula. Additionally, fibular rotation angle (FRA) was calibrated as an angle between a line drawn between anterior and posterior points of incisura and a line drawn in the fibula representing its orientation (Figure 5). C-A distance and A/C ratio were also calculated as indicator for fibular rotation. C-A distance represented difference between posterior and anterior TF distances. Syndesmosis was considered incongruent (inadequate reduced) when C-A distance measured more than 2 mm.[12]

Accuracy of syndesmotic reduction and TF congruency was compared between the two main groups as per forementioned radiological parameters. Incidence of inadequate reduction in each group was reported. Besides, preoperative, and postoperative calibrated measurements were compared. Regards PM size to tibial articular surface, patients were categorized into three categories (<10%, 10-25%, >25%), of which patients were subdivided into two groups either by PM-fixation or SS-fixation. Syndesmotic reduction was questioned again in those categories, via the forementioned radiological parameters. Correlation of PM size to radiological findings was reported.

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS Statistics for Windows, version 22. 0. Qualitative data were described using number and percent. Quantitative data were described using median for non-parametric data and mean, standard deviation for parametric data. The t test and Man Witney U test were utilized comparing two independent groups with normal and abnormally distributed data. Significance of obtained results was judged at 0.05 level.

RESULTS

Out of 87 patients, 63 males and 4 females were included in this study with mean age of 47.6±12.2 years. The right ankle was severed in 51 cases (58.6%) and 37 patients had their left ankle injured. Fracture pattern was a trimalleolar in nature in 47.1% (41/87), and bimalleolar in 36 patients of whom, 32 patients had lateral and PM fractures, and 4 patients had medial with PM fractures.

Table 1: Preoperative and postoperative radiological measurements in all patients.

Radiological parameters	Preoperative	Postoperative	P value
AP-distance	4.2±2.7 mm	3.38±1.84 mm	0.0093*
B-distance	5.12±1.9 mm	3.67±1.2	<0.00001*
Rotation			
FRA	10.01°±2.49°	9.36°±2.78°	0.035*
C-A distance	3.33±2.7 mm	3.39±2.19 mm	0.872
A/C ratio	0.58±0.33	0.54±0.26	0.33
A-distance	4.84±2.8 mm	3.93±2 mm	0.01*
C-distance	8.17±1.5 mm	7.32±1.7 mm	0.00005*

*Significant difference

Table 2: Comparison between pre and postoperative measurements in SS reduction and PM fixation groups.

Radiological parameters	SS reduction method (N=46)			PM fixation method (N=41)		
	Preoperative	Postoperative	P value	Preoperative	Postoperative	P value
AP-distance	3.75±2.3 mm	3±1.56 mm	0.054	4.7±3.14 mm	3.72±2 mm	0.051
B-distance	5.22±1.45 mm	3.48±1.1 mm	<0.00001*	5±1.85 mm	3.88±1.28 mm	0.0009*
Rotation						
FRA	9.9º±2.47º	9.36º±2.17º	0.211	10.13º±2.54º	9.36º±3.37º	0.124
C-A distance	3.27±2.19 mm	4.24±1.91 mm	0.0013*	3.4±3.32 mm	2.43±2 mm	0.059
A/C ratio	0.58±0.27	0.46±0.2	0.0092*	0.59±0.38	0.63±0.3	0.59
A-distance	4.79±2.52 mm	3.51±1.63 mm	0.0024*	4.89±3.14 mm	4.4±2.38 mm	0.63
C-distance	8.06±1.45 mm	7.76±1.53 mm	0.162	8.29±1.72 mm	6.83±1.8 mm	0.00018*

*Significant difference

Table 3: Correlation between postoperative measurements utilizing two methods of syndesmotic reduction.

Postoperative radiological parameter	P value
AP-distance	0.052
B-distance	0.063
Rotation	
FRA	0.89
C-A distance	0.00003*
A/C ratio	0.0008*
A-distance	0.28
C-distance	0.005*

*Significant difference

As per Haraguchi classification, Type I represented 60.9% (53/8), type II and III accounted for 11.4% and 27.5%. PM size was divided into three categories. < 10% of tibial articular surface in 28 patients (32.18%), 10-25% in 37 patients (42.52%), and >25% in 22 patients (25.28%). Syndesmotic reduction was performed via SS-fixation in 41 patients and through PM-fixation in 46 patients. Significant change was noted in TF translational and rotational syndesmotic relation between preoperative and postoperative radiological status, further detailed measurements were represented in (Table 1). Significant difference in postoperative C-A distance and A/C ratio in both reduction methods (p<0.005). Radiological findings with both techniques and comparison in-betweenid depicted in (Table 2-3). Also, relating both techniques in different PM sizes preoperatively and postoperatively were ascertained in (Table 4-6). Difference amidst postoperative measurements after PM-fixation amongst all groups was detailed in (Table 7). A significant difference between both techniques was noted in term of fibular rotation. In patients with PM <10%, a significant difference was obvious in postoperative AP-translational and rotational findings between both techniques. furthermore, preoperative, and postoperative relation via both techniques in PM <10% and 10-25% groups was shown in (Table 8). Overall malreduction incidence rate of 68.9% was reported in this study, with 84.7% rate in patients managed with SS-fixation, whilst 51.2% rate in those managed via PM-fixation. Different sized-PM showed malreduction incidence rate of 100%, 65%, and 100% after SS-fixation, whilst a malreduction incidence rate of 20%, 58.8%, and 52.6% was reported with PM-fixation.

Table 4: Comparison between pre and postoperative measurements in patients with PM <10% utilizing two methods of syndesmotic reduction.

PM size	First group (<10%) (N=28)			
Reduction method	**SS reduction method (N=23)**		**PM fixation method (N=5)**	
Radiological parameters	**Preoperative**	**Postoperative**	**Preoperative**	**Postoperative**
AP-distance	2.72±1.55 mm	2.57±0.98 mm	2.24±0.25 mm	4.82±0.5 mm
B-distance	4.46±1.75 mm	3.36±1 mm	3.24±0.7 mm	4.22±0.7 mm
Rotation				
FRA	9.93±2.4	10±1.7	7.6±0.89	7.4±0.89
C-A distance	3.46±1.52 mm	5±1.42 mm	4.6±0.12 mm	0.46±1.3 mm
A/C ratio	0.52±0.21	0.39±0.13	0.33±0.05	0.92±0.21
A-distance	4±2.24 mm	3.2±1 mm	2.4±0.62 mm	6.74±1.98 mm
C-distance	7.55±0.98 mm	8.29±0.9 mm	7±0.65 mm	7.2±0.72 mm

Table 5: Comparison between pre and postoperative measurements in patients with PM 10-25% utilizing two methods of syndesmotic reduction.

PM size	Second group (10-25%) (N=37)			
Reduction method	**SS reduction method (N=20)**		**PM fixation method (N=17)**	
Radiological parameters	**Preoperative**	**Postoperative**	**Preoperative**	**Postoperative**
AP-distance	5.38±2.2 mm	3.4±1.93 mm	17±4.2 mm	3.82±2.5 mm
B-distance	6.29±2 mm	3.43±1.14 mm	4.93±2.1 mm	3.34±1.53 mm
Rotation				
FRA	9.6±2.54	8.1±1.8	9.58±3.37	8.58±2.4
C-A distance	2.46±2.29 mm	3.28±2 mm	2.39±4.2 mm	2.5±2.4 mm
A/C ratio	0.71±0.29	0.53±0.25	0.71±0.5	0.59±0.37
A-distance	6±2.47 mm	3.72±2.18 mm	5.76±4 mm	3.35±2.18 mm
C-distance	8.46±1.59 mm	7±1.48 mm	8.15±1.86 mm	5.85±1.41 mm

Table 6: Comparison between pre and postoperative measurements in patients with PM >25% utilizing two methods of syndesmotic reduction.

PM size	Third group (> 25%) (N=22)			
Reduction method	**SS reduction method (N=3)**		**PM fixation method (N=19)**	
Radiological parameters	**Preoperative**	**Postoperative**	**Preoperative**	**Postoperative**
AP-distance	0.86±0.05 mm	4.6±1.13 mm	4.39±1.84 mm	3.35±1.81 mm
B-distance	4±1.21 mm	4.7±0.88 mm	5.53±1.55 mm	4.27±1 mm
Rotation				
FRA	11.6±1.5	12.66±2.3	11.28±0.8	10.57±4
C-A distance	7.13±2 mm	4.63±2.25 mm	3.98±2.65 mm	2.89±1.7 mm
A/C ratio	0.24±0.02	0.48±0.07	0.55±0.25	0.61±0.19
A-distance	2.26±0.4 mm	4.1±1.04 mm	4.47±2.24 mm	4.71±2.2 mm
C-distance	9.4±2.43 mm	8.73±3.2 mm	8.74±1.64 mm	7.61±1.96 mm

DISCUSSION

Regardless the PM size to the tibial articular surface, our findings suggest lower risk of postoperative inadequate syndesmotic reduction with PM-fixation (51%) compared to SS-fixation (85%) in surgical management of ankle fractures with syndesmotic instability. Evident radiographic malreduction often occurs after non-anatomical fixation of ankle fractures.[12] On radiographic assessment of both ankles, Gardner et al reported 52% incidence rate of syndesmotic malreduction, as well as, a 39% malreduction rate was reported by Baca et al.[6,13] Nonetheless, CT assessment can reveal postoperative inadequate reduction, even with a reduced syndesmosis on X-rays.[6,13] CT confronts a significant challenge due to the lack of normal measurmental values, even, contralateral comparison may lead to false prediction for malreduction.[14]

Table 7: Correlations between postoperative measurements after PM fixation in the three groups. P: between the three groups, P1: between first and second groups, P2: between first and third groups, and P3: between second and third groups.

Postoperative radiological parameter	P	P1	P2	P3
AP-distance	0.2	0.2	0.04	0.26
B-distance	0.015	0.11	0.45	0.17
Rotation				
FRA	0.14	0.15	0.05	0.04*
C-A distance	0.046*	0.04*	0.0037*	0.28
A/C ratio	0.077	0.04*	0.002*	0.43
A-distance	0.003*	0.002*	0.038*	0.036*
C-distance	0.015*	0.02*	0.32	0.002*

*Significant difference

Table 8: Correlation between two methods of reduction in terms of postoperative measurements.

Postoperative radiological parameter	P value	
	PM <10%	**PM 10-25%**
AP-distance	0.00025*	0.3

B-distance	0.5	0.4
Rotation		
FRA	0.004*	0.24
C-A distance	<0.0001*	0.14
A/C ratio	<0.00001*	0.28
A-distance	<0.00001*	0.3
C-distance	0.127	0.011*

*Significant difference

Table 9: Incidence of postoperative inadequate reduction in each group.

Groups	N	%
All patients	60/87	68.9
SS reduction group	39/46	84.7
PM fixation group	21/41	51.2
SS reduction method in PM <10%	23/23	100
PM fixation method in PM <10%	1/5	20
SS reduction method in PM 10-25%	13/20	65
PM fixation method in PM 10-25%	10/17	58.8
SS reduction method in PM >25%	3/3	100
PM fixation method in PM >25%	10/19	52.6

Non-appropriate syndesmotic reduction often disrupts ankle biomechanics, stability, endowing ankle arthritis with incidence of 4% overall reported incidence and up to 34% in trimalleolar fracture.[15,16] Incidence of syndesmotic malreduction might be overestimated. Elgafy et al reported anterior and posterior TF distances (A, C distances) to be 2 mm and 4 mm.[17] 2 mm was noted quite small to rely upon, hence, Nault et al suggested absolute distances to be 4 mm and 8 mm.[12] Our study aimed at outlining radiological TF relationship numerically with different methods of syndesmotic reduction, banking on the Nault anterior TF space (AP-distance) responsive to posterior translation, Leporjärvi clear space (B-distance) responsive to lateral translation. FRA and A/C ratio were contemplated reactive to fibular rotation.[12,18]

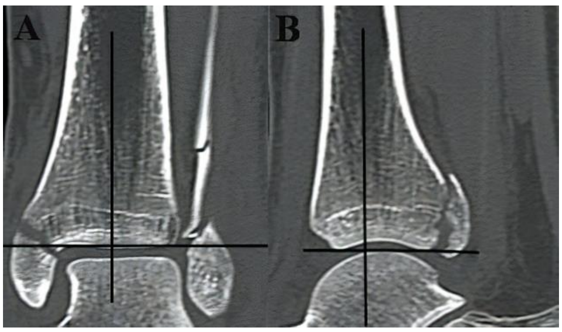

Figure 2: Reformatted CT to produce standardized, axial slices, A) transverse reference axis parallel to tibial plafond, B) longitudinal reference axis parallel to long axis of tibia.

In this study, we relied upon pre and postoperative CT scans on the injured ankle only, that was attributed unavailability of the CT scan of contralateral ankle. We compared our findings to previous published studies. No set of standardized measurements exist to objectively describe normal TF translational and rotational relationship.[12] It may be not ideal to establish normal values but still gives reference range. Absolute cut off value for detecting syndesmotic pathology may not exist. No measurment method has been widely accepted.[15] Previous studies reported normal syndesmosis, the mean B-distance measured 2.8 mm, Nault AP-distance measured 2.3 mm.[12]

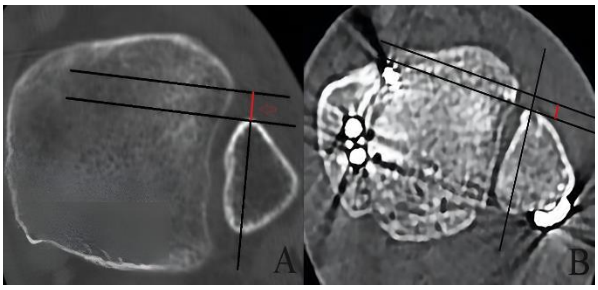

Figure 3: A) Preoperative, B) Postoperative axial slice showing AP fibular translation distance (red line).

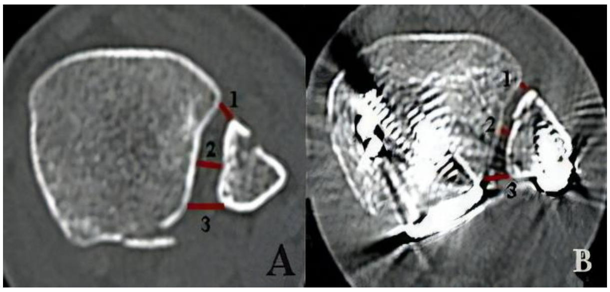

Figure 4: A) Preoperative, B) Postoperative axial slices, showing (1) anterior, (2) middle, and (3) posterior inter tibiofibular distances.

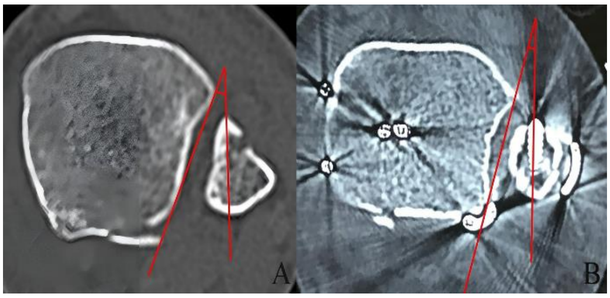

Figure 5: A) Preoperative, B) Postoperative axial slice showing fibular rotation angle.

Anterior and posterior TF inter-space expressed wide variation; A-distance measured 1.7 mm-17.4 mm and C-distance measured 2.3 mm-8.88 mm.[19,20] Fibula showed rotation with wide variation from 8.7º to 13.4º with mean A/C ratio of 0.54.[12,20] To the best of our knowledge, no previous similar studies neither compared syndesmotic reduction surgical methods radiologically, nor correlated impact of PM size on postoperative radiological CT measurements. C-A distance and A/C ratio were considered more solid righteous radiological parameters.

Regardless the PM size, postoperative C-A distance and A/C ratio revealed a significant difference among the two methods of reduction. Besides, C-A distance appeared significantly different amongst the PM sizes back of PM fixation (p=0.046). The SS-fixation technique might not restore syndesmosis precisely, this was obvious in AP-distance. Fibula was shifted more anteriorly than in PM-fixation group, with a mean difference of 0.7±0.44mm. Undoubtedly, medial, and lateral malleolar fractures were obligatory stabilized as basic elements of trimalleolar fracture, nonetheless, PM fixation was questioned in each case.[21] Previously, fixation of PM necessitated involvement of 25-33% of tibial articular surface or when displaced more than 2 mm, though, the need for stabilization has expanded to incorporate fibular notch involvement and impacted intercalary articular fracture.[22,23] Biomechanically, PM-fixation obviates the need for syndesmotic stabilization as tension on posterior inferior TF ligament is restored being attached to reduced coronal fragment.[13] fixation of PM alone restores 70% of syndesmotic stability, the need for SS removal is abandoned. Postoperative rehabilitation would be quicker.[1] Intraoperative difficulties while introducing SS are negated.[6] It seems important to address the posterior coronal fragment as a separate entity of ankle fracture to appropriately restore the syndesmosis. Withal, anatomical PM-fixation whatever its size was favored in previous studies.[24] In this study, The PM three sized groups showed malreduction incidence of 100%, 65%, and 100% with SS-fixation, whilst they experienced malreduction incidence of 20%, 59%, and 53% with PM- fixation. Surprisingly, malreduction incidence was nearly same with both techniques in PM group sized 10-25% out of tibial articular surface. This can be attributed to limited number of involved patients and the non-weight-bearing nature of CT assessment. Certainly, proximity of radiological measurement findings in PM >25% sized group amongst both techniques, could be appertaining to limited number of patients underwent SS-reduction, that might be considered an inappropriate management with a higher anticipated fixation failure. Thus, correlation between both techniques amongst this group might be benefit-less. The strength of our study could be expressed in assessment of valid radiological parameters utilizing standardized methodology taking advantage of same CT workstation machine. Besides, postoperative radiographic comparison to contralateral ankle with excluding patients with non-reduced syndesmosis unconcealed the necessity for contralateral CT comparison. Withal, the uniformness of fixation order among PM-fixation group, PM was initially fixed then lateral, and medial malleoli.

Limitations

Study limitations were represented in its retrospective nature, limited number of involved cases, with no correlation to functional outcome, besides, CT used was a non-weight-bearing CT without contralateral comparison. Future studies utilizing weight-bearing CT, larger number of patients with clinical correlation might be more depictive.

CONCLUSION

Finally, we concluded that moving closer to reference values for syndesmotic reduction utilizing CT, expressed in Ap and rotational TF relation, might benefit the preoperative planning and detect intraoperative malreduction. Additionally, PM-fixation could limit syndesmotic malreduction risk whatsoever the PM size. Further future clinical studies correlating these findings to clinical outcome would be more helpful.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the institutional ethics committee

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Cite this article as: Elshahhat A, Youssef K, Elkasaby M, Gaarour OS. Relevance of posterior malleolar fracture fixation to ankle syndesmotic reduction, a comparative study. Int J Res Orthop 2022;8:660-7.